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Effects of Slow Steaming Strategies on a Ship Fleet

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Abstract:
Currently container ships operators have implemented slow steaming strategies in their fleets to improve the profit margins by reducing operational costs. However, some ship owners are not yet convinced of this practice because the navigation time is increasing that cause a reduction of the number of travel per year of the ship. The use of speed reduction by liner shipping has been widely discussed in the literature. Nevertheless, this effect has not been studied in bulk carriers because they are navigating slower than container ships. This paper proposes a simulation model of a bulk carrier's fleet composed by 13 ships from a unique ship-owner in three conditions: the actual condition of navigation, the slow steaming and ultra-slow steaming. A discrete-event simulation model has been developed considering historical data of a bulk carrier fleet. The results obtained are the total fuel consumption, emissions and the cargo transported for one year. These values are showing that the fleet can be operated with higher efficiency when the slow steaming strategy is used. Indeed, the saving in fuel cost and emissions are balancing the reduction of the cargo transported per year.

1 – Introduction

In the last decade, the world merchant fleet dedicated to international trade has increased. In January 2015, the ship world fleet grew by 3.5% and reached 1.75 billion DWT that consisted of 89464 vessels including bulk carriers, oil tankers and container carriers. The sea shipping industry is responsible for 90% of world trade; it demands a total international cargo over the 9841 millions of tons (UNCTAD, 2015).

Consequently, it produces a growth of fuel consumption and Green House Gas (GHG) emissions at sea. The GHG emission of ship engines have raised the concern of International Maritime Organization (IMO) on the consequences for environment and human health.

In addition, IMO first adopted MARPOL Annex VI in 1997. It limits the main air pollutants in ships exhaust gas, including sulphur oxides SO_X.

Following entry into force of MARPOL Annex VI the main changes are a progressive reduction in emissions of SO_X, NO_X and Particulate Matter (PM), as well as the introduction of Emission Control Areas (ECA). ECA are created to further reduce emissions of those air pollutants in designated sea areas.

Nevertheless, the shipping industry is facing huge challenges. First, main concern of shipowners is to reduce operating cost and maximize incomes, whereas the fuel price has increased significantly over the years. Second, customers such as shippers and freight forwarders are increasingly demanding on-time delivery (Lee, Lee, & Zhang, 2015). Third, ships must fulfil the rules regarding environmental restrictions implemented by the IMO (emissions limitations).

In the case of fuel cost, the fuel consumption of sea vessels depends heavily on the steaming speed. The practice of slow steaming (speed reduction denoted in this paper as SS) has become more common in cargo fleets especially in liner shipping (Cariou, 2011).

The study of SS practice in liner shipping became more frequent in the last years, (Wong, Tai, Lau, & Raman, 2015), (Tai & Lin, 2013), (Cariou, 2011), but this practice is not a common strategy for bulk carriers.

Delivering on time is a difficult challenge due to port congestion, inefficient port operations, extreme weather conditions, machine breakdowns and other factors, (Lee, Lee, & Zhang, 2015). In addition, some industries criticize the SS because it is necessary to build more ships to transport the same quantity of product and achieve targets of delivery time.

Lastly, one positive effect of SS is that it reduces GHG emissions, that are proportional to the amount of fuel burned, (Cariou, 2011).

Recently they have been significant advances in SS approach not only in the study of economic aspects (Rahman, Yang, Bonsall, & Wang, 2015), (Notteboom & Cariou, 2013), (Maloni, Paul, & Gligor, 2013), (Ferrari, Tei, & Parola, 2012) but also in others areas as resistance (Tezdogan, Incecik, Turan, & Kellett, 2016), shipping time, bunker cost, ability to deliver on time (Lee, Lee, & Zhang, 2015) and environmental advantages (Cariou, 2011).

In this paper, the influence of SS on one fleet of 13 bulk carrier ships trough simulation is analysed. This model uses criteria based on speed, fuel oil consumption, distance travelled, cargo and emissions quantity (CO2 and SOX). Then, the results of a simulation model suggest that SS implementation is a possible solution to turn navigation more profitable in economic and environmental aspects for bulk carriers.

2 – Methodology

This section presents the developments of the model including the explanation of the methodology, the database (DB) used in the analysis as well as the criteria selection. Thereafter, the definition and implementation of the models are presented. The main steps of the proposed methodology are shown in Figure 1.

