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WORLD MARITIME UNIVERSITY

Shanghai, China

ECONOMIC ANALYSIS ON THE SUSTAINABILITY OF SLOW STEAMING IN LINER SHIPPING

BY

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China

A research paper submitted to the World Maritime University in partial fulfillments of the requirements for the award the degree of

MASTER OF SCIENCE

ITL

2011

Declaration

I certify that all the material in this research paper that is not my own work has been identified, and that no materials are included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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Dong Zhou.

2011-06-09

Supervised by

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Abstracts

Title of Research paper: **Economic Analysis on the Sustainability of Slow Steaming in Liner Shipping**
Degree: **M.Sc.**

The research paper is a sustainability assessment of a widely adopted strategy - slow steaming in liner shipping. A complete overview of both effectiveness and impact of speed reduction are examined to evaluate market feedbacks on this strategy. With highly compliments on this strategy in bunker costs saving, absorption of excess tonnage and good environmental performance, and this paper challenge the feasibility of slow steaming by thorough speed-related costs analysis creating a breakeven point for the average value for one loaded Forty Feet Container. An application on Far East/North America proves that a large number of liner services now under slow steaming being inappropriate for adopting this strategy. The average value for one FEU exporting from Far East is set to be a filter eliminating those services which are sacrificing shippers' interest with more in-transit inventory costs. Additionally, cancellation of ports of calls for these "non-slow-steaming" services is more effective coping with the high bunker price. Slow steaming is just an un-optimal optimization which could be effective for both shipping lines and shippers combined with synchronous re-design of liner services.

KEYWORDS: Slow Steaming, Liner Shipping Market, Transit Inventory Costs, Far East/North America Trade, Sustainability Analysis

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List of Abbreviations

BAF	Bunker Adjustment Factor
BSFC	Brake Specific Fuel Consumption
COSCO	China Ocean Shipping Corporation
DDLT	Demand During Lead Time
ECNA	East Coast of North America
EDDLT	Expected Demand During Lead Time
FC	Fuel Consumption
FEU	Forty-Feet Equivalent Unit
GHG	Green House Gas
HFO	Heavy Fuel Oil
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
LRF	Lloyd’s Register Fairplay
LSFO	Low Sulphur Fuel Oils
LT	Lead Time
MCR	Maximum Continuous Rate
MDO	Marine Diesel Oil
MEPC	Marine Environment Protection Committee
NYK	Nippon Yusen Kaisha
OPEX	Operating Cost
R&M	Repair and Maintenance
SFOC	Specific Fuel Oil Consumption
SS	Safety Stock
TEU	Twenty-Foot Equivalent Unit
UNCTAD	United Nations Conference of Trade and Development
WCNA	West Coast of North America

Chapter 1 Introduction

1.1 Background

The financial crisis and economic recession dominated the international community since December, 2008, which put strong pressure on maritime sector. Unsurprisingly, shipping lines struggled with a series of problem, such as, overcapacity in fleet due to the high enthusiasm ordering newbuildings in 2007-08; dramatic fluctuations in bunker price and louder voice on green shipping development. (Notteboom & Rodrigue, 2010)

Slow steaming is the one of the “products” from the above scenarios, which is widely adopted in current operational process. Apparent benefits from slow steaming contributed a great cost-savings for carriers both in bunker consumption and absorption for extra-capacities. (AXS-Alphaliner, 2010) Moreover, the carbon dioxide emission has been controlled effectively through reduction in fuel consumption. Due to the depressed market climate, this strategy became more and more popular in liner shipping operation. According to the United Nation Conference on Trade and Development, by 2009, there were 42.9% of vessels and 34.8% of services were under slow-steaming. (UNCTAD, 2010, p. 61) In the year of 2010, majority of liner companies set this strategy as a long-term tactic dealing with impacts from the recession. Significantly, most of them are big players, like Maersk announced that “slow steaming is here to stay”, (MAERSK, 2010) CMA CGM applied super slow steaming as a standard for CMA CGM vessels. (Gerard, 2010)

However, when shipping lines advocated substantially for the slow steaming, criticisms and concerns about this strategy arouse across the related industry. Shippers complained and questioned slow steaming for the increasing stock cost regarding longer transit time. As the Elkem, the Norwegian silicon producer claimed in 2010 that the carriers have made a lot of savings but the financial impact on the customers has never been investigated. (Marle, 2010, p. 3)

Despite the operational and financial aspects, the environmental contribution from slow steaming is considerable. Box shipping giant, A.P. Moller-Maersk reduced 9% of CO_2 emissions in 2008 compared to 2007. More significantly, every 10% of speed reduction helps to reduce 19% of CO_2 emission per ton-mile. (UNCTAD, 2010, p. 66) Nevertheless, certain technical barriers are still to be addressed. (Faber, Freund, Kopke, & Nelissen, 2010, p. 23)

The cooperation between liner shipping companies and associated businesses highlights the globalization; it is worthy thinking over the truth of slow steaming in today's liner shipping operation concerning all the interested parties and issues. From all the perspectives above, this paper intends to evaluate the sustainability of slow steaming in liner shipping market. *Is this just a transient fashion or a strategy here to stay?*

1.2 Objectives of the Study

The first objective of the paper is to *investigate* current and potential effects and concerns brought by slow steaming through the whole value chain. The second objective of the paper is to *determine* the sustainability of slow steaming subject to several correlative factors. The third objective of the paper is to *prove* the assumption through an application to Far East/America trade route.

1.3 Methodology

The purpose of the paper is to analyze and assess the sustainability of slow steaming in an overall perspective. To achieve the mentioned goal, the paper will first analyze speed-related economic factors of this strategy based on current circumstances and future trends. Meanwhile, value for one Forty Feet Container (FEU) exporting from Far East to United States will be estimated representing inventory costs which largely neglected by shipping lines. Secondly, a cost analysis/comparison from initial to actual speed is used to create a threshold for inventory cost, i.e., the average value of containerisable cargo on board. To make the approach more clear, we will simply use a case study of “Shanghai-Rotterdam” trade seeing the tendency of breakeven point when going slow. Thirdly, based on the model, breakeven points for each liner service which under slow steaming currently on Far East/North America are used to compare with the filter - the average value of containerisable cargo to assess whether slow steaming is feasible and sustainable.

1.4 Outline of the Paper

Chapter 2, literature review, intends to overview relevant research papers and market reports/comments on the slow steaming. Several studies highlight effects of slow steaming across the value chain. **Chapter 3, economic factors in slow steaming.** In this chapter, three major speed-related costs will be presented and analyzed for corresponding current situation and future development direction. **Chapter 4, sustainability of slow steaming in liner shipping**. Configuration of algebra model is to determine the sustainability of slow steaming by creating the threshold for inventory costs. Then an application to Far East/North America is used to assess the feasibility and sustainability of slow steaming on that trade route. **Chapter 5, conclusions.** The summary of findings, implication and limitations of this study and practical recommendation will be presented.

Chapter 2 Literature Review

2.1 Introduction

As stated in the previous chapter, the slow steaming raised the attention from shipping-related markets. From the sake of shipping line, cost reduction with revenue soaking up is always the theme of operation. With sky-high bunker price, reducing the speed seems an effective way to cut fuel consumption. Furthermore, the emission of Green-House Gas (GHG) could be substantially reduced through the slow steaming which relieves the environmental debt of liner companies. However, an inevitable consequence of slow steaming is longer transit time which shippers are reluctant to accept. Since shipping lines no longer radiate global container trades, the liner service tends to a more customer-oriented differentiation exercise. (Notteboom, 2004, p. 95) Time increasing at sea adding with some unexpected delays elevates shippers' inventory level and supply chain management afterwards.

In this chapter, we will first review the effectiveness of slow steaming. Next the time factor in logistics will be observed. Finally, different quantitative methods assessing the sustainability of slow steaming will be studied.

2.2 Effectiveness of Slow Steaming

The wide adoption of slow steaming across liner operation, to some extent, is not irrational. The main three advantages of slow steaming is reduction in fuel consumption, controlling in GHG emissions and absorption of extra capacities.

(Drewry Shipping Consultancy, 2010)

2.2.1 Effect on Fuel Cost

(1) Considerable fuel cost in liner shipping

Firstly, bunker price increased considerably. According to various databases such as, Clarkson Research Lab, Bunker world, since 2007, bunker prices in port of Rotterdam have increased steeply and peaked at $679.5/ton in July, 2008. Logically, given the persistent high bunker price and extraordinary cost on bunker, shipping lines are challenged to control fuel consumptions. Vernimmen, B., and T.E., Notteboom (2009) provided three major ways coping with the high bunker price (a) the use of cheaper grades of bunker; (b) actions in vessels design and (c) actions with regard to the commercial speed of fleet and the scale of the vessels. (Vernimmen & Notteboom, 2009) Fuel cost falls into the category of voyage cost in a tradition method of shipping cost allocation. Secondly, bunker cost is a considerable part of shipping cost. Stopford, M. (1997) pointed out that fuel cost accounts for 47% of voyage cost applying to all the shipping sectors. (Stopford, 1997, p. 160) Specifically, during 2008-09, this proportion, in liner shipping, has been raised up to 56% according to the calculation of OOCL annual report. (Oriental Overseas (International) Limited , 2009) Vernimmen and Notteboom (2009) identified that a succession of companies reporting on the effect of high bunker expense standing on their accounting bottom line. (Vernimmen & Notteboom, 2009, p. 326)

(2) Relationship between speed and fuel consumption

Firstly, J.J., Corbett, Wang, H.F. and Winebrake, J.J. (2009) represented that fuel consumption (FC) of merchant vessels directly links to main engine power (P). (Corbett, Wang, & Winebrake, 2009) Generally, fuel consumption is based on installed power, load factors for main and auxiliaries engines as given speed. So, based on this, Psaraftis, H.N. and C.A., Kontovas (2010) gave the formula as follows:

$$FC(tn/day) = BSFC(gr/kWh) \times 10^{-6}(tn/gr) \times P(kW) \times 24(h/day) \qquad (2.1)$$

The authors concluded with several surveys with engine manufacturers that "Brake specific fuel consumption" (BSFC) can be a constant since the variance in BSFC is not very high. Therefore, the rest variable, power of engine, is related to the fuel consumption. (Psaraftis & Kontovas, 2010) Whilst another expression of BSFC is SFOC (specific fuel oil consumption), Cariou, P. (2011) calculated the daily consumption of main engine by taking load factor into consideration because vessels are built to sail at designed speed, which is 70%-90% of the maximum continuous rate (MCR). So, in most studies, the SFOC or BSFC are set around 180-195gr/kWh. (Cariou, 2011)

Secondly, as a rule of thumb, a cubic relationship is used to determine the relationship between speed and fuel consumption. (Faber, Freund, Kopke, & Nelissen, 2010, p. 7) Several studies confirmed that. Notteboom T.E. and P. Cariou (2009) used 2,245 observations from Lloyd's Register Fairplay Ship Database resulting in an exponent of 3.331 with R^2=0.99 through regression model (Notteboom & Cariou, 2009) However, the cubic law is not always existed. According to the Barrass, C.B. (2004), for speed exceeding 20 knots, an exponent of 4 or greater is to be used. (Barrass, 2004) MAN Diesel (2006) proposed a relationship in the power of 4.5 for large high-speed container vessels.

(3) Slow steaming in reducing fuel consumption

With high bunker price and exponential relationship between speed and fuel consumption, reduction in speed was set as an operational method dealing with the fuel puzzle. In this part, we will examine the effectiveness of slow steaming in reducing fuel consumption.

Most researches showed that speed reduction decreased the fuel consumption dramatically in accordance to various vessel categories. Vernimmen and Notteboom (2009) evaluated relationship between speed reduction and daily fuel consumption through four vessel capacity categories (3,000 TEU, 5,000 TEU, 8,000 TEU and 10,000 TEU) based on statistics from Germanischer Lloyd. As it turned out, by given the bunker price \$450/ton at that time, for an 8,000TEU vessel, service speed going down from 26 to 23 knots saved daily fuel consumption by 80 tonnes and reserved the reduction of \$36,000 in daily running cost. Furthermore, according to their research methodology, the measurement of fuel consumption should be on the basis of transported unit, in the liner shipping, TEU (twenty feet equivalent unit). Under the same speed of 22 knots, cost difference between a 5,000TEU vessel and 12,000TEU vessel is 39%. At the speed of 24 knots, the cost difference reached to 41%. (Vernimmen & Notteboom, 2009) Later on, Notteboom and Cariou (2009) reviewed that relationship in terms of per TEU-mile obtaining the bunker price at \$350/tonne. It appears that vessels in the range between 5,000 and 10,000+TEU give similar and better results based on fuel cost per TEU-mile, under the same circumstance with Notteboom and Vernimmen (2009), the cost difference is around 7%. (Notteboom & Cariou, 2009) Kontovas and Psaraftis (2010) provided a generic formula illustrating the fuel consumption (FC) with slow steaming strategy considering the time in port. Combined the fact that many vessels reporting sailing speed halved the normal speed, they used “a” fraction ($0<a<1$) to define the new speed. Moreover, in order to observe the fuel consumption in different legs within one voyage, they divided the consumption in “at sea” and “at port”. The conclusion is if time in port is constant or less, speed reduction, for both cases, leads to a decrease in fuel consumption per trip.

