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The impact assessment of short-term measure on Ghana's maritime trade.

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THE IMPACT ASSESSMENT OF SHORT-TERM MEASURE ON GHANA'S MARITIME TRADE

By

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Declaration

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

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

(Signature):

……………………………………………

Date: 21 September 2021

Supervised by: Prof. Aykut I Olcer

Supervisor's affiliation**………………………………**

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Abstract

Title of Dissertation: The Impact Assessment of Short-term Measure on Ghana's Maritime Trade.

Degree: **Master of Science**

The dissertation is a study on the impact assessment of the mandatory operational goal-based short-term measure on reduction of emission of greenhouse gases (GHG) specifically speed reduction on Ghana's maritime trade. The International Maritime Organization (IMO), has proposed short, medium and long term measures under the Initial IMO Strategy to regulate emissions from shipping. In 2018, the Initial IMO Strategy which was adopted stands as an important step at the international level to reduce pollution from ships to the environment at a global level. The focus of this dissertation is to conduct an impact assessment of speed reduction as one of the means to achieve the short-term goal-base measure, EEXI or CII on Ghana's maritime trade. The pressing issues with these measures are the uncertainty of how the measure will impact shipping, that is either negatively or disproportionately negatively when the IMO decides in 2023.

The Slow Steaming Analysis (SSA) model was used in order to achieve this aim. Two models were developed in excel, the first model is the emission impact and the second is the economic impact. The emission model helps to calculate the total emissions from a fleet operating in a particular route and the economic model is used to calculate the impact on the economy of the countries involved in the trade. The impacts are calculated over a range of selected speeds to give a wide range of observation on emissions and trade as the speed reduces. The type of ships considered are container vessels and bulk carrier.

Furthermore, the model is beneficial for the study on Ghana and provide guidance on the environmental and economic gains for a range of speeds to select from. From the model designed for Ghana, under the 2012 GAS scenario, ships serving the routes selected may yield a negative impact when these ships operate at speeds below 12.4 knots (average) which is GSA 6. Below this speed, additional ship may be required which will result in increased emissions and transport cost.

KEYWORDS: Impact Assessment, Speed Reduction, Emission Reduction, Short-term Measures, Greenhouse Gases, Economic Impact, Emission Impact.

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List of Abbreviations

AER	Average Emission Ratio
APEC	Asia-Pacific Economic Cooperation
CO2	Carbon Dioxide
CIF	Cost, Insurance and Freight
CO2eq	Carbon Dioxide Equivalence
CH4	Methane
COP	Conference of Parties
CII	Carbon Intensity Indicator
EPL	Engine Power Limit
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing Ships Index
EU	European Union
EPA	Economic Partnership Agreement
EF	Emission Factors
EEOI	Energy Efficiency Operational Index
FOB	Free On Board
GHG	Greenhouse Gases
GWP	Global Warming Potential
GSA	Global Speed Average
GAS	Global Average Speed

GDP	Gross Domestic Product
HBL	High Baseline
HFO	Heavy Fuel Oil
IMO	International Maritime Organization
ISWG	Intersessional Working Group
LF	Load Factor
LAF	Load Adjustment Factor
LDCs	Least Developed Countries
MCR	Maximum Continuous Rating
MEPC	Marine Environmental Protection Committee
MARPOL	International Convention for the Prevention of Pollution from Ships
Mt	Metric tons
N2O	Nitrous Oxide
OEC	Observatory of Economic Complexity
SIDs	Small Island Developing States
SSA	Slow Steaming Analysis
TEU	Twenty-foot Equivalent Unit
UNFCCC	United Nations Framework Convention on Climate Change
UNCTAD	United Nations Conference on Trade and Development
UAE	United Arab Emirates
UK	United Kingdom
WHR	Waste Heat Recovery