The goal of this work is to evaluate the potential economic and environmental benefits of new navigation condition: slow steaming (SS) and ultra-slow steaming (USS).

The proposed framework consists of a discrete event simulation (DES) model to represent the voyage process. Both economic and environmental parameters were considered to assess the influence of SS and USS in a fleet of bulk carrier ships. The design of the alternatives is based on the review literature and expertise.

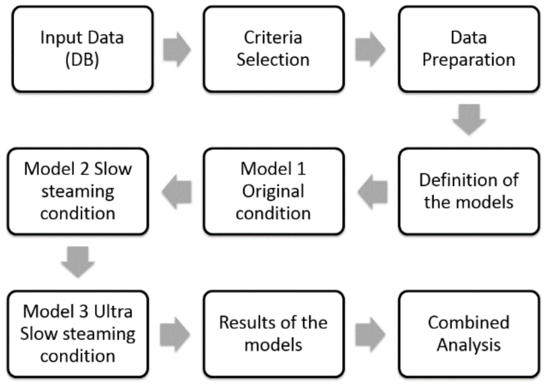

Figure 1 – Flowchart of the methodology

This approach is similar to previous studies proposed by (Cepeda & Caprace, 2015). The previous mentioned study analyses the influence of the SS and USS on one fleet of 15 bulk carriers considering only the fuel consumption, distance, and cargo. In addition to these variables, the present model consider the emissions that is a critical parameter to fulfil current regulations.

Several alternatives were designed for different variable settings. DES was then used to valuate key performance improvements.

DES is the process that by a model can mimic an existing complex system using a sequence of events and provide to the decision-maker a vision on how that system might perform, (Sweetser A. , 1999).

The model is developed to balance and evaluate the operational decision on speed reduction with the factors on bunker cost, fuel oil consumption, distance travelled, cargo quantity, and carbon dioxide emission and sulphur oxide.

2.1 – Database and Input Analysis

The simulation stage was based on a valid process model. The main steps of the proposed methodology are shown in Figure 1.

In this study, 13 bulk carrier vessels from a ship fleet of a unique ship owner are considered. Table 1 gives a highlight on ship main features.

The DB represents a period of 2.5 years. That means 6844 records corresponding to 223 voyages (one way travels).

The information available is obtained in laden and ballast conditions. The simulation were developed to split the ship fleet in three ship types based on maximum displacement of each one.

Table 1 – Ship fleet mean features (13 vessels)

Description	Mean	Standard Deviation
Total Length (m)	289.5	16.7
Breadth (m)	46.7	3.6
Draft (m)	18.0	0.7
Design speed (Knots)	14.22	0.77
Max. displacement (tons)	202052	36274
DWT (tons)	179438	33351

Ship type 1 is composed by vessels that have a maximum displacement between 167963 and 191668 tons. It represents 54% of the whole fleet. Ship type 2 is composed by vessels that have a maximum displacement between 201550 and 224978 tons. It represents 31% of the whole fleet. Finally, the ship type 3 is composed by vessels that have a maximum displacement between 259711 and 280313 tons. It represents the 15% of the entire fleet.

The model simulates one-way voyages of the vessels using ARENA for both ballast and laden conditions. For each sub-model (original, SS or USS), inputs and outputs are detailed in the Table 3.

The present study includes the CO_2 and SO_X emissions.

IMO defined the Energy Efficiency Operational Indicator (EEOI). It is an expression of emission efficiency in the form of CO_2 emitted per unit of transport work, (IMO, 2009). The ECO_2 is given by Equation 1, ECO_2 represents the amount of CO_2 emission released into the atmosphere, where j is the fuel type, FC is the mass of consumed fuel in Kg, C_{F} is the fuel mass to CO_2 mass conversion factor in Kg-CO_2/t-fuel, see Table 2. M is the cargo carried in tons and D is the travel distance in nautical miles. A higher value of this indicator denotes a lower efficiency.

$$ECO_2 = \frac{\sum_j FC_j \times C_{F_j}}{M \times D} \qquad (1)$$

Today there are commercial software used to estimate the EEOI value before the trip. Even though the indicator EEOI is not enough to measure the overall efficiency of ships, it indicates the amount of CO_2 released into the atmosphere.