2.2.2 Effect on Emission Reduction

At the 58th session of the Marine Environment Protection Committee (MEPC), held in

London in October 2008, actions regarding to air pollution from ships was mixed. Eefsen, T., and Cerup-Simonsen, B., (2010) and Psaraftis & Kontovas (2009) stated that containerships represent 4% of global fleet but emitted 20% of CO_2 from international shipping. (Psarafits & Kontovas, 2009) (Eefesen & Cerup-Simonsen, 2010) So, in this section, we will review results from several researches concerning contribution to GHG emission reduction.

(1) The measurement of emission

Generally, the “emission factor” is used in determining the GHG emission. By definition, the emission factor refers to how many kilograms of CO_2 are emitted per ton of fuel burned. Logically, by multiplying the quantities of fuel consumed, we could have how many CO_2 are released to the atmosphere. In early literature, factor of 3.17 was settled from an empirical test. However, whether this result is appropriate depends on the parameters. Kontovas and Psaraftis (2010) argued that 3.17 factor was not fuel-dependant. It tends to divide into Heavy Fuel Oil (HFO) and Marine Diesel Oil (MDO) separately. Guideline 2006 from Intergovernmental Panel on Climate Change (IPCC) showed that the factor 3.13 is for HFO while 3.19 for MDO. More recently, in MEPC 58/4/3 (2008), INTERTANKO based on the average carbon molecular weight in relevant fuels and conducted a workshop setting 3.082 for MDO, 3.075 for Low Sulphur Fuel Oils (LSFO) and 3.021 for High Sulphur Fuel Oils (HSFO) (International Maritime Organization, 2008) Nevertheless, Cadaro, M.A., Lopez, L.A., Comez, N. and Tobarra, M.A. (2010) took other factors including the distance cover, the tonnage transported and the means of transport chosen into account. The study was based on Spanish export and import which showed that inland transportation took a large proportion to GHG emission through the box distribution. (Cadarso, Lopez, Gomez, & Tobarra, 2011)

(2) Slow steaming in CO_2 emission reduction

Cariou (2011) assessed the impact of slow steaming on CO_2 emission reduction from 2008 to 2010, both in trade lanes and vessels types (1,000-2,000TEU, 2,000-3,000TEU, 3,000-5,000TEU, 5,000-8,000TEU and >8,000TEU) through the data from Alphaliner and Lloyd's Register Fairplay (LRF). The author used the following formula to estimate the CO_2 emission change where ME stands for fuel consumption by main engine regarding to SFOC, load factor in 90% and engine power while D refers to time at sea or port respectively assuming that consumption at port is 5% of which at sea.

$$\Delta CO_2 = 3.17 \times \sum_{k=1}^{n} (ME_{k,sea} \times D_{k,sea} + ME_{k,port} \times D_{k,port}) \tag{2.2}$$

$$ME_k = SFOC_k \times LF_k \times P \tag{2.3}$$

Under their estimation, the result showed that in 2010, CO_2 reduction decreased by 11% resulting from slow steaming even through taking 137 more vessels to maintain the service schedule. There was more significant reduction in the mega-sector, emissions from vessels capacities over 8,000TEU reduced more than 17%. On trade differences, in the scale of 387 services into eight routes, two biggest reductions occurred on Multi-trade, services covering more than two trade routes, such as around-the-world and pendulum services achieved more effective than Europe/Far East routes. The former (35.1% of capacity) decreased about 16.5% of GHG emission while the latter (14.6% of capacity) represented reduction in CO_2 emission by 16.4% compared to 2008. This 11.1% of reduction evidenced a fall from 170 million tonnes of CO_2 in 2008 to 151 million in 2010. (Cariou, 2011) Similar study generated by Corbett *et al.*, (2009) demonstrated that when the emission reduction can be up to 70% when the speed is halved. (Corbett, Wang, & Winebrake, 2009) Alternatively, Psaraftis *et al.*, (2009, 2010) stated that emissions can be reduced even further through cutting time in port without any extra capacities introduced into operation. To maintain a constant total trip time, one knot decreasing in speed will lead to a 25 minute increasing in voyage time. If it were available, this would to be a very satisfactory result with 10%

reduction in emissions. However, they also pointed that it needs drastic port re-engineering and performance improvements. (Kontovas, Psaraftis, & Kakalis, 2009)

2.2.3 Effect on Extra Capacities Absorption

Prior to the crisis, newbuilding market was frenzy. Shipyards struggled to meet the huge appetites from shipping lines ordering new and bigger vessels. (Notteboom & Rodrigue, 2010, p. 18) Thus, with the "impressive" downturn in demand of container trade, in 2009, trade volumes firstly dropped in the past two decades, by 9% according to the figure from UNCATD, which means that 124 million TEUs loss occurred that year. (UNCTAD, 2010) Shipping lines dealt to with the supply-demand-imbalance problem mainly in three ways: short-term idling ships; cancellation of order; and slow steaming. So, in this sector, we will review some literatures related to the effectiveness in absorbing extra capacities.

(1) Determination of effectiveness on absorption

Notteboom (2006) and Notteboom and Vernimmen (2009) gave one inequality limiting the minimal number vessels deployed on a specific service depending on the desired service frequency and vessel speed.

$$S \geq \frac{(\sum_{i=1}^{n} T_{pi} + \frac{D}{V \times 24}) \times F}{7} \tag{2.4}$$

where 7 stands for the 7 days/week. Normally, shipping carriers will try to have at least a weekly service. (Notteboom, 2006, p. 20) T_r is the round voyage time in days; T_{pi} is the total port time in port i in days; D is the distance of round voyage in nautical meters (nm); V is the vessels speed. (Vernimmen & Notteboom, 2009) But there is no very generic algorithm in this formula, just setting a baseline. Kontovas and Psaraftis

(2009) connected the speed variation to vessel number and proved their configuration through Aframax tanker and Panamax bulker fleet through the following equation as

$$\Delta N = N \times \left(\frac{\frac{L}{V_1 - \Delta V} + \frac{L}{V_2 - \Delta V} + T_{AB}}{\frac{L}{V_1} + \frac{L}{V_2} + T_{AB}} - 1 \right) \tag{2.5}$$

with ΔN is additional vessel number into operation to maintain the *same throughput*; L is voyage distance; V_1 and V_2 stands for different speed in laden and ballast leg respectively; ΔV is how many knots speed reduced; T_{AB} is total port time in a round voyage. (Psaraftis & Kontovas, 2009)

(2) Slow steaming in extra-capacities absorption

Vernimmen and Notteboom (2009) compared the deployment profile on Far East/Europe route in February 2005 and December 2007. The average number of vessels deployed on this route in two years is 8.12 and 8.50, separately. With the introduction of the ninth vessel to fix a weekly service, as a matter of fact, there were no less than **11** Far East/Europe loops in 2007 using 9 vessels while in 2005 there were only **4** such loops. They also revealed that due to entry of bigger vessels, deployment of nine 9,500TEU vessels at lower speed (20-24knots) together with cancellation of ports of call could be just the same as eight smaller vessels at normal speed to guarantee the same weekly call. (Vernimmen & Notteboom, 2009, pp. 332-334) On the shipping lines side, slow steaming is not sufficient. Re-designing the service route, especially on the backhaul from Europe to Far East, became more and more popular among shipping lines. Rerouting to the Cape of Good Hope rather than Suez Canal attributed to longer distance which directly need **10** vessels on average. Furthermore, the cost from canal transition could also be cut off. The typical example of this is Maersk Line, 15 services rerouted from the Cape compared to only 6 such services in early 2009. (Containerisation International, 2009) More significant effects could be seen from Alphaliner. In the beginning of 2010, the so-called extra slow steaming (17-18 knots) absorbed **2.3%** of ship capacities equivalent to 230,000 TEUs. This 2.3% of absorption rate almost doubled at the end of 2010 with **4.4%** of the cellular fleet representing 625,000 TEUs. The analysis also pointed out that the upper limit of absorption through extra slow steaming would therefore stand at about 900,000 to 1 million TEU in total or **7%** of current fleet capacities. (AXS-Alphaliner, 2010)

To sum up, in this part, we reviewed several research papers and analyses based on the effectiveness of slow steaming and further extra slow steaming from three aspects: reduction in fuel consumption, controlling in GHG emission and absorption in extra capacities. Most outcomes were very impressive and probably this is why shipping lines had a big crush on slow steaming. However, concerns were also mentioned in these papers such as damage to main engine, rudder control and some maritime safety issues. But the most remarkable point is the longer transit time from slow steaming. So in next sector, negative sides of slow steaming concerning with time factor will be studied.

2.3 Time Impact of Slow Steaming

As the old adage goes that "there is no free lunch", slow steaming is not 100% perfect. Obviously, longer transit time is the direct consequence of slow steaming. In this section, we will review several time related factors in logistics and consequences of longer transit time.

2.3.1 Time Related Factors in Logistics

(1) Lead time (LT)

Lumsden (2007) defined that lead-time is the time from order placement to delivery or the customers waiting time. The shorter lead-time, the more trustworthiness the company will gain. (Lumsden, 2007) More specific definition of lead time is provided by Tersine (1982) which consisting orders preparation, order transit, supplier lead time, delivery time and set-up time. (Tersine, 1982) It is widely recognized that the lead time is composed by time of delivery (t_L) and time of order (t_d) in the equation followed:

$$LT = t_L + t_d \tag{2.6}$$

To avoid stock out situation, the inventory should be large enough during the lead time.

(2) Safety Stock (SS)

The inventory should cover the demand for the entire goods flow. (Lumsden, 2007) This means that the inventory along with the normal demand (D), which is satisfied by the cycle stock. Statistically, demand during lead time (DDLT) always follows a normal distribution with its expected DDLT (EDDLT) and reorder point defining as EDDLT+SS. (Vernimmen, Dullaert, & Engelen, 2007, p. 206) Safety stock aims at to meet the extra demands during the lead time in the case of stock out.

$$SS = Z \times \sigma \tag{2.7}$$

where Z the safety factor is a value which limits the probability of a stock-out during any lead time period; σ is the standard deviation of DDLT. If the lead time is independent of demand and demands itself is not autocorrelated[1], the σ could be calculated as:

$$\sigma = \sqrt{(L \times \sigma_D^2) + (D^2 \times \sigma_L^2)} \tag{2.8}$$

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[1] Today's demand does not rely on the yesterday's data.

Where, D refers to the average demand, L refers to the average lead time; σ_D^2 is the variance of demand while σ_L^2 is the variance of lead time.

2.3.2 Impact from Longer Transit Time

The most significant impact from slow steaming is adding more inventory cost to shippers/consignees. Notteboom (2006) stated that short transit time is a competitive factor in liner shipping, in particular with time-sensitive goods. The author generated a calculation of one delay of a post-Panamax vessel at sea generating substantial costs for the shipping line. Assuming one TEU cargo worthies €40,000, typically, the inventory cost consists following two parts: (a) opportunity costs (3%-4% per year) and (b) economic depreciation (10%-30% per year for consumer products). The inventory cost on daily basis will be at least €57,000. Compared to the time charter rate for post-Panamax ($40,000 per day), the inventory cost is much higher, indicating that the shipping line could definitely charter out the vessel rather than operate it. (Notteboom, 2006) Similar studies run by Stemmer (2008) investigated more specific on the transport cost composed by *transportation cost*[2] and inventory carrying cost with high and low valued cargo categories. The conclusion is more significant. Inventory cost averages at 58.5% of the total costs of transport depending on low ($5,000/TEU) and high cargo ($10,000/TEU) value in different scenarios of long and short transit time. But the author focused more on the sea transportation section rather than the further supply chain management. (Stemmler, 2008)

More complete analysis on the time impact on logistics is driven by Vernimmen B., Dullaert W. and Engelen S. (2007) combining all the time related factors in logistics management. The paper used one case study one service from Santos (Brazil) to Port Elizabeth (South Africa) between which the voyage could be covered in 7 days

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[2] The sum represents the costs of the physical transport, including freight charges, handling cost, fees and commissions from the source to the destination of unit cargo.

implying the vessel speed is 24 knots. On the other side, the lead time[3] of goods of shippers/consignees is 3+8.1+1=12.1 days. The variance of lead time is 1+1.68+0.5=3.18 day^2.

Based on the equation (2.8), the paper showed that 0.5 day reduction in voyage will results decrease the standard deviation of DDLT (defined in section 2.3.1) more than 20%, resulting in a similar decreasing in safety stock level (number of containers in warehouse). Moreover, safety stock is directly related to the inventory cost. The paper also analyzed the benefits of 20% reduction in safety stock even with both high and low value spare parts. For the low value cargo (€20,000 per container load), this 0.5 days reduction in transit time leads to a decreasing in safety stock of 40.13 containers with a cost saving of €240,780. For high-value spare parts (€100,000 per container load), the result is more significant with a substantial cost saving at €2,000,000 on the annual basis!!! (Vernimmen, Dullaert, & Engelen, 2007, pp. 207-209)

In conclusion, most studies highlighted the time both in liner shipping and supply chain management. With longer time in carriage of goods, the impact on the shippers is amplified. There is no way that shipping line pay no attention to the customers. So, in the next section, we will go through more on the assessing the sustainability of slow steaming considering both sides.