CHAPTER ONE- INTRODUCTION

1.1 Background of the study.

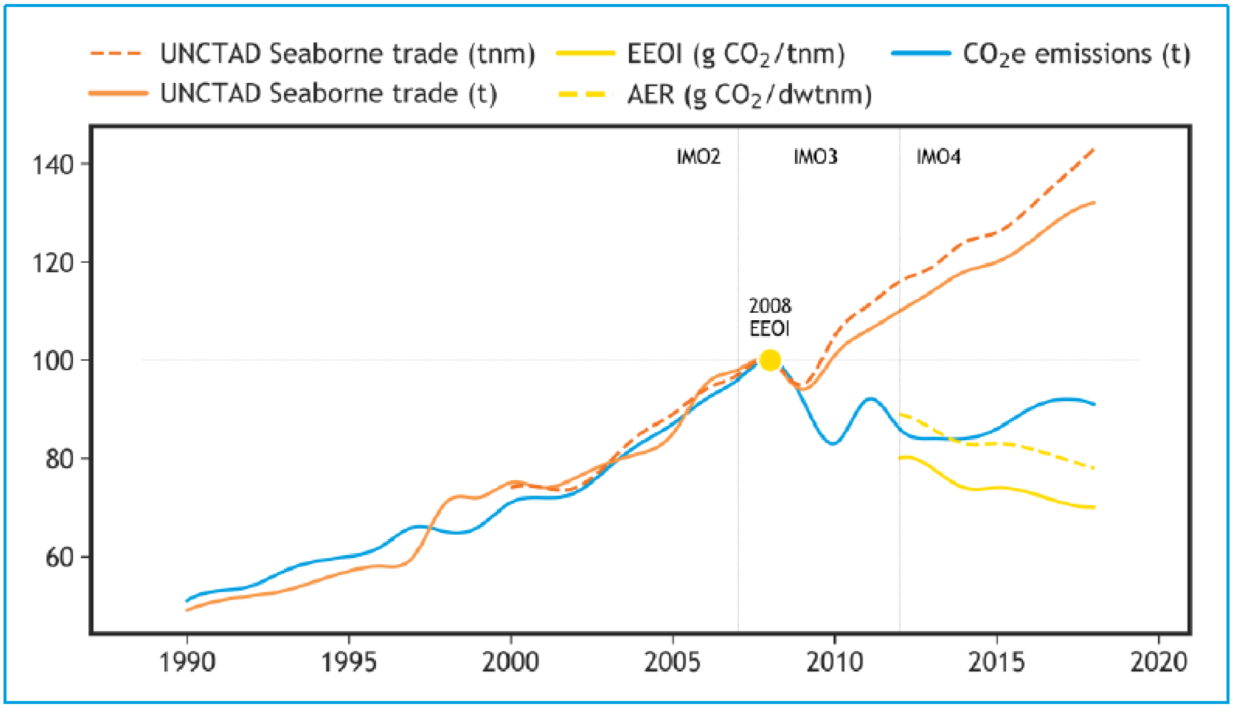
Global warming and climate change are currently the pressing issues facing the world today, which calls for drastic measures to help mitigate their effects to the environment and mankind. To reduce the effects of global warming and climate change, human activities which leads to emissions of greenhouse gases (GHG) need to be reduced as much as possible. The challenge with achieving this reduction is the high dependency of the increasing population on energy, mainly the use of fossil carbon fuels. With the rate of growth of economies and increase of human population across the globe which requires more energy, the dependency on fossil fuel for supply of energy cannot be stopped immediately, nor in the short term (Ming et al., 2014). According to Ming et al. (2014), to replace dependency on carbon-dioxide renewable energies with environmentally friendly alternatives will be long, expensive and difficult. They further state that to tackle climate change will require significant reductions of carbon intensity of the world economy. The relevance of developing new low-carbon technologies which will be adopted globally should be a priority (Ming et al., 2014).

Another alarming issue is from the 4th IMO GHG study (2020) which indicates that CO_2, methane (CH_4) and nitrous oxide (N_2O) expressed in carbon dioxide equivalence (CO_2e) increased from 977 million tonnes in 2012 to 1076 million tonnes in 2018 representing a 9.6% increment. These are the GHG emissions from the total international shipping including international, domestic and fishing. The share of shipping emissions in global anthropogenic emissions were observed by the 4th IMO GHG study (2020) to have increased from 2.76% in 2012 to 2.87% in 2018 which calls for immediate measures to reduce emissions. Furthermore, the types of ships noticed to have contributed the most to international shipping's GHG emissions were container ships, bulk carriers and oil tankers, which amount to 86.5% generated on voyage base calculations when the three major contributors are combined with chemical tankers, general cargo ships and liquefied gas tankers (4th IMO GHG study, 2020). The 4th IMO GHG study (2020) also indicates that Heavy Fuel Oil (HFO) is the most dependent fuel used in international shipping which represents 79% of fuel consumed totally in terms of energy content in 2018 by "voyage-based calculations" (p.8). Another aspect of emissions production is related to ship operations which depends on the type of ship and also when the ship is at sea, maneuvering, at anchorage or berthed. Furthermore, container, cruise ships and oil tankers produced the smallest emissions when cruising as compared to liquefied gas tankers and other liquid tankers which produced the largest (APEC, 2019).