The ESO_X is given by Equation 2, ESO_X represents the amount of SO_X emission released into the atmosphere per unit of transport work, where j is the fuel type, FC is the mass of consumed fuel in Kg, C_{S} is the fuel mass to SO_X mass conversion factor in Kg-SO_X/t-fuel, see Equation 3. M is the cargo carried in tons and D is the travel distance in nautical miles.

$$ESO_{\mathrm{X}} = \frac{\sum_j FC_j \times C_{S_j}}{M \times D} \qquad (2)$$

$$C_S = SF \times 20 \times VB \qquad (3)$$

Where SF is the percentage of sulphur present in the fuel and VB is the volume of bunker in Tons of Fuel.

Table 2 – Fuel mass to CO_2 mass conversion factors CF in [Kg-CO2/t-fuel]

Type of fuel	Carbon content	C_{F}
Diesel/Gas Oil	0.88	3.21
LFO – Light Fuel Oil	0.86	3.15
HFO – Heavy Fuel Oil	0.85	3.11
LPG – Liquefied Petroleum Gas – Propane	0.82	3.00
LPG – Liquefied Petroleum Gas – Butane	0.83	3.03
LNG – Liquefied Natural Gas	0.75	2.75

The ESO_X is in Kg-SO_X/t-fuel and it depends on the type and sulphur content of the fuel used by the ship, (Cooper, 2002). It has to multiply total bunker consumption by the percentage of sulphur present in the fuel and subsequently by a factor of 20 to compute SO_2 emissions. The 20 SO_X factor is exact and comes from the chemical reaction of sulphur and oxygen to produce SO_2. A higher value of this indicator denotes a lower efficiency.

The SF is calculated based on the actual sulphur content in the fuel, see Equation 4. The dilution factor is calculated by the average quantity of sulphur content that depends on the type of bunker fuel (IFO or MDO) on-board and the quantity of the fuel in this operation in the port of refuel. The fuel quality can be altered depending on the refuelling port, which influences the quality of the bunker.

It is assumed that the average sulphur content (SF) for IFO and MDO are 2.5% and 0.25% respectively, if the information about quality of fuel (sulphur content) is not available, (Cepeda M. , 2016).

$$SF = ABQ \times ASC + RBQ \times RSC \qquad (4)$$

Where ABQ is the actual quantity of bunker on-board in Tons, ASC is the percentage of concentration of SO_X of the bunker on-board, RBQ is the quantity of bunker to be refuelled in Tons, RSC is the percentage of the average concentration of SO_X of bunker to be refuelled.

The models represent 360 days (one year) and it is running for 200 iterations. Semi-random numbers have been altered between each iteration.

Model 1 represents the original (ORI) condition of the system. The main parameter to define the model is the speed. Model 2 represents the SS condition of the system where speed is decreased by 2 knots compared with the ORI model. Model 3 represents the USS condition of the system where speed is decreased by 4 knots compared with the ORI model.

The inputs parameters are fixed for laden (LC) and ballast (BC) conditions as well as for original, SS and USS strategies. Total consumption of fuel, and average daily emissions parameters are modified due to speed effect.

Table 3– Input and output values for laden and ballast conditions

Inputs	**Outputs**
Average daily speed (knots)	Total of Cargo transported (tons)
Total consumption of fuel (IFO) (tons)	Total of fuel consumed (IFO) (tons)
Distance (nautical miles)	Total of emission (tons)
Cargo (tons)	
Average daily emissions (tons)	

The simulation workflow used is the same for Original, SS, and USS as shown in Figure 2.

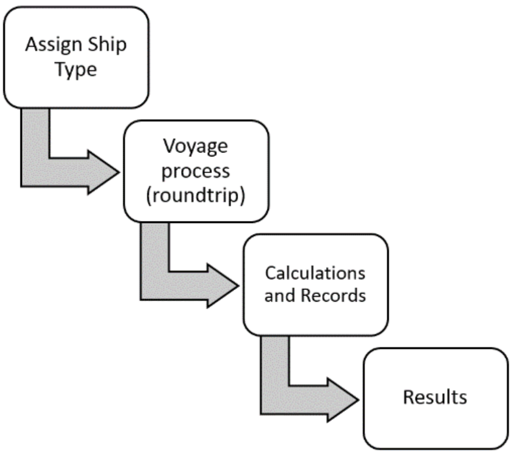

Figure 2 – Workflow of the voyage simulation of the bulk carrier fleet

In the simulation the ships are created and initialized according to specific rules. It has been calculated based on the average travel time per year of whole ship fleet and the number of ships.