2.4 Quantitative Methods on Sustainability of Slow Steaming

Many papers and researches glued benefits and potential expenses together observing the sustainability of slow teaming major for the sake of shipping lines. Several researches took deep insight on the cost/benefits of this strategy seeking under which circumstances that the slow steaming could be applied. In this section, several cost/benefits analysis from bunker price and speed optimization setting the benchmark

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[3] The lead time includes the time of carriage before port of loading, transit time and oncarriage to shippers' premises.

of sustainability of slow steaming.

2.4.1 Bunker Price Benchmarking (BP*)

Cariou (2011) analyzed that the long-term sustainability of slow steaming depends on the additional operational cost for the n vessel added ($OC_{\Delta n}$), on changes in the inventory costs (IC_{teu}) multiplied by extra time (ΔRot) at sea when vessels are slow steaming.[4] **The strategy sustained only under the circumstance that bunker price (IFO) on east/west route is in the scale of $350-400 per ton.** The equation is as followed.

$$BP^* \geq \frac{OC_{\Delta n, ds \to ss} + \Delta Rot_{ds \to ss} \times IC_{teu}}{\Delta FC_{ds \to ss}} \tag{2.9}$$

The author indicated that as long as the current bunker price is significantly over the BP*, slow steaming is viable as well as controls the CO_2 emission. The different bunker price break-even points on different services routes are attached within **Figure 1**. Figure 1 depicts the results on different services routes, comparison with the maximum and minimum bunker price in Rotterdam. Implications from results are as followed, in the Australia/Oceania, Latin America/Caribbean trades, the bunker break-even point is relatively high (over the maximum IFO price in Rotterdam) as a result of the low ratio between time at sea, and time in port. For other trades, the BP*is close to the average value in Rotterdam, the author suggested that a tax levy of around $50 could be enough to pass the break-even point.

However, limitations appeared in this methodology, the apparent one is less consideration of inventory costs for different value of cargo. The assumption of one

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[4] Speed changes from designed speed (ds) to slow steaming (ss) with different types of vessel according to respective deployment.

TEU cargo valued at $27,331 is not reliable to all the trade routes. (Cariou, 2011, p. 9) This leads to the inventory cost fluctuation influencing on the results. The second is that these costs are not sufficient constituting the sustainability analysis. The long term sustainability could be more rely on future newbuildings into the market, bunker price trends and technical improvement.

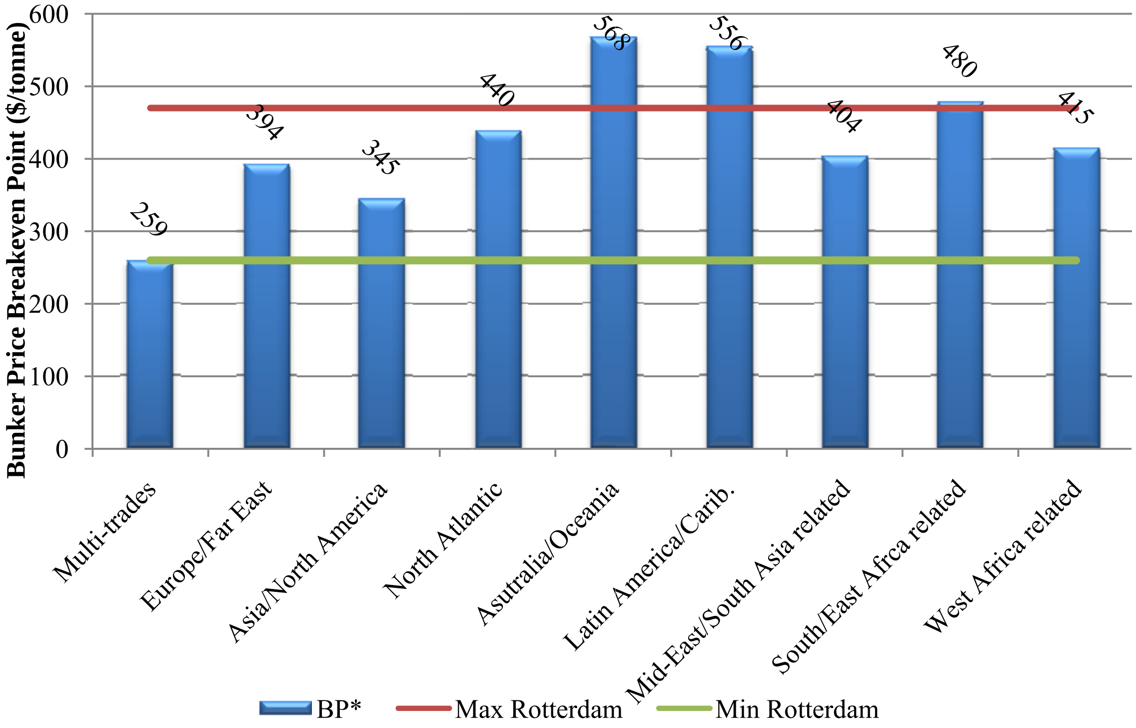

Figure 1 - Bunker Price Break-even Points ($/ton)
Source: Cariou, P. (2011). Is *slow steaming a sustainable means of reducing CO_2 emissions from container shipping?* Transportation Research Part D

2.4.2 Speed Optimization under Slow Steaming

Corbett *et al.* (2009) conducted an optimized speed function specific to containership and route characteristic to model cost changes in two scenarios with additional vessels or not. However, four assumptions should be given under this situation. Firstly, the trade development over the next decades will not change too much; Secondly, the containership fleet will change little in the near future; Thirdly, the freight rate will not fluctuate drastically consisting to the recent-year data; Fourthly, freight rates will not be affected by the cost changes. Given the assumptions, the optimized speed for a ship *k* operating from origin i to destination j is shown the equation:

$$S_{1k} = \left(\frac{(C_k + P \times AF_k) \times S_{0k}^3}{2P \times MF_k} \right)^{1/3} \qquad (2.10)$$

where C_k the fixed cost per day for ship k including capital cost; P stands for bunker price (\$/ton); MF_k represents main engines (s) daily fuel consumptions; AF_k represents auxiliary engine (s) daily fuel consumptions; S_{1k} and S_{0k} stand for the operational and designed speed of vessel *k*.

Applying the speed reduction to CO_2 reduction, authors compared with European Commission Carbon Market Price, which means the lower the price, the less sustainability of slow steaming will be. When there is no need to add more ships[5], the marginal cost can be less than the average 2008 price in carbon exchange markets. However, when additional capacities needed into operation, the marginal cost is always well above the market price for carbon whereas the cost effectiveness ranges of \$35-\$200/ton CO_2 for a speed reduction of 20%. (Corbett, Wang, & Winebrake, 2009, p. 597) The authors implied that the shipping industry would be a net buyer in a universal cap-and-trade carbon exchange market if there will be extra capacities in the service. This marginal cost effectiveness is the highest among the field where Endresen, O., Skjong, R., Longva, T., Alvik, S. and M.S. Eide (2009) reported a cost savings for a speed reduction from 25kn to 22kn is less than \$50/ton for CO_2 exchange price which is the criteria for shipping investors. (Eide, Endresen, Skjong, Longva, & Alvik, 2009) Apparently, this study gives more credits on the ship's operator without concerning shipper/consignee's interest. This potential loss of customers' loyalty is another cost to taken into consideration. Another concern is about assessing on different routes. The data and information collected by authors are among all the routes without analyzing on different service routes with different

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[5] Vessels carry more containers to meet constant container demands through increasing capacity factor or using more efficient package system.

profit-maximizing characteristics.

Reviewing the foregoing literatures, the major quantitative methods measuring the sustainability of slow steaming is highly related to the bunker price or CO_2 exchange price, which for the shipping lines, the biggest part in their daily operation. However, there are few researches taking the time impact on shippers/consignees interests into consideration which could cause tremendous opportunity cost on shipping lines.

2.5 Summary

In this chapter, we reviewed relevant researches from three aspects, namely, effectiveness of slow steaming, negative impact of slow steaming and economic sustainability of slow steaming. From an objective perspective, this strategy relieved more pressure for shipping lines under economic crisis and high fuel cost. The huge cost saving both in environment and bunker attracts liner shipping companies to establish this as a “win-win” strategy. (MAERSK, 2010) Nevertheless, shipper’s interest is largely sacrificed since the longer transit time from slow steaming, accompanying with additional inventory carrying cost, longer lead-time and upgrading safety stock. The slow steaming is regarded to put “butterfly effect” on the whole supply chain. (Marle, 2010)

In term of sustainability of slow steaming in long term, many scholars pointed that it should be carefully examined subject to different benchmarks, normally, fuel price related. Quantitative analysis is limited to the shipping line’s interests with less considering different cargo value or trade route characteristics. Generally, it is a very huge system taking all the related factors into consideration. The literature review provides not only some qualitative review on this strategy, but more quantitative analysis is more confirmed. So, in the next chapter, three major costs in slow steaming will be presented with detailed analysis.

Chapter 3 Economic Factors in Slow Steaming

3.1 Introduction

As widely accepted by main researches, the slow steaming strategy is effectively coping with high fuel consumption. But fuel consumption shall not be the only decisive criteria for slow steaming. In this chapter, three major factors in slow steaming will be listed out and an algebra method to assess the significance of each components upon total sustainability analysis.

3.2 Bunker Cost

3.2.1 Bunker Fuel Price Evolution

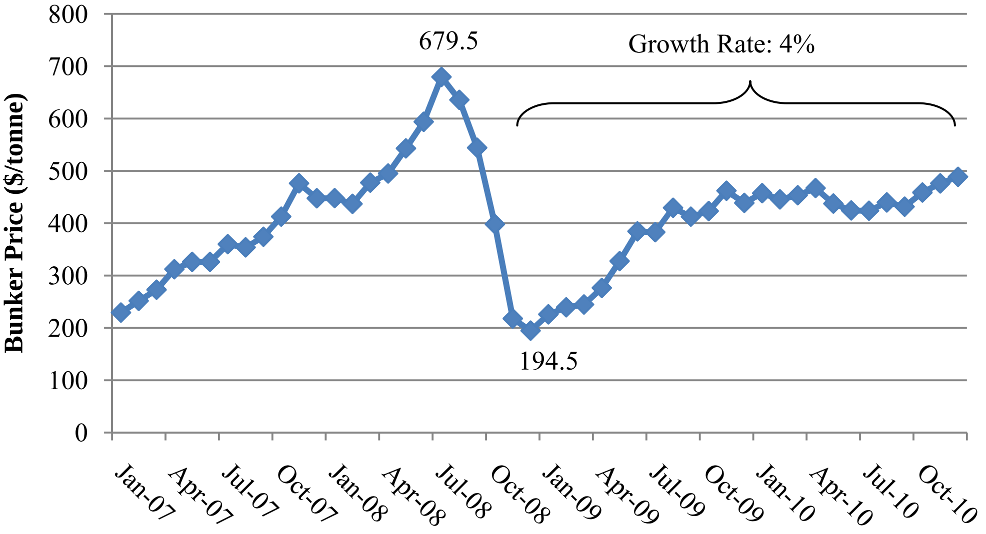

Figure 2 - Monthly Bunker Price at Port of Rotterdam Evolution 2008-10 ($/tonne)

Source: Own presentation based on data from Clarksons Shipping Intelligence Network (2011)

Figure 2 depicts the up and down of the bunker fuel[6] price at Port of Rotterdam where is always considered as the cheapest bunkering port. In the pre-crisis era, the price of 380 CST climbed all the way and finally peaked at \$679.5/tonne. With a sharp downwards, the fuel price dropped to the bottom which was around \$194.5/tonne within only three months with an impressive 70% decline! Moreover, during the recession, the bunker price crept steadily eventually arrived to the pre-crisis level with 4% average growth rate.

Volatility and up-trend were two characteristics of bunker price during the economic crisis. The former adds more risks for shipping lines. Several shipping lines including China Ocean Shipping Corporation (COSCO), Nippon Yusen Kaisha (NYK) hedged the bunker price fluctuation and charging Bunker Adjustment Factor (BAF). The latter, has an upward effect on costs which becomes a thorny problem for shipping lines. In the last couple of years, bunker price increased in line with the crude oil price. (Vernimmen & Notteboom, 2009, p. 325) Obviously, shipping companies cannot influence the crude oil price as well as the bunker price. The shipping industry's response to upcoming high bunker price is to control the fuel consumption.

3.2.2 Fuel Consumption

The actual fuel used by ship depends on her the speed and hull condition. As many researches shown, there is a cubic law between vessel speed and fuel consumption variation.

$$FC_{ss} = FC_d \times \left(\frac{V_{ss}}{V_d} \right)^3 \tag{3.1}$$

Where: FC_{ss} = fuel consumption under slow steaming (tons/day)

FC_d = designed fuel consumption

V_{ss} = speed under slow steaming (knots = nautical miles/day)

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[6] 380 CST grade – CST means the unit centistokes and related to the kinematic viscosity of the residual fuel

V_d = designed speed

In order to find effectiveness of speed reduction on fuel consumption, it is essential to collect current containership designed speed and fuel consumption. We extracted fleet information from Clarkson Shipping Intelligence Network within 2,001 observations categorized into nine groups according to ship size. We limited vessels younger than 20 years for the age of vessel differing fuel consumption by 20%. (Stopford, 1997, p. 170) Table 1 show our estimations based on cubic law on different vessels for speed varying from designed speed to actual speed and their corresponding fuel consumptions.