The 4th IMO GHG study (2020) observed the continuation of some trends in the 3rd IMO GHG study, the average ship sizes and installed power across container, bulk carriers and oil tankers were increased. The study also indicated an increase in average ship's fuel consumption for each of these three ship types over the study period between 2012 to 2018, which was at a lower rate than the increase in average installed power. The difference in the rate of increase between the installed power and fuel consumption is as a result of a general trend of continuous reduction in operating speeds and the average number of days at sea (4th IMO GHG study, 2020). This reduction in operating speed, according to the study was not observed as a constant decline for all ship types over the period. The study states that a key driver of trends in emissions and rate of emissions growth is the operating speed of ships and the operating speed is open to change if the market forces and trends in behavior of shippers also changes.

The shipping industry for years has provided transport services for the movement of cargo from one port/country to another. These activities across the oceans have helped economies to grow and develop, however, the environment has been affected negatively by these activities. The International Maritime Organisation (IMO) continues to carry out efforts in establishing regulations to govern maritime activities globally. The organizations efforts in coming up with regulations on safety, pollution and operational measures in shipping over the years have been and will continue to be beneficial. In spite of these efforts the organization is currently challenged with the high level of pollution from GHG emissions from shipping. Statistics support this argument, which is an expected increase from about 90% of 2008 emission level in 2018 to 130% of 2008 emissions by 2050 with a likelihood of long-term economic and energy scenario (4th IMO GHG study). Though this projection is expected, emissions may be more or less depending on the high or low rates of economic growth than the assumed in the 4th IMO GHG study. Also, with respect to how economies will recover from the COVID-19 pandemic the 4th IMO GHG study (2020) indicates that emissions over the next decades may be a few percentages lower than expected.

Figure 1 – International shipping emissions and trade metrics, indexed in 2008, for the period 1990-2018, according to the voyage-based allocation of international emissions.



Source: 4th IMO GHG study (2020).

Figure 1 shows the trade, emissions and carbon intensity estimated across the 4th IMO GHG study and previous two studies. From the three studies, there is a consensus for three discrete periods for international shipping's GHG emissions which are: 1990 to 2008, growth in emissions (CO2e) and emissions increase alongside maritime trade (UNCTAD, 2018). Secondly, for the period 2008 to 2014, there was reduction in emissions though there is increase in demand for maritime transport (UNCTAD, 2019), implying that carbon intensity reduction (EEOI and AER) helped to separate demands from emissions. And thirdly, the period 2014 to 2018 yielded a moderation in carbon intensity (EEOI and AER) at a lesser rate compared to demand (4th IMO GHG study). These trends indicate the importance for immediate efforts to reduce emissions.

One of the initial efforts to stabilize the concentrations of GHG emissions in the atmosphere, is the United Nations Framework Convention on Climate Change (UNFCCC) which was established to address the problem of global warming and climate change. The first effort was the "Protocol", which was agreed on in Japan with the aim of reducing emissions of GHG in developed countries.

The target set was to achieve a 5.2% below the 1990 level by between 2008 to 2012 (Wiley, 1998; Maamoun, 2019) for a list of countries. The GHG's involved were CO_2, CH_4, N_2O, and some halocarbons. Wiley (1998) concludes that, temperature and sea level rise reduction under the Protocol and its extensions are relatively small which, however, is an important step to climate system stabilization.

To support the relevance of the Kyoto Protocol, Maamoun (2019) states that the Protocol was successful with approximately 7% emission reduction from countries which ratified the convention, this reduction could not have been achieved without the Protocol. The period within which the Protocol applied was set for the years 2008 to 2012 and 2013 to 2020. In order to maintain an international climate protection process after 2020, a new climate agreement was adopted in 2015 at the Conference of Parties (COP) in Paris as the Paris Agreement. The Paris Agreement for the first time included specific target which requires limiting global warming well below 2^0 C above pre-industrial levels (IPCC, 2018). After years of debate on ways to include shipping under the Paris Agreement, the IMO developed a plan for decarbonizing shipping. The strength of this plan is the adoption of the Initial IMO Strategy to reduce GHG emissions from shipping and this represented the IMO's response initially to global goals on climate change of the Paris Agreement (Gritsenko, 2017).