The average time between arrivals is about one every four days. Three sub-processes have been created to map the three ship types defined before. Each of them is respecting the assignments sequence shown in Figure 2.

As an illustration, Table 4 shows the distributions used to define the input parameters of ORI model of ship type 1.

Distance and total consumption of fuel (IFO) parameters correspond to lognormal distribution, the others distributions are normal distributions, see Table 4.

Table 4 – Input distributions for ship type 1 ORI model for laden (LC) and ballast(BC) conditions

Parameter	**Mean**	**Standard Deviation**
Distance (nautical miles)	4934.76	4148.39
Total consumption of fuel (IFO) in BC (tons)	664.41	567.96
Total consumption of fuel (IFO) in LC (tons)	897.72	790.72
Average daily speed in BC (Knots)	12.90	1.33
Average daily speed in LC (Knots)	11.56	1.11
Cargo in BC (tons)	72344	14130
Cargo in LC (tons)	169614	10578
Average daily emissions of CO_2 in BC (tons)	4.88	0.85
Average daily emissions of CO_2 in LC (tons)	2.82	0.75
Average daily emissions of SO_X in BC	7.61	1.56
Average daily emissions of SO_X in LC	4.30	1.31

The voyages implemented in each sub-process correspond to Equation 5:

$$Tv = D/S \tag{5}$$

Where Tv is the voyage time distribution in days is, D is the distance distribution in nautical miles, and S is the average daily speed distribution in nautical miles per day.

The model estimate the information above mentioned as results, the total of cargo transported, the total of fuel consumed, the total CO_2 emission, and the total SO_X emission.

The following variables are evaluated for each ship and each iterations: L_T is the cargo transported, T_{FC} is the total fuel consumed, T_{CO_2} is the total CO_2 emission and T_{SO_X} is the total SO_X emission.

3 – Results and discussions

The influence of SS and USS on the fleet of 13 bulk carrier ships is show in this section.

The result for the three models is given in Table 5. We observe the amount of cargo transported (in tons) in each of the proposed alternatives (ORI, SS and USS), total consumption of fuel of the fleet (in tons), and the total of emissions (CO_2 and SO_X) in tons for a fixed period of one year.

Table 5 – Result descriptions in tons for ORI, SS and USS models

Results	ORI	SS	USS
Cargo transported	7852017	7844856	7311822
Total consumption of fuel	70562	34356	10908
Total CO_2 emissions	51	30	12
Total SO_X emissions	82	43	17

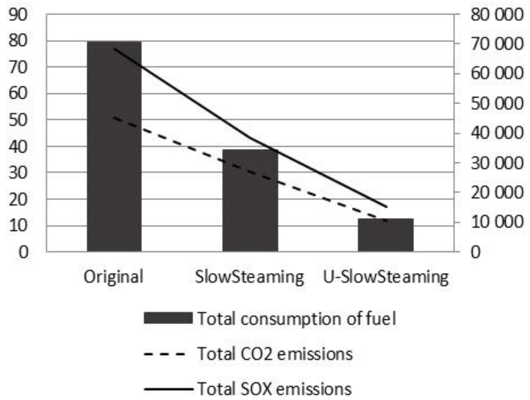

Figure 3 – Total consumption of fuel in tons right y-axis and Total consumption of emissions in tons left y-axis for ORI, SS and USS models

The results show that the values of consumption decrease by 49% and 15% in SS and USS respectively. The values of CO_2 emissions decrease by 60% and 23% in SS and USS respectively. Finally, the values of SO_X emissions decrease by 43% and 13% in SS and USS respectively, see Figure 3.

Figure 4 shows the average of fuel consumption for each ship and the number of ships that leave the round trip in the simulation. That is important to analyse the advantage of SS and USS to each ship type. In all cases, USS strategy is the most advantageous.