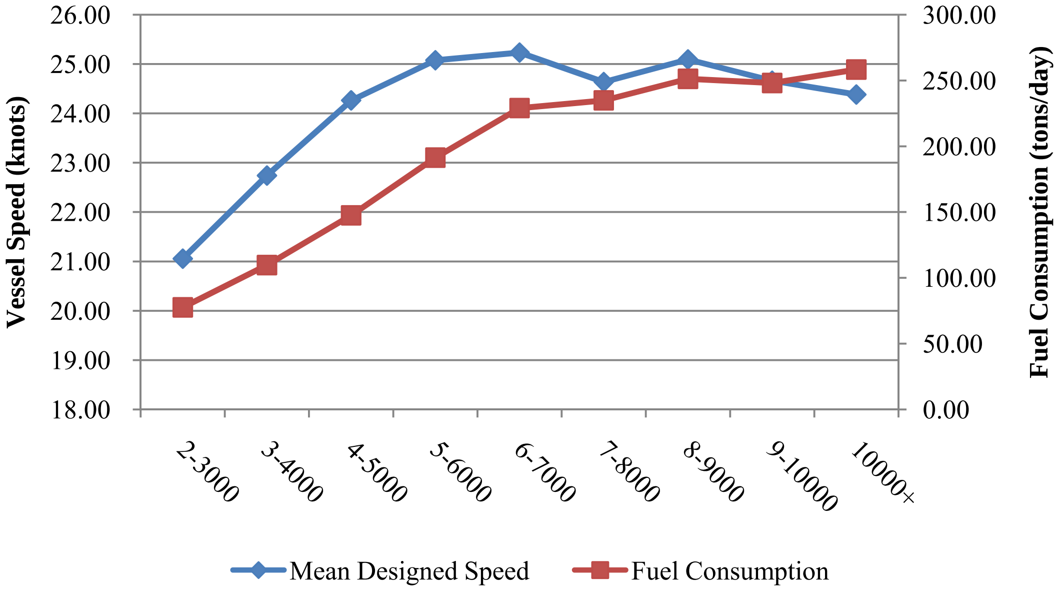

Figure 3 - Relationship between Vessel Size and Speed/Fuel Consumption
Source: Own Presentation

Figure 3 illustrates the relationship between vessel size and speed/daily fuel consumption. For vessels less than 7,000 TEU capacity, daily fuel consumption and speed are in line with ship capacity. However, a turning point occurs in which larger ships have lower speed. According to our observation and estimation, the average designed speed of 7-8,000 TEU vessels is only 24.66 knots. More significantly, 10,000 TEU has almost the same speed as 5,000 TEU vessels. On the other hand, the fuel consumption is getting flat with growth of vessel size. The gap of fuel consumption based on different categories is getting narrow since the fuel consumption is also depending on age, machinery and hull condition. Obviously, larger vessels came into operation in recent years, particularly, the 10,000 TEU class, with an age of two years while the 2-3,000 TEU class approaches to their scrapped point. This is largely due to the improving ship design technology and diesel engine. Apart from the technique, the cost effectiveness largely relies on speed variation.

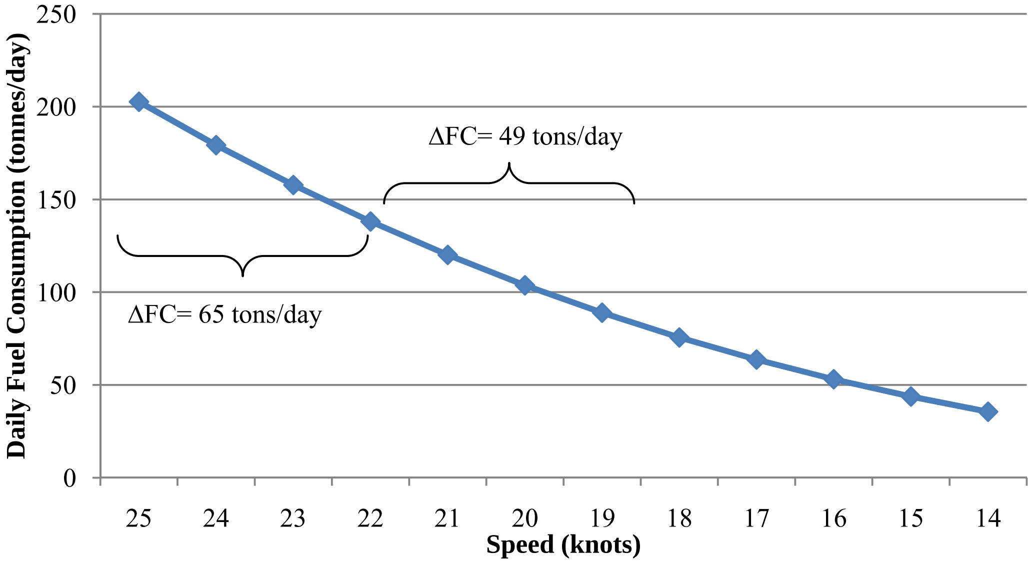

Figure 4 - Effectiveness of Speed Reduction on Fuel Consumptions

Source: Own Presentation

Figure 4 depict the effectiveness of speed reduction of a 7,024 TEU, 2007 built fully cellular containership[7]. The figure indicates that several knots dropping in speed leads to a drastic decrease in fuel consumption. (Vernimmen & Notteboom, 2009, p. 327) For instance, three knots (from 25 to 22 knots) reduction in speed gives rise to 65 tons fuel saving per day for a 7,024 TEU containership. Given the current bunker price haunting around $500/ton, which 65 tons bunker saving translates into daily cost saving to $32,270. But the cost effectiveness will diminish, if the ship sails further slower, from 22 to 19 knots, cost saving drops to $24,567/day. As long as bunker price increases, lower speed brought more cost savings.

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[7] "*Ever Safety*", owned and operated by Evergreen Marine Corporation

Table 1 - Results of Observation and Estimation

	2-3000	3-4000	4-5000	5-6000	6-7000	7-8000	8-9000	9-10000	10000+
Number of Vessel	288	288	574	303	193	43	189	57	58
Mean Size (TEU)	2,456	3,428	4,376	5,403	6,535	7,324	8,345	9,290	12,249
Mean Age	13	11	7	7	6	7	4	4	2
Mean Designed Speed	21.06	22.74	24.26	25.08	25.23	24.64	25.09	24.66	24.38
Fuel Consumption	77.65	109.76	147.59	191.40	229.09	234.93	251.33	248.13	258.39
Speed Variation (knots)	**Fuel Consumption (tons/day)[8]**								
25	-	-	-	190	223	245	249	258	279
24	-	-	143	168	197	217	220	229	246
23	-	-	126	148	173	191	194	201	217
22	89	99	110	129	152	167	169	176	190
21	77	86	96	112	132	145	147	153	165
20	67	75	83	97	114	126	127	132	143
19	57	64	71	83	98	108	109	113	122
18	49	54	60	71	83	92	93	96	104
17	41	46	51	60	70	77	78	81	88
16	34	38	42	50	58	64	65	68	73
15	28	32	35	41	48	53	54	56	60

Source: Own calculation based on fleet statistics from Clarkson Shipping Intelligence Network (2011)

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[8] Estimation based on equation 3.1

3.3 Operating Cost of Additional Capacities

3.3.1 Newbuildings in Containership Fleet

The primary reason for shipping lines to use slow steaming is to save fuel bill while the “bonus” for them is to relieve the overcapacities pressure. Due to strong “appetite” for newbuildings in 2006 and 2007, new capacities flooded into market during recession. With slow steaming, extra vessels are required to fleet maintain a weekly service. (Notteboom, 2006, p. 20) This perfectly settled shipowner’s trouble of oversupply.

Table 2 - Forecast of Containership Fleet Growth

Vessel Capacities (TEU)	**2010**	**2011**	**2012**	**2013**
10,000-15,500	884,798	1,486,708	2,240,418	**2,924,314**
7,500-9,999	2,262,471	2,498,644	2,687,204	**3,096,932**
5,100-7,499	2,637,656	2,853,297	3,009,343	**3,070,095**
4,000-5,099	3,074,686	3,232,212	3,436,004	**3,522,144**
3,000-3,999	1,098,580	1,139,543	1,190,304	1,256,396
2,000-2,999	1,821,452	1,854,864	1,888,905	1,937,021
1,500-1,999	987,871	1,007,845	1,026,029	1,032,957
1,000-1,499	831,438	865,023	889,343	894,729
500-999	591,517	603,359	609,617	609,617
100-499	87,390	87,128	87,128	87,128
Total	14,277,859	15,628,623	17,064,295	18,431,333

Source: Alphaliner (2011)

Future capacities into market absolutely determine the slow steaming. As Table 2 shown, Alphaliner predicted the containership fleet capacities in terms of TEU based on orderbook as at 01 March 2011 and assumption of no ships being cancelled after that date. In the next three years, global containership fleet will enter into the “mega” era. At the end of 2013, categories of vessels larger than 4,000 TEU will all be around three million TEUs slot capacities. Larger-than-10,000TEU class gives out an impressive annual growth rate of 48.1% according to Alphaliner’s calculation. During the next three years, orderbook of larger than 10,000 TEU is twice as much as the current fleet. On the other hand, smaller vessels (less than 1,000 TEU) will be almost static or even declining.

More newbuildings entering market will somehow break the current balance between supply and demand, especially in larger sectors. For speed reduction, it shall be going further slower. Actually, several shipping lines adopted “extra slow steaming” (second stage of slow steaming). But as discussed in section 3.2.2, the cost effectiveness in fuel consumption will be less significant. With more new capacities into operation, vessels go further slower, which makes shipping lines step into the third stage slow steaming – super slow steaming that will reach the barrier due to additional vessels and equipment. (Alphaliner, 2010)

3.3.2 Operating Cost (OPEX)

With new vessels introduced to string, shipping lines will face to pay extra OPEX. Normally, operating costs are the ongoing expenses connected with the daily operation of the vessel, plus periodic maintenance and repairs for day-to-day. (Stopford, 1997, p. 160) OPEX is regarded as “essential” costs whether the vessel is under operation or not. The principal components of OPEX are: manning (crewing); insurance; repairs and maintenance (R&M); stores and supplies; management and administration.

Among these five components, manning becomes the most critical for today’s shipping industry. Many shipping companies reported difficulty in finding qualified seafarers and wages are still increasing for experience officers. It is impossible to operate a ship without a captain. Total manning cost may account for up to half of OPEX with regard to crew deployment policy and the size of vessels. (Stopford, 1997, p. 161) Figure 5 vividly shows the gap between supply and demand of officers in shipping during past two decades. Demand for officers exceeded supply alongside in the whole 20 years while the future is getting worse. The fewer workers on board, the higher the salary will be paid without considering crew deployment for new vessels. Furthermore, with bigger ships, more crew members are required. Numbers for a typical 2,000 TEU vessels are 15 while for 10,000 TEU are 20-22. (Drewry Shipping Consultancy Ltd., 2010) Based on this, shipping lines will have no choice but to obtain extra officers with higher wages which finally lift up the OPEX.

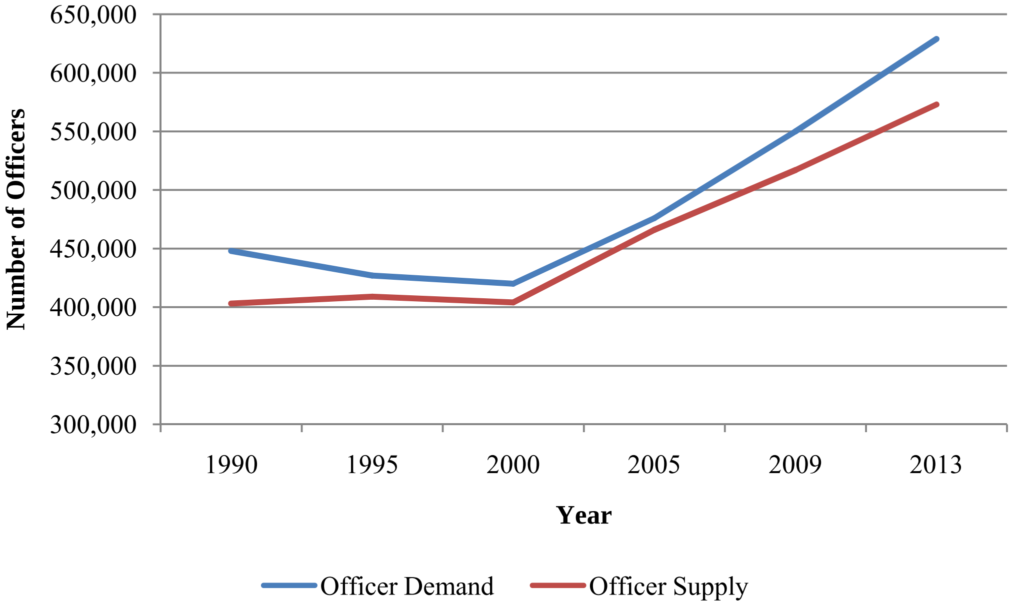

Figure 5 - Seafarers Supply/demand Imbalance
Source: BIMCO/ISF (1990-95), PAL/Drewry (2009-13)

3.4 Transit Inventory Cost

In transportation system, generally, shippers tend to be more/less willing to pay for a faster/slower service depending on the cargo capital costs which varies from commodity to commodity. (Ma, 2010, p. 42) Besides, trade structure also varies in international scale. So, in this section, we will observe both cargo value and structure.