Subsequently, another effort to reduce GHG emissions is the efforts of the Marine Environmental Protection Committee (MEPC) 72 on 13 April 2018, which is the adoption of resolution MEPC302. (74) on the Initial IMO Strategy on reduction of GHG emissions from ships (IMO, 2018). The resolution outlined short, medium and long term measures which could help reduce GHG emissions and also focused on the impact assessment of these measures on developing countries before implementation. Also to reduce carbon intensity was the introduction of Energy Efficiency Existing Ship Index (EEXI) and the Carbon Intensity Indicator (CII) as amendments to MARPOL Annex VI chapter 4. The MEPC 72 outlines procedures for a comprehensive assessment of measures before adoption by developing states, especially Small Island Developing States (SIDs) and Least Developed Countries (LDCs). The strategy has an ambition of reducing the average CO_2 emissions per transport work by 40% in 2030 and 70% in 2050 compared to 2008 (MEPC.304 (72)), with an expectation of international shipping's total annual GHG emissions to reduce to 50% in 2050.

One of the means of meeting the requirement of the EEXI or CII is speed reduction. Speed reduction is a trade-off between reducing emissions, transit time increase and managing it with how shipper's will adapt to delay (Finnsgård et al., 2020). When the adaption to delay by the shipper's in waiting for their cargo is not achieved, the tendency of shifting to other means of transport which produces more emissions is possible (APEC, 2019). Speed reduction is also a concern for economies that depend solely on sea transport trade for essential products that support the development of the country and their citizens. An advantage with implementing speed reduction is that, ships can apply the measure without carrying out any modifications to the ships machinery (APEC, 2019).

1.2 Aim and objectives

The aim of this dissertation is to assess and analyze the impact of the approved short-term measures specifically speed reduction on container and bulk carrier shipping on Ghana's trade and shippers. The study will target the following objectives:

1. To understand the trade profile of Ghana.
2. To collect and identify data for Ghana's trade relation with other countries.
3. To apply the SSA model to know the effect of slow steaming on shippers and trade.

The following are the research questions:

1. To know the number of additional ships required if speed reduction is adopted for container vessels and bulk carriers for Ghana.
2. To know the emission reduction to be achieved when speed reduction is adopted.
3. To understand the impact of speed reduction on transport cost for shippers.

1.3 Justification of the study.

With the adoption of the two-tier approach by the IMO on the implementation of measures to decarbonise the maritime sector, the organization's first focus is on the limited short-term measures, after which the implementation of more comprehensive medium and long-term measures will be tackled. MEPC 75 agreed on a combined short-term measure which comprises of technical measure, the EEXI as well as an operational measure and the CII which comes with a defined carbon intensity reduction goal (IMO, 2021). The goal, however, according to document MEPC 76/INF.68 does not specify the means to achieving this carbon intensity goal. As part of the guiding principles of the initial strategy, there is a need for the impact of the measures on States to be assessed, and this should be carried out by paying particular attention to developing countries, especially SIDs and LDCs (IMO, 2018).

These countries may also be affected economically and to understand the level of impact requires carrying out an assessment. The concerns and specific needs of developing States in combating climate change has been topics of discussions by the United Nations Conference on Trade and Development (UNCTAD), IPCC, UNFCCC and others (Psaraftis & Zis, 2020). The IMO encourages impact assessments to be done considering the eight criteria, that is, geographical remoteness and connectivity to main markets, transport dependency, food security, cargo value and type, cost effectiveness, socio-economic progress and development and disaster response (ISWG-GHG 6-2). The IMO guidelines, also expects that impact assessment need to include detailed qualitative and/or quantitative assessment of specific negative impacts on States, including disproportionately negative impacts (Psaraftis & Zis, 2020).

1.4 Problem statement/motivation.

To address the requirement of the IMO for the conduct of impact assessment, under the candidate short-term measures of the Initial Strategy, further state speed optimization and speed reduction as one of the means of the operational measure EEXI for consideration and analysis. This measure is required to be analysed with consideration on safety issues, travelled distance, how market and trade will be affected and most importantly this measure need not impact ships' ability to serve remote geographic areas (MEPC 304 (72)). In order to address the requirement of the Initial Strategy of short-term measures specifically the impact of speed reduction on Ghana as a developing country, this thesis is aimed at adopting the SSA (Slow Steaming Analysis) model applied in IMO document GHG-ISWG 7/2/17 in analysing the impact of slow steaming on the APEC countries. The SSA model is made up of two models, the emission and economic model. The model will help determine the level of impact on container and bulk carrier trade on Ghana's economy and shippers when speed reduction is adopted in 2023. These two types of ships are considered because their trade is consistent and there is enough data available. However other vessels like oil tankers, chemical tankers and so on can be analysed with the model.

1.5 Research methodology

The dissertation will employ both qualitative and quantitative methodologies. The qualitative methodology will rely on a systematic literature review on slow steaming impact on shipping and trade. The quantitative analysis will use the SSA model which will be designed in excel. The Slow