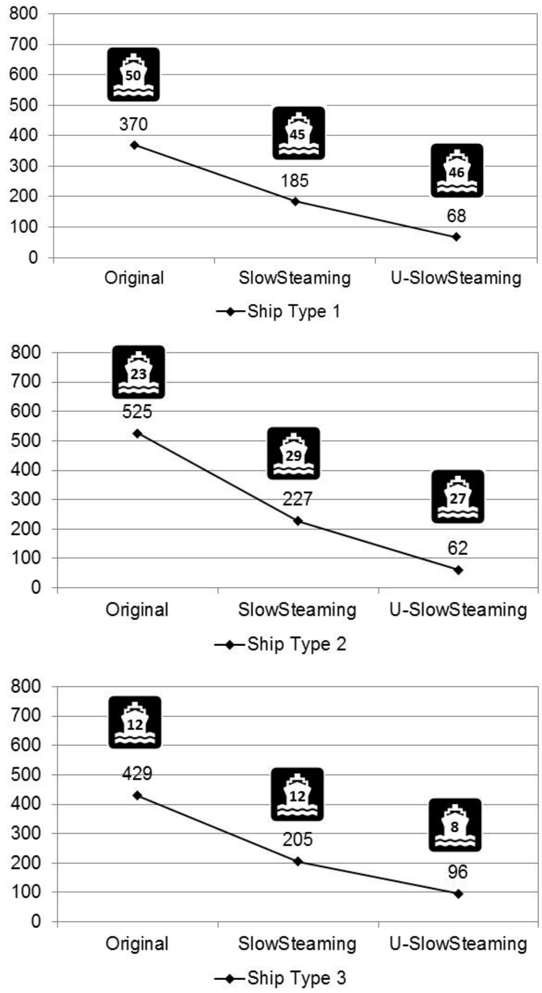

Figure 4 – Examples of average of fuel consumption (tons) reduction for ship type 1, 2 and 3, including the quantity of ships that are necessary to complete this simulation

The major disadvantage of slow steaming strategy for shippers is the longer shipping times. This factor is associated with the cargo transported. In the model proposed the total cargo transported by each ship in SS and USS strategies is compared with the total cargo transported in original model. Consequently, to move the same amount of cargo (in same number of days) it would be necessary to use a larger number of vessels in the fleet.

The difference of the cargo transported between models shows that the fleet needs one more ship to transport the same quantity of cargo in both proposed strategies (SS and USS), see Table 6.

This analysis is general, and it considers the increase of ship in a global way. In future works, the economic analysis can be improved including the increment of ships with a separate analysis for each ship type to transport the same quantity of cargo in SS and USS strategies.

Table 6– Cargo transported by the fleet and the percentage of cargo in the three navigation strategies

Model	Cargo Transported [ton]	Percentage of cargo
ORG	7 852 017	100.00%
SS	7 844 856	99.91%
USS	7 311 822	93.12%

According (Cariou, 2011) to determine the sustainability of SS strategies, the cost of adding vessels to a service under this strategy as well as the increase in costs for shippers must be considered. Operational costs vary according to the number of vessels added and their characteristics.

Assuming the fuel price about 257 USD for a metric ton (Ship & Bunker, 2016), cost savings of SS and USS are assessed respectively to 9.3 and 15.3 millions of USD annually as shown in Table 7.

Sea costs in shipping are composed of: Capital expenditure (CAPEX), Operational expenditure (OPEX) and Travel cost at sea. In this study, the CAPEX and OPEX costs are considered constant per ship travel. Here, the Travel cost at sea (TCS) or running cost varies for ORI, SS and USS strategies. The TCS is composed by: fuel cost, port charges, channel crossing rates, commissions, cleaning holds and tanks, and other relate expenses. Considering that the ships take the same routes, only fuel costs could be considered variables (Assis 2014). Therefore, the variations of fuel consumption are enough to take into account the variation of TCS.