3.4.1Estimation on Containerisable Cargo Value

In the past two decades, global production and manufacture had been fueled by containerization. Unlike bulk commodities, containerized cargo are manufacturing and consumer goods ranging from clothes to electronic devices. In order to determine the value of cargo packed in one FEU, we observe 19 mostly traded containerized cargo, accounting for 90% of container trade worldwide. Due to lacking in existing data, we estimated average value of one 40ft container through annual value of cargo (Asia exporting to North America) divided by corresponding transported quantities in one year[9].

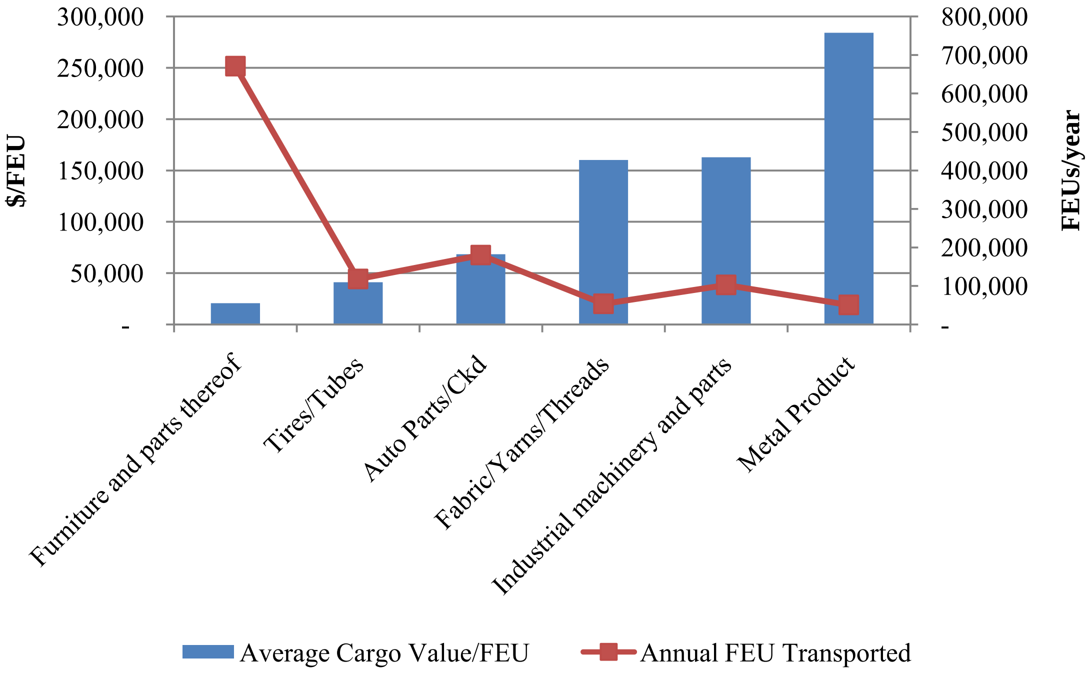

Figure 6 - Average Value per FEU and Annual Quantities for Selected Containerisable Cargoes
Source: Own presentation based on various issues of Chinese Custom Statistics, UNCTAD, Journal of Commerce

Some of our estimations are shown in Figure 6. Firstly, the average value varies strongly in accordance to what is in the container. Among 18 types of cargo, “fashion accessories or handbags” is the highest value with $526,915/FEU. However, one same box of “furniture and parts of” values at $20,694, which accounts for only 4% of “fashion products”. The reason is that the fashion product has a shorter life cycle or higher economic/technical depreciation ratio. (Notteboom, 2006, p. 27) Secondly,

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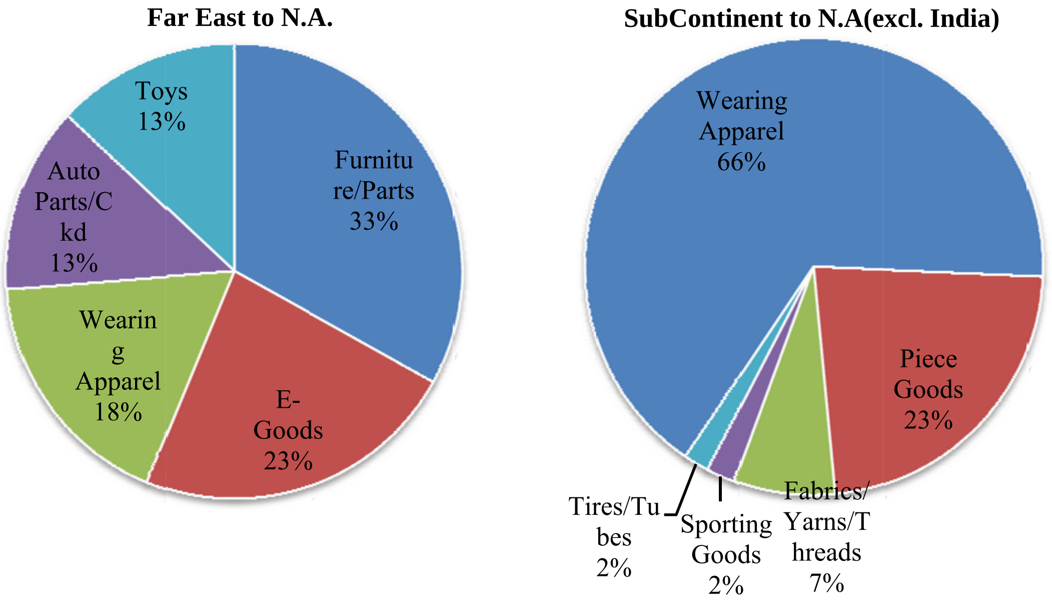
[9] See detailed calculation in Appendix I

from volume perspective, it quite differs from value. Furniture and its components have the largest transportation quantities with 671,052 FEUs from Far East to North America. The reason is furniture manufacturer IKEA, what they sell is just "semi-finished" product and still needed to be assembled. It is similar for auto parts. Thirdly, from demand side, fashion clothing is "sophisticated demand" products and what shippers want is to satisfy customers' demand on this regardless of transportation costs. Besides, tires and auto components are involved in the intermediate stage of "just-in-time" production. Car manufacturer will keep lead time as short as possible in order to avoid extra safety stock. (See the discussion in 2.3) On the other hand, basic demand goods, like furniture, with low value itself, cannot bear any additional costs for faster delivery. (Langen, 1999, p. 46)

Above all, we prove that cargo price which determines the in-transit inventory cost differs largely depending on what kinds of cargo on board. During our estimation of cargo value, the structure of merchandise trade is also distinct among different exporting countries.

3.4.2 Structure of Containerized Cargo Trade


Far East to N.A.

SubContinent to N.A(excl. India)

Figure 7 - Top 5 Goods Exporting from Sub-Continent and Far East to North America in 2009
Source: Own presentation based on data from Journal of Commerce PIERS (2011)

Specialization of different countries gives rise to the international trade. With trade agreement and policies among different partners, structure of transported cargo varies from region to region.

We select top 5 cargo exported from Far East[10] and Sub Continent[11] to North America. Figure 7 describe proportion of each top five cargo in terms of quantities (FEUs). The gap between commodities exported from Far East to North America is narrow. The biggest market share of exports is furniture, 33% while the smallest of ones are toys and auto part, 13%. In contrast, freight flows from Sub Continent are not as balanced as in Far East. Most exported merchandise is wearing apparel (clothing), accounting for 66% compared to 2% of sporting goods and tires/tubes.

Two reasons could explain this phenomenon. Firstly, the degree of production maturity in Far East is much higher than Sub Continent. Top five commodities traded between Far East and North America is exactly top five containerisable cargo traded between Asia and North America. Most cargoes from Far East are semi-finished/finished products; while from Subcontinent are raw materials in production stage, e.g., piece goods, fabric/yarns for clothing industry. Secondly, the diversity in goods exported. From the exporting list from Far East to North America, almost all the daily consumer goods could be found, like electronic goods, furniture and wearing apparel. However, 96% of top five commodities are just for ONE industry – clothing. (23% of piece goods + 66% of wearing apparel + 7% of fabrics/yarns/threads)

Based on above, shippers have different requirements and preference on velocity of transportation depending on cargo types and exporting countries. Consequently, the assessment of slow steaming is substantially based on different service routes.

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[10] Countries include Japan, Korea (South), China (Hong Kong, Taiwan), Singapore, Malaysia, Indonesia, Thailand, Philippines, Brunei, Cambodia, Laos, Myanmar and Viet Nam.

[11] Countries include Sri Lanka, Pakistan, Bangladesh

3.5 Summary

In this chapter, we list out three major economic factors related to vessels speed. Firstly, bunker costs. With no influence in oil market, the only way shipping lines could deal with considerable fuel costs is to taking control over fuel consumption. Based on cubic law, we calculate the fuel consumption of different vessels in terms of sizes. Secondly, operating costs. It is the essential costs for whether the vessels being assigned to transportation or not. The biggest part of operating costs is manning which will increase in the foreseeable future. Thirdly, the transit inventory costs. This is the cost that largely neglected by shipping lines when considering speed reduction. The value for one FEU is much depended on what inside the container. And due to the trade pattern and different production level in countries, the average value for one loaded container will be much different on different exporting countries.

Based on these three costs, in next chapter, we will do a cost/comparison study by setting several parameter constant aiming to observe how cargo price affecting the sustainability of slow steaming.

Chapter 4 Sustainability of Slow Steaming in Liner Shipping

4.1 Introduction

After identifying all the speed-related costs in liner shipping, slow steaming analysis is just based on cost comparison from fast to slow transportation. In this chapter, algebra of sustainability assessment will be first established followed by application to different services routes on Asia/North America trade.

4.2 Algebra of Sustainability Assessment

Hypothetically, a fleet of N identical containerships go back and forth between port A and B between which the distance is known as L_{AB} (nm). For simplicity, N ships are fully loaded from A to B and completely empty coming back.[12] The designed speed of ship equals to V_d (knots) while, under slow steaming, it goes down to V_s (knots). The annual operating cost for each ship is O.C. ($/year) and annual operating days for each ship is 350 days.

Round voyage time: $T = 2 \times L_{AB} / V_d$ (4.1)

Number of Round voyage per year: $n = 350 / T$ (4.2)

Number of vessel in string: $N = T / 7$ (4.3)

Not included in O.C. are bunker costs and transit inventory based on our discussion in Chapter 3. *Firstly,* the bunker cost. The actual daily fuel consumption, F.C.

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[12] The assumption is very close to trade from Far East to North Europe or North America

(tonne/day), is calculated based on fuel consumption from ship's designed speed according to cubic law. Concerning with bunker price P_b ($/tonne), we primarily set it as a constant during that voyage even though it's time-wise strongly fluctuated. *Secondly,* standing at a logistic view, reducing speed will consequently drive more inventory cost due to the late delivery. The daily inventory cost for a ship is assumed equal to I.C., which is determined by average retail price of containerisable cargo, P_c ($/TEU); discounted rates, R, as capital costs for goods in transit and vessel capacities, W (TEU). In order to simplify the scenario, the inventory cost occurs on loading, transiting (loaded) and discharge, excluding time spent in port and inland transportation. (Psaraftis & Kontovas, 2009)

Based on above, annual cost for a single vessel under initial speed is,

$$(F.C.\times P_b + P_c \times \frac{R}{365} \times W) \times 350 + O.C. \tag{4.4}$$

Then for N containerships, total fleet costs will be,

$$T.F.C._d = \left[(F.C.\times P_b + P_c \times \frac{R}{365} \times W) \times 350 + O.C. \right] \times N \tag{4.5}$$

When all N containerships sail from V_d to V_s, to maintain a weekly service (Notteboom, 2006), more ships have to be into fleet, assuming ΔN ships is as same as N ships in capacities.

$$\Delta N = {}^{\Delta T}\!/_{7} \tag{4.6}$$

Then, under slow steaming, total fleet annual cost will change to:

$$T.F.C_s = \left[(F.C.\times \left(\frac{V_s}{V_d} \right)^3 \times P_b + P_c \times \frac{R}{365} \times W) \times 350 + O.C. \right] \times \left(N + \Delta N \right) \tag{4.7}$$

Clearly, whether slow steaming is sustainable depends on cost changes. As long as

T.F.C.$_s$ less than T.F.C.$_d$, then reductions make sense. So, $\Delta T.F.C._{d \to s} \geq 0$ benchmarks the break-even point. As in our hypotheses, both bunker price and operating cost during one year remain constant; the inventory cost determines threshold of sustainability.