Table 7– Annual costs and consumption saving in USD and projection to the next 10 years

Description	ORI	SS	USS
Total annual consumption [ton * 1000]	70.6	34.4	10.9
Annual cost of total consumption [$mUSD]	$18.1	$8.8	$2.8
Annual saving consumption [ton * 1000]	-	36.2	59.7
Annual saving consumption [$mUSD]	-	$9.3	$15.3
Total saving consumption in 10 years [$mUSD]	**$0**	**$93.0**	**$153.3**
Total consumption in 10 years [ton * 1000]	705.6	343.6	109.1
Total saving consumption in 10 years [ton * 1000]	-	362.1	596.5
Quantity extra of ships to fulfill the total cargo	0	1	1
Extra cost of extra ships [$mUSD]	**$0.0**	**$58.0**	**$58.0**
Extra annual consumption of extra ships [$mUSD]	$0.0	$0.11	$0.03
Extra consumption of extra ships in 10 years [$mUSD]	$0.0	$1.06	$0.34
Total Costs in 10 years [$mUSD]	**$181.3**	**$147.4**	**$86.4**
Total Saving - Costs in 10 years [$mUSD]	**$0.0**	**$34.0**	**$95.0**
Percentage of Total Costs in 10 years	100%	81%	48%

Considering that the CAPEX price of a new bulk carrier vessel (Capesize, 170 000 DWT) is about 58 mUSD, (UNCTAD, Review of Maritime Transport, 2011) the annual costs and consumption saving can be assessed and projected on 10 years. Then, profitability of SS and USS can be evaluated, see Table 7.

Figure 5 shows the effectiveness analysis of SS and USS simulation, in SS strategy. The emissions are reduced to 57% and 22%, the consumption of fuel is reduced to 49% and 15%, the total cost in the next 10 year is reduced to 57% and 15% respectively in comparison with the ORI model.

The convergence is verified for each model, e.g. cargo transported convergence after 200 iterations is shown in Figure 6. Semi-random numbers have been altered between each iteration. The 3 strategies are evaluated in 200 iterations each one with semi-random numbers automatic generated by the ARENA program.

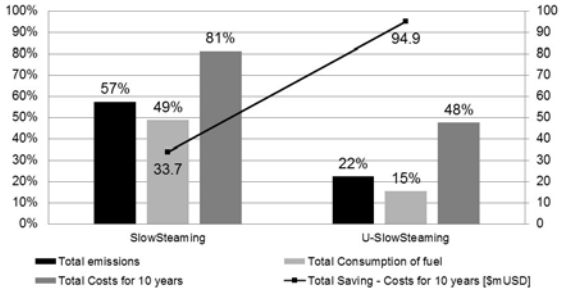

Figure 5 – Effectiveness analysis of SS and USS simulation

Figure 6 – Convergence of cargo transported in tons for the SS model

Table 8– Sensitivity analysis comparing the Total cost for 10 years prediction by fuel price and extra ship cost variation

Fuel price [$USD /ton]	Total cost for 10 years by fuel Variation		Extra ship price [$m USD]	Total cost for 10 years by CAPEX Variation	
	SS	USS		SS	USS
$180	95%	61%	$41	72%	38%
$206	89%	56%	$46	75%	41%
$231	85%	51%	$52	78%	44%
$257	81%	48%	$58	81%	48%
$283	78%	45%	$64	84%	51%
$308	76%	42%	$70	88%	54%
$334	74%	40%	$75	91%	57%
$360	72%	39%	$81	94%	60%
$386	71%	37%	$87	97%	64%

This study considers a sensitivity analysis to show how the CAPEX and bunker value as TCS are units that vary cyclically and it is affecting completion. Table 8 shows the results of a sensitivity analysis comparing the Total cost for 10 years prediction by TCS and CAPEX variation. This results don't affect the fact that the use of SS and USS is more profitable. However, it is noticed that when the fuel price is low or when the extra ship price is high the SS strategy may not be anymore efficient.

4 – Conclusions

Main results evidenced the reduction of transported cargo by less than 8% for two conditions (SS and USS), while the total consumption decreased by almost 51% and 85%, respectively.

This study prove that the speed reduction (SS and USS strategies) through just-in-time-arrival is possible without reducing the capacity of the maritime transport systems, with the increment of one unit of new ship. This paper shows that slow steaming has reduced emissions by around 57% an 22% over one year; it fulfil the target of IMO.

Savings in operational costs, considering fuel consumption and emissions (CO_2 and SO_X) invites us to reflect on the number of extra vessels required to fulfil the cargo transport objective. Due to the need for increase the number of ships to move the same amount of cargo transported in the same time, USS is more profitable X`than ORI and SS conditions to the bulk carrier fleet.

The findings of this study bring useful insights about different simulation approaches used as decision support systems in the field of navigation strategies. This study increment the literature about the use of DES focused on SS and USS for bulk carrier ships.

This simulation contribute to the limited literature that uses SS with DES. This paper explores the use of DES as modelling tools used to support decision-making.

The use of DES can help to simulate scenarios with real historical data, assisting ship-owners in making decisions about the number of ships in their fleet and establishing best operating strategies.

5 – Future work

The hypothesis considering acquisition of new ships in the fleet should be assessed in more detail, to evaluate if it is necessary to buy one ship of each type or several of the smaller. This improve the economic evaluation in a future research.

6 – Acknowledgment

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7 – References

Assis, L. F. (2014). Estrutura de Custos do Transporte Marítimo. *COV770-Transportes Marítimos II*. Rio de Janeiro, RJ, Brasil.

Cariou, P. (2011). Is slow steaming a sustainable mean for reducing liner shipping CO2 emissions? *Transportation Research Part D: Transport and Environment, 16*(3), 260-264.

Cepeda, M. (2016). *Analysis of ship fleet performance using Data Envelopment Analysis and Multi Criteria Decision Analysis estimators.* Rio de Janeiro: COPPE.

Cepeda, M., & Caprace, J.-D. (2015). Simulating Economical Impacts of Slow and Ultra slow Steaming Strategies on a Bulk Carrier Fleet . *Proceeding of the XXIX Congresso de Pesquisa e Ensino em Transportes* (pp. 1052-1062). Ouro Preto, Brazil: ANPET.

Cooper, D. (2002). *Quantification of emissions from ships associated with ship movements between ports in the European Community.* Goteborg: IVL - Swedish Environmental Research Institute Ltd.

Ferrari, C., Tei, A., & Parola, F. (2012). Facing the economic crisis by cutting costs: The impact of low-steaming on container shipping networks. *Conference Proceedings of International Association of Maritime Economists (IAME) Conference* (pp. 1-16). Taipei, Taiwan: Porteconomics.eu.

IMO. (2009). *Guidelines for Voluntary Use of the Ship Energy Efficiency Operational Indicator (EEOI).* IMO - International Maritime Organization.

Lee, C.-Y., Lee, H., & Zhang, J. (2015, April). The impact of slow ocean steaming on delivery reliability and fuel consumption. *Transportation Research Part E: Logistics and Transportation Review*, 176-190.

Maloni, M., Paul, J. A., & Gligor, D. M. (2013). Slow steaming impacts on ocean carriers and shippers. *Journal Maritime Economics & Logistics, 15*(2), 151-171.

Notteboom, T., & Cariou, P. (2013, September). Slow steaming in container liner shipping: is there any impact on fuel surcharge practices? *The International Journal of Logistics Management, 14*, 73-86.

Rahman, N., Yang, Z., Bonsall, S., & Wang, J. (2015, December). A Fuzzy Rule-Based Bayesian Reasoning Method for Analysing the Necessity of Super Slow Steaming under Uncertainty: Containership. *International Journal of e-Navigation and Maritime Economy, 3*, 1-12.

Ship & Bunker. (2016). *http://shipandbunker.com*. Retrieved 8 31, 2016, from Ship & Bunker: http://shipandbunker.com/prices/apac/sea/sg-sin-singapore#IFO380

Sweetser, A. (1999). A comparison of system dynamics and discrete event simulation. *Proceedings of 17th International Conference of the System Dynamics Society.* Wellington, New Zeland.

Tai, H.-H., & Lin, D.-Y. (2013, June). Comparing the unit emissions of daily frequency and slow steaming strategies on trunk route deployment ininternational container shipping. *21*, 26-31. doi:10.1016/j.trd.2013.02.009

Tezdogan, T., Incecik, A., Turan, O., & Kellett, P. (2016). Assessing the Impact of a Slow Steaming Approach on Reducing the Fuel Consumption of a Containership Advancing in Head Seas. *Transportation Research Procedia, 14*, 1659-1668.

UNCTAD. (2011). *Review of Maritime Transport.* Geneva: UNITED NATIONS.

UNCTAD. (2015). *Review of Maritime Transport 2015.* (J. Rogers, Ed.) Geneva: UNITED NATIONS.

Wong, E., Tai, A., Lau, H., & Raman, M. (2015, June). An utility-based decision support sustainability model in slow steaming maritime operations. *Transportation Research Part E: Logistics and Transportation Review, 78*, 57-69.