$$\Delta T.F.C_{d \to s} = F.C. \times D \times P_b \times \left[N - \left(\frac{V_s}{V_d} \right)^3 \times (N + \Delta N) \right] + P_c \times \frac{R}{365} \times W \times D \times \Delta N + O.C. \times \Delta N \geq 0 \tag{4.8}$$

$$P_c \leq \frac{F.C. \times 350 \times P_b \times \left[N - \left(\frac{V_s}{V_d} \right)^3 \times (N + \Delta N) \right] - O.C. \times \Delta N \Big/ \Delta N \times 350}{R \times W \big/ 365} \tag{4.9}$$

The slow steaming is only viable when cargo price does not exceed P$_c$, which means saving bunker bill while, simultaneously not causing additional inventory costs. One may consider that even though accounting in inventory cost, the threshold would be large enough. But it is not necessarily true. (Psaraftis & Kontovas, 2009)

In order to make our approach more clear, two scenarios are used to demonstrate it. Assuming one 8,000TEU vessel, typically deployed on Far East – Europe (via Suez Canal) trade route, goes from Shanghai to Rotterdam, a distance of 10,392 nm. The base speed for her is V$_d$=25 knots and the fuel consumption at which is 245 tonnes/day, then concerning the bunker price of P$_b$ = \$600/tonne, which is during a period of high price. If we decide to sail vessel under lower speeds, 80% and 70% of base speed V$_{s1}$=20, V$_{s2}$=18, knots. The annual operating cost for one 8,000 TEU vessel is \$4,104,060. (Drewry Shipping Consultancy Ltd., 2010) And we use 10% as discount rate which is the minimum standard for any assets or capital. Then we will have:

Table 3 - Results of Case Study

25 to 20 knots

v (knots)	**25**	**20**
Voyage Time (days)	34.43	43.04

Round Voyages/year (#)	10	8
Number of Vessel (#)	5	6
Fuel Consumption (tonnes/day)	245	125
Bunker Price ($/tonne)	600	600
Daily Bunker Cost($/day)	147,000	75,264
BC/year ($/year)	51,450,000	26,342,400
Daily Inventory Cost ($/day)	199,954	199,954
IC/Year ($/year)	69,983,940	69,983,940
OPEX/year ($/year)	4,104,060	4,104,060
Total. Cost/ship/year ($/year)	125,538,000	100,430,400
Total Fleet Cost/year ($/year)	**617,467,620**	**617,467,620**
Break-Even Point for Cargo Price ($/FEU)	-	*182,458*

25 to 18 knots

v (knots)	**25**	**18**
Voyage Time (days)	34.43	47.82
Round Voyages/year (#)	10	7
Number of Vessel (#)	5	7
Fuel Consumption (tonnes/day)	245	91
Bunker Price ($/tonne)	600	600
Daily Bunker Cost($/day)	147,000	54,867
BC/year ($/year)	51,450,000	19,203,610
Daily Inventory Cost ($/day)	170,319	170,319
IC/Year ($/year)	59,611,620	59,611,620
OPEX/year ($/year)	4,104,060	4,104,060
Total Cost/ship/year	115,165,680	82,919,290
Total Fleet Cost/Year	**566,450,623**	**566,450,623**
Break-Even Point for Cargo Price ($/FEU)	-	*155,416*

Source: Own calculation

The result of case study clearly shows that with going further slow, the threshold for average cargo price breakeven point is getting limited. This means shipping lines starting to deteriorate more shippers' interests in lower speed. Consequently, slow steaming will no longer be profitable. Of course, the break-even point may yield to different assumptions. For longer voyage distance, the break-even point is much higher because bunker cost saving is significant in long haul. Hence, evaluating the sustainability of slow steaming is much depended on different trade routes.

4.3 Application of Sustainability Analysis on Asia/America Trade Route

In this section, we will apply our sustainability assessment to real life data of Asia/North America trade in the period of 2008 to 2010 during which slow steaming started. In the last sub-section, the average value of containerisable cargo is used to determine the sustainability of slow steaming for each liner services.

4.3.1 Slow Steaming on Asia/America Trade Route 2008- 2010

According to Drewry Quarterly Container Forecast, there are 80 liner services in 2008 and 78 in 2010 offered by 23 shipping lines or strategic alliances on Asia/North America trade. For the present paper, we divide liner services into three categories in accordance to destinations, Far East/East Coast of North America, Far East/West Coast of North America and Far East/Mixed[13] services.

Table 4 - Comparison of Liner Services on Far East/North America Trade, 2008-10

	Number of Services (#)		**Average Size of Vessels (TEU)**	
	2008	**2010**	**2008**	**2010**
Far East/ECNA	19	9	4,411	5,339
Far East/WCNA	55	55	3,749	5,210
Far East/Mixed	6	14	4,601	5,187

Source: Own calculation based on Drewry Container Forecaster (2010)

As Table 4 indicates, in the end of 2008, 19 services are offered on Far East/ECNA while in 2010 shrinks down to 9. Number of services on Far East/WCNA remains the same in two years. However, on Far East/Mixed route, 8 additional services are added during 2008-10. Concerning with the size of vessels deployed, all three sectors upgrade to 5,000+ TEU class. Particularly, 5,000 TEU class is the biggest ship that allowed transiting current Panama Canal when routing on Far East/ECNA. Nevertheless, the variation of ship size is strong among three sectors. In 2010, For Far East/ECNA, the smallest and the biggest one are 4,024 TEU and 6,812 TEU. The

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[13] Port of calls in North America are both in west and east coasts, some are in the gulf region.

biggest gap appears on the Far East/WCNA, being 1,641 TEU and 9,685 TEU, with an average size of 5,210 TEUs. Big difference also occurs in the number of ships deployed. Taking the Far East/WCNA as an example of which services number is the same, as shown in Figure 8, in 2008, 28 out of 55 services are being run with 5 vessels while in 2010, a number of shipping lines start to add one or two additional vessel to the string which prompt services under "6 vessels" and "7 vessels". In an extreme case, there appears a 17 vessels loop on this trade in 2010. Increasing in number of vessels has a much higher impact on potential vessel speed reduction. (Vernimmen & Notteboom, 2009, p. 333)

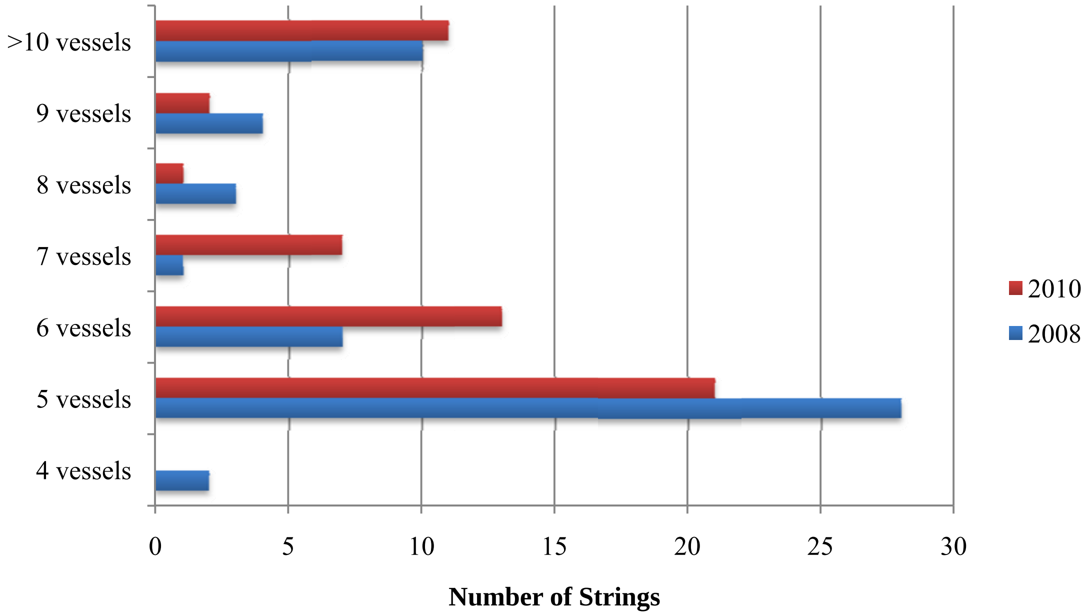

Figure 8 - Vessel Deployment on the Far East/WCNA Trade, 2008,2010
Source: Drewry Container Forecaster (2008,2010)

Table 5 - Slow Steaming on Asia/America Trade, 2010

	Number of Service	**% service slow steaming**	**Number of Vessels**	**% vessels slow steaming**	**Average Size of Vessel under Slow Steaming(TEUs)**
Far East/ECNA	9	67%	81	68%	4,841
Far East/WCNA	55	35%	389	36%	5,809
Far East/Mixed	14	31%	143	35%	5,323

Source: Drewry Container Forecaster (2008, 2009, 2010)

Table 5 shows the status of slow steaming on Asia/North America Trade regarding to longer transit time between ports of call. In Far East/ECNA, there are 6 services $(9 services \times 67\%)$ and 55 vessels $(81 vessels \times 68\%)$ are under slow steaming, which is the highest among three sectors. From the perspective of size of vessel, on Far East/WCNA and Mixed, bigger vessels are intended to sail slower compared to Far East/ECNA, with the average size of 5,809 TEU and 5,323 TEU. Obviously, a large number of liner services adopt slow steaming during recession. In next section, we will verify the sustainability of each service under slow steaming through the breakeven point for cargo value.

4.3.2 Breakeven Point for Cargo Value of Far East/N.A. Liner Service

Table 6 - Break Even Point of Cargo Price on AEX

Service Code/Sector	AEX/ECNA	
Distance (nm)	25,068	
Average Capacities (TEU)	5,712	
Port of Calls	16	
Speed Variation (knots)	26	22
Voyage Time (days)	56	63
Days @ Sea	40	47
Number of Vessel (#)	8	9
BC/year ($/year)	28,500,000	20,210,000
IC/Year ($/year)	30,291,550	31,637,841
OC/year ($/year)	3,701,830	3,701,830
Total Cost/ship/year	62,493,380	55,549,671
Fleet Cost/Year	499,947,040	499,947,040
Break-Even Point for Cargo Price ($/FEU)	-	154,852

Source: Own Calculation

Note: The round voyage distance is based on “port to port distance” on www. searates.com.

We calculate the breakeven point for cargo value on 24 services currently under slow steaming on Far East/N.A. through the designed the model in previous section (4.2). Table 6 is one of our estimations. Firstly, the round voyage distance for AEX is 25,068 nautical miles with 16 ports of call alongside. The average size of ships deployed is 5,712 TEU. In the year 2008, the voyage time is 56 days, in order to determine time at sea, we simply assume that each vessel spends one day in each port of call. (Vernimmen & Notteboom, 2009, p. 333) For example, in 2008, each vessel spends 40 days at sea per round voyage. Then we could get the vessel speed variation from 26 knots to 22 knot in 2008 to 2010. According to our estimation on daily fuel consumption (see, table 1), the daily bunker consumption decreases from 190 tonnes/day to 115 tonnes/day. The bunker price is set to be $600/tonne which is very close to current situation. Then, based on equation (4.9), the breakeven point of value for one FEU will be $154,852, which is higher than average value for one FEU exporting from Far East to North America, $116,175 as we estimated in section 3.4.1. So, slow steaming could be applied on AEX in future since shipping carrier does not sacrifice shippers' interest.

4.3.3 Assessment of Sustainability Slow Steaming on Far East/North America Trade

Then, we calculate the breakeven point for all the services under slow steaming on Far East/North America Trade route.[14] Table 7 shows the result.

Table 7 - Breakeven Point for Each Service on Far East/North America Trade

Break-Even Point for Cargo Price ($/FEU)		
Service Code		**Carriers**
Far East/ECNA		
AEX	154,582	Grand Alliance
NCE	63,233	Grand Alliance
SZX	170,691	New World Alliance
AWE1/AWH	156,958	CKYH
AWE3/AWY	179,219	CKYH
AWE5/AWN	76,227	CKYH
Far East/WCNA		
SSX	86,232	Grand Alliance
SCX	119,958	Grand Alliance

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[14] See Appendix II for detailed calculations

PNX	18,310	Grand Alliance/ZIM
PS2	174,573	New World Alliance
SAX	187,856	New World Alliance
PSX	174,737	New World Alliance
PCE	54,163	New World Alliance
PSW1	30,547	CKYH
PSX	89,637	CKYH
CAX	71,863	CKYH
UAM	108,473	Evergreen
PRX	77,831	MSC/CMA CGM
TP2/EAGLE	142,582	Maersk/CMA CGM VSA
TP8/NOX/Bohai Rim	73,317	Maersk/CMA CGM VSA
Far East/Mixed		
TP3-9	47,966	Maersk/CMA CGM VSA
APX/CNY	91,656	New World Alliance
PEX3	99,740	CMA CGM
PEX2/PACAR/AAE	59,760	CMA CGM/CSAV/CSCL

Source: Own calculation

The average value of one FEU, $116,175 is set to be a filter eliminating liner services out of "slow steaming zone". **Any services of which breakeven point for cargo value is lower than this filter are deemed to be unsuitable for slow steaming.** Then,

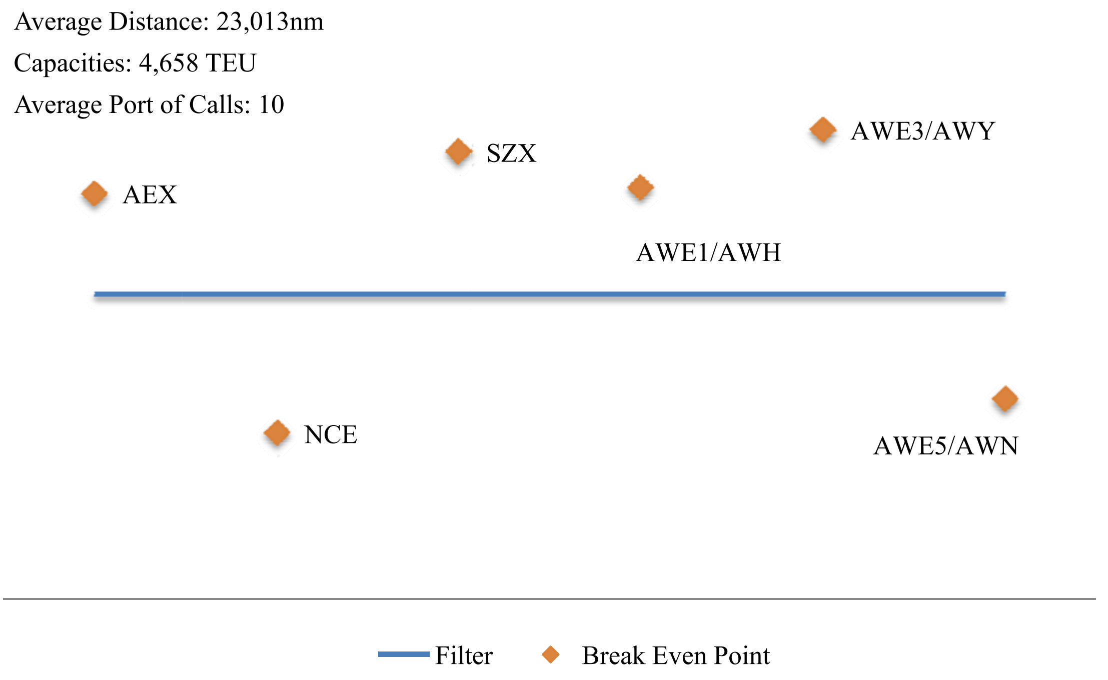

Figure 9 - Slow Steaming Assessment of Far East/ECNA
Source: Own presentation based on results

On Far East/ECNA, 2 services are being eliminated by filter while 4 services remain to be adaptive for slow steaming. It is largely because the distance between Far East to East Coast of USA is much longer together with fewer ports of calls. Breakeven points for the rest 4 service are high enough to pass our filter which means that these four services could be go further slower if the bunker price constantly climbing up.

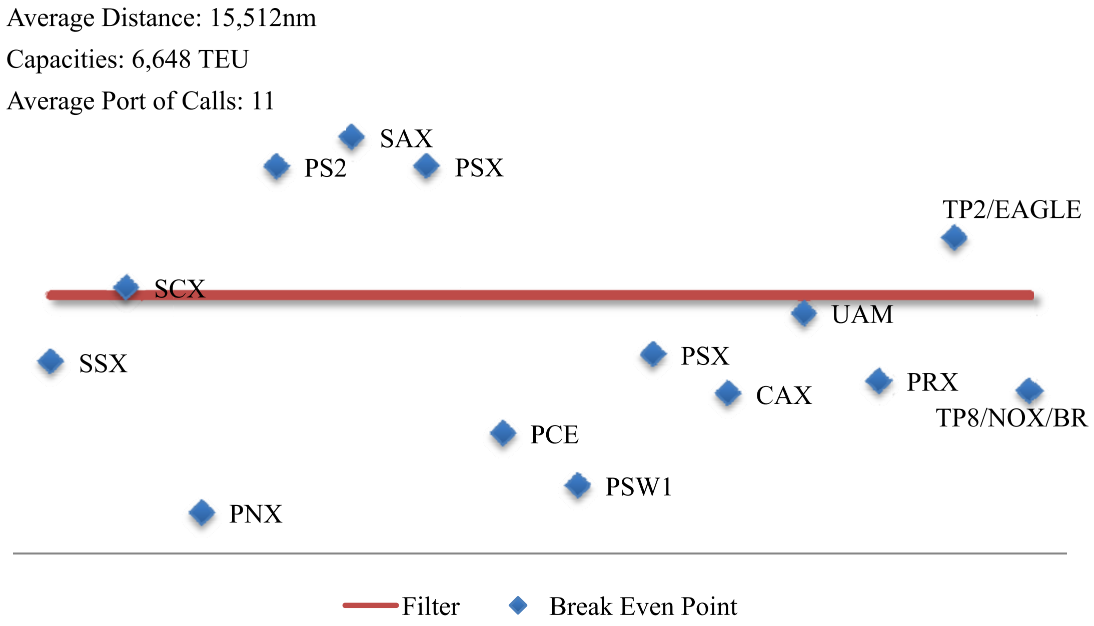

Figure 10 - Slow Steaming Assessment of Far East/WCNA
Source: Own presentation based on results

It is much different for west coast trade compared to east coast. A large number of services is cut on west coast, 9 services are in the “non slow steaming zone”. Compared to Far East/ECNA, the number of port of calls is the same but due to the transit distance of which Far East/WCNA is only 67% of the east coast trade, time at sea become shorter which press breakeven point downwards. From Figure 10, we could see two services almost stand on the filter. For SCX operated by Grand Alliance, they will start to deteriorate shippers’ interests as soon as vessels go further slower. In contrast, if ships on UAM from Evergreen speed up a little, then it will pass the filter.

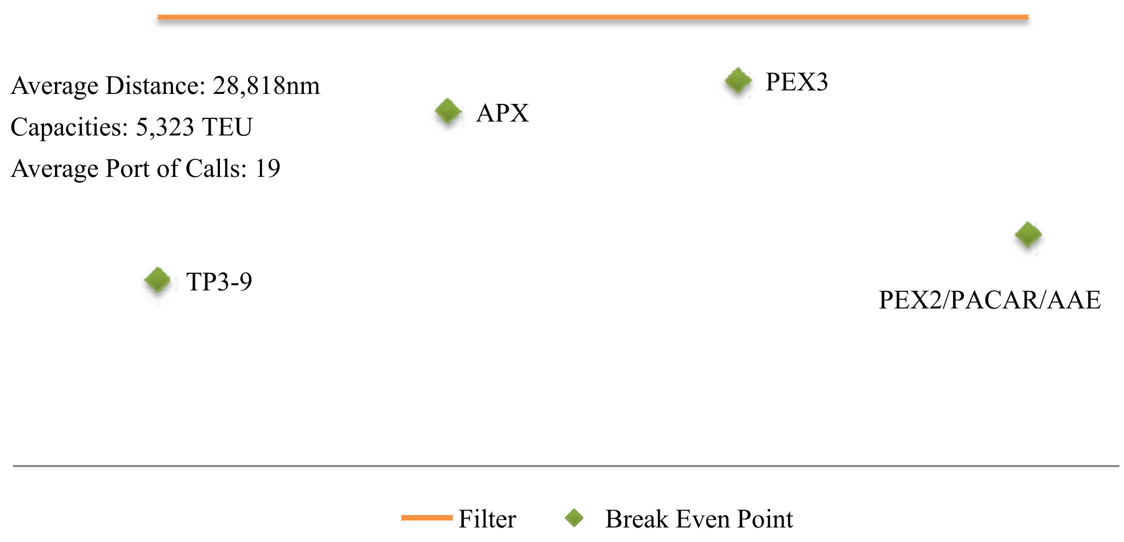

Figure 11 - Slow Steaming Assessment of Far East/Mixed
Source: Own presentation based on results

The most extreme result is on the mixed trade. None of 4 services is “survived” from the filter. Explanation for this is the longer transit distance and more ports of calls. Given the characteristics of mixed trade, it involved the two round-the-world (RTW) voyages, one double loop and one pendulum service. Taking PEX3[15] offered by CMA CGM as an example, among 15 ports of calls, almost half of them are in USA which make days at sea shorter. With longer round voyage distance, more ports of calls will reduce the days at sea leading to less bunker saving. Hence, the breakeven point is well below the filter. Under this situation, if the carrier keeps the vessel speed low, the only way is to cancel a few number ports of calls to will raise the breakeven point to pass the filter.

Table 8 summarizes our estimations on slow steaming for Far East/North America trade route. Comparing to Table 5, number of services has been reduced from 6 to 4 on Far East/WCNA On the other hand, Far East/WCNA is largely cut from 14 to 5 services. From 2008 to 2010, a number of operators providing West Coast services are

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[15] Port of Call: Chi wan – Shanghai – Pusan – Balboa (Panama) – Manzanillo Int’l Terminal – Houston – Mobile – Miami – Jacksonville – Savannah – Charleston - Port Tanger Med (Morocco) – Jeble Ali (Dubai, UAE) – Hong Kong – Chi wan

Table 8 - Estimation of "Actual" Number of Services under Slow Steaming

	Number of Services under Slow Steaming		**Number of Service**	**%**	
	Current	Estimation		Current	Estimation
Far East/ECNA	6	4	9	67%	44%
Far East/WCNA	14	5	55	25%	9%
Far East/Mixed	4	0	14	31%	0%
Average				**41%**	**18%**

Source: own calculation

sacrificing shippers' interest. Together with no services is suitable for adopting slow steaming in Far East/Mixed service; there could be 18% of total services using slow steaming whereas according to various market reports and research papers, around 41% of services of Far East/North America are under slow steaming.

4.4 Summary

In this chapter, we firstly establish a cargo price threshold for assessing the feasibility and sustainability of slow steaming. Secondly, by using a case study from "Shanghai-Rotterdam", we find that with lower speed, shipping lines could only take low value cargo leading to lower profits. Finally, the application to the real life data on Far East/North America trade route proves that a large number of liner services currently under slow steaming have caused shippers more inventory costs during transit with its breakeven point for cargo price not passing the average value containerisable cargo exporting from Far East.

Chapter 5 Conclusions

Organizations involved in container trade are facing great pressure from increasing oil prices and oversupply market pattern. Based on two reasons, shipping lines have no choice but to use slow steaming as a “self-rescue” strategy for covering great loss. The paper reveals the sustainability of this strategy from an overall cost analysis.

5.1 Main Findings

Firstly, today, interests of shippers on container trade is largely deteriorated by slow steaming for bearing more capital tied-up in transit. A large proportion of cargoes exported from Far East to North America are involved in manufacture process, with longer transit time, shippers will be forced to raise safety stock to maintain the same production level. Just as the estimation by Vernimmen *et al.* (2007) that 0.5 days increasing in transit time will cause shipper 2 billion euro additional annual storage cost in manufacturing process. (Vernimmen, Dullaert, & Engelen, 2007, pp. 207-209) The results also reflect rising complaints from shipper for slow steaming with various presses on this issue. US shippers have criticized slow steaming as a “carrier-driven” strategy which has hit supply chain. Moreover, the Federal Maritime Commission started to examine whether the overall impact on supply chain. Because slow steaming has driven some shippers to use “near-sourcing” which appears in higher fashion retailer, starting importing valuable cargo from Europe rather than Far East.

Secondly, the sustainability analysis of slow steaming is rational when shipping lines start to taking inventory costs into account. Through slow steaming, shipping lines seem to save substantial cost from fuel consumption reduction. But it is based on their ignorance of inventory costs. If inventory cost accounts for one component of voyage cost, the total cost changes is less significant. Shipping lines shall by no means neglect shippers' interest in today's integrated transportation chain. Imagine when the vessels sail at extremely low speed, it will provoke shippers stop choosing maritime transportation as its catastrophic *economic* damage to their goods.

Thirdly, slow steaming could be sustainable under better liner services designations. Indeed, shipping lines many argue about higher fuel price, but slow steaming not the only choice for dealing with it. A better alternative is designation of liner service. From our estimation for three Far East/North America sectors, for longer voyages, cancellation of port of calls could substantially uplift the breakeven point which will has a more positive effect in reducing bunker costs and not interfering shippers' interests.

5.2 Limitations of Research

Firstly, when assessing the sustainability of slow steaming, we simply set the bunker price and operating cost constant. However, these two costs vary regarding to different scenarios. For bunker price, apart from its time-wise fluctuation, the bunkering place is also a very critical part. Secondly, in collecting value of containerisable cargo, we just include the dry cargo container for lack of information for reefer cargoes which is more sensitive to transit time. Thirdly, the paper just analyzes the impact of slow steaming for shipper on the leg of water transportation. As many literature shown, longer time for shipper waiting will magnify on their further supply chain management.

Backing to question raised at the very beginning of the paper, "***is slow steaming a transient fashion or strategy here to say?***" It much depends on shipping lines reactions to today’s liner shipping market. Firstly, major shipping lines started another round of newbuilding orders to expand their market share. The year 2013 will witness the biggest number of containership deliveries. Slow steaming has absorbed large excess tonnage and almost reaches its barrier. When new capacities floods into the market, oversupply will be more critical than what we have seen today. Secondly, thanks to slow steaming, environmental performance is much improved during 2008 to 2010. Under no circumstance should green shipping become a hypocrisy hiding “green” ($) bottom line. (Notteboom & Rodrigue, 2011) When the international trade is recovering and demand for transportation is rising, every shipping line would like to offer a fast service catching as much as shipments they can. At that time, a low carbon footprint will be nothing to them.

Based on major conclusions we have, slow steaming is just an un-optimal optimization which could be effective for both shipping lines and shippers combined with synchronous re-design of liner services.

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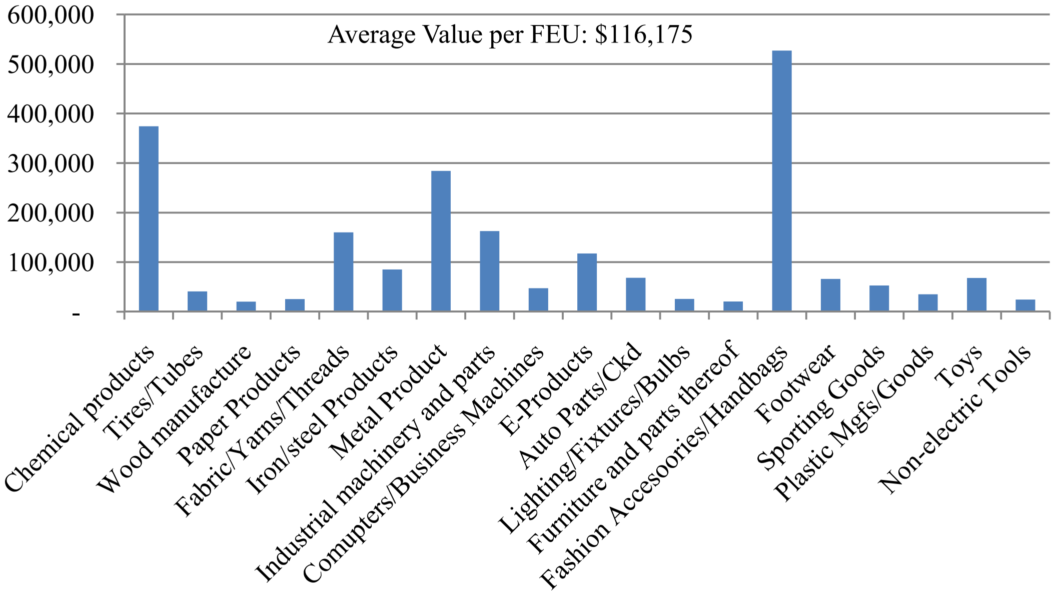
Appendix I – Average Value for Containerisable Cargo (Far East – North America)

Product Name	$/Year	FEUs/Year	$/FEU
Chemical products	20,389,400,004	54,476	374,282
Tires/Tubes	4,858,449,068	118,038	41,160
Wood manufacture	1,194,433,601	58,319	20,481
Paper Products	2,632,116,282	103,686	25,385
Fabric/Yarns/Threads	8,581,622,958	53,561	160,221
Iron/steel Products	4,794,181,744	56,316	85,130
Metal Product	14,392,329,207	50,654	284,130
Industrial machinery and parts	16,726,001,755	102,666	162,917
Computers/Business Machines	6,304,123,796	133,219	47,322
E-Products	48,067,521,004	409,311	117,435
Auto Parts/Ckd	12,320,989,825	180,219	68,367
Lighting/Fixtures/Bulbs	2,433,581,626	94,539	25,742
Furniture and parts thereof	13,886,463,486	671,052	20,694
Fashion Accessories/Handbags	43,326,089,419	82,226	526,915
Footwear	12,460,419,627	188,141	66,229
Sporting Goods	5,973,448,808	112,621	53,040
Plastic Mgfs/Goods	6,481,273,284	184,464	35,136
Toys	15,422,104,679	225,833	68,290
Non-electric Tools	2,071,056,000	84,737	24,441

Source: Chinese Custom Statistics, UNCTAD, Journal of Commerce



Appendix II - Breakeven Point for Cargo Price for Far East/North America Trade Routes

Far East/East Coast of North America (6)

Service Code	**AEX**		**NCE**		**SZX**	
Distance (nm)	25,068		21,878		23,225	
Average Capacities (TEU)	5,712		4,922		5,006	
Port of Calls	16		8		11	
Speed Variation (knots)	26	22	19	17	22	19
Voyage Time (days)	56	63	56	63	56	63
Days @ Sea	40	47	48	55	45	52
Number of Vessel (#)	9	10	8	9	8	9
BC/year ($/year)	28,500,000	20,210,000	12,780,000	9,350,000	21,768,750	14,386,667
IC/Year ($/year)	35,098,733	36,658,677	12,790,427	13,027,287	32,920,851	33,814,997
OPEX/year ($/year)	3,701,830	3,701,830	3,167,835	3,167,835	3,701,830	3,701,830
Total Cost/ship/year	67,300,563	60,570,507	28,738,262	25,545,122	58,391,431	51,903,494
Fleet Cost/Year	605,705,068	605,705,068	229,906,097	229,906,097	467,131,447	467,131,447
Break-Even Point for Cargo Price ($/FEU)	-	179,426	-	63,233	-	170,691

Service Code	**AWE1/AWH**	**AWE3/AWY**	**AWE5/AWN**
Distance (nm)	22,081	23,609	22,215

Average Capacities (TEU)	4,024		4,198		4,083	
Port of Calls	10		8		8	
Speed Variation (knots)	20	17	20	18	19	17
Voyage Time (days)	56	63	56	63	56	63
Days @ Sea	46	53	48	55	48	55
Number of Vessel (#)	8	9	8	9	8	9
BC/year ($/year)	14,317,500	9,010,000	17,280,000	11,000,000	12,780,000	9,350,000
IC/Year ($/year)	24,874,636	25,475,472	30,918,999	31,491,573	12,790,427	13,027,287
OPEX/year ($/year)	3,167,835	3,167,835	3,167,835	3,167,835	3,167,835	3,167,835
Total Cost/ship/year	42,359,971	37,653,307	51,366,834	45,659,408	28,738,262	25,545,122
Fleet Cost/Year	338,879,764	338,879,764	410,934,669	410,934,669	229,906,097	229,906,097
Break-Even Point for Cargo Price ($/FEU)	-	156,958	-	179,219	-	76,227

Far East/West Coast of North America (14)

Service Code	**SSX**		**SCX**		**PNX**	
Distance (nm)	13,195		17,117		15,425	
Average Capacities (TEU)	8,063		6,508		8,342	
Port of Calls	9		15		12	
Speed Variation (knots)	21	17	25	17	21	19
Voyage Time (days)	35	42	49	56	42	49
Days @ Sea	26	33	28	41	30	37
Number of Vessel (#)	5	6	7	8	6	7

BC/year ($/year)	22,932,000	12,870,000	22,800,000	10,762,500	22,050,000	17,284,286
IC/Year ($/year)	24,763,841	26,192,524	21,388,648	27,404,205	5,230,789	5,529,692
OPEX/year ($/year)	4,104,060	4,104,060	3,986,895	3,986,895	3,986,895	3,986,895
Total Cost/ship/year	51,799,901	43,166,584	48,175,543	42,153,600	31,267,684	26,800,872
Fleet Cost/Year	258,999,506	258,999,506	337,228,799	337,228,799	187,606,106	187,606,106
Break-Even Point for Cargo Price ($/FEU)	-	86,232	-	119,958	-	18,310

Service Code	**PS2**		**SAX**		**PSX(New World Alliance)**	
Distance (nm)	15,867		15,788		15,830	
Average Capacities (TEU)	5,780		6,622		6,292	
Port of Calls	13		8		11	
Speed Variation (knots)	23	18	19	16	21	17
Voyage Time (days)	42	49	42	49	42	49
Days @ Sea	29	36	34	41	31	38
Number of Vessel (#)	6	7	6	7	6	7
BC/year ($/year)	21,460,000	10,954,286	25,160,000	12,475,714	22,940,000	11,562,857
IC/Year ($/year)	33,403,975	35,543,145	48,282,514	49,905,455	38,907,292	40,879,551
OPEX/year ($/year)	3,701,830	3,701,830	3,986,895	3,986,895	3,986,895	3,986,895
Total Cost/ship/year	58,565,805	50,199,261	77,429,409	66,368,064	65,834,187	56,429,303
Fleet Cost/Year	351,394,827	351,394,827	464,576,451	464,576,451	395,005,121	395,005,121
Break-Even Point for Cargo Price ($/FEU)	-	174,573	-	187,856	-	174,737

Service Code	**PCE**		**PSW1**		**PSX(CKYH)**	
Distance (nm)	15,877		13,377		13,167	
Average Capacities (TEU)	4,591		4,613		7,643	
Port of Calls	10		10		9	
Speed Variation (knots)	26	21	22	17	21	17
Voyage Time (days)	35	42	35	42	35	42
Days @ Sea	25	32	25	32	26	33
Number of Vessel (#)	5	6	5	6	5	6
BC/year ($/year)	21,450,000	15,360,000	16,500,000	8,160,000	22,620,000	12,705,000
IC/Year ($/year)	8,515,832	9,083,554	4,825,832	9,083,554	24,400,606	25,808,334
OPEX/year ($/year)	3,167,835	3,167,835	3,167,835	3,167,835	4,023,030	4,023,030
Total Cost/ship/year	33,133,667	27,611,389	24,493,667	20,411,389	51,043,636	42,536,364
Fleet Cost/Year	165,668,336	165,668,336	122,468,336	122,468,336	255,218,181	255,218,181
Break-Even Point for Cargo Price ($/FEU)	-	54,163	-	30,547	-	89,637

Service Code	**CAX**		**UAM**		**PRX**	
Distance (nm)	13,975		28,761		12,848	
Average Capacities (TEU)	5,482		5,570		8,242	
Port of Calls	9		30		7	
Speed Variation (knots)	31	22	20	18	19	15
Voyage Time (days)	28	35	91	98	35	42
Days @ Sea	19	26	61	68	28	35

Number of Vessel (#)	4	5	13	14	5	6
BC/year ($/year)	20,662,500	12,012,000	13,654,615	10,345,714	18,312,000	9,450,000
IC/Year ($/year)	12,816,972	14,031,212	19,418,224	20,100,363	24,604,752	25,629,950
OPEX/year ($/year)	3,701,830	3,701,830	3,701,830	3,701,830	4,104,060	4,104,060
Total Cost/ship/year	37,181,302	29,745,042	36,774,669	34,147,907	47,020,812	39,184,010
Fleet Cost/Year	148,725,210	148,725,210	478,070,700	478,070,700	235,104,060	235,104,060
Break-Even Point for Cargo Price ($/FEU)	-	71,863	-	108,473	-	77,831

Service Code	**TP2/EAGLE**		**TP8/NOX/BR**	
Distance (nm)	13,382		12,556	
Average Capacities (TEU)	7,043		8,280	
Port of Calls	8		8	
Speed Variation (knots)	21	16	19	15
Voyage Time (days)	35	42	35	42
Days @ Sea	27	34	27	34
Number of Vessel (#)	5	6	5	6
BC/year ($/year)	23,490,000	10,880,000	17,658,000	9,180,000
IC/Year ($/year)	37,141,948	38,976,119	22,453,154	23,561,951
OPEX/year ($/year)	4,023,030	4,023,030	4,104,060	4,104,060
Total Cost/ship/year	64,654,978	53,879,149	44,215,214	36,846,011
Fleet Cost/Year	323,274,891	323,274,891	221,076,069	221,076,069
Break-Even Point for Cargo Price ($/FEU)	-	142,582	-	73,317

Far East/Mixed

Service Code	**TP3-9**		**APX**		**PEX3**		**PEX2/PACAR/AAE**	
Distance (nm)	35,912		30,260		26,745		22,356	
Average Capacities (TEU)	7,069		4,761		5,079		4,383	
Port of Calls	17		26		15		16	
Speed Variation (knots)	18	17	22	19	20	18	17	15
Voyage Time (days)	98	105	84	91	70	77	70	77
Days @ Sea	81	88	58	65	55	62	54	62
Number of Vessel (#)	14	15	12	13	10	11	10	11
BC/year ($/year)	15,968,571	13,552,000	10,295,000	7,650,000	16,005,000	12,005,455	8,262,000	5,918,182
IC/Year ($/year)	13,436,883	13,624,889	14,446,257	14,944,404	19,083,562	19,556,708	9,687,711	10,111,753
OPEX/year ($/year)	4,023,030	4,023,030	3,167,835	3,167,835	3,701,830	3,701,830	3,167,835	3,167,835
Total Cost/ship/year	33,428,485	31,199,919	27,909,092	25,762,239	38,790,392	35,263,993	21,117,546	19,197,769
Fleet Cost/Year	467,998,787	467,998,787	334,909,101	334,909,101	387,903,921	387,903,921	211,175,464	211,175,464
Break-Even Point for Cargo Price ($/FEU)	-	47,966	-	91,656	-	99,740	-	59,760

Source: all calculation based on information from Drewry Container Forecast (2008, 2009, and 2010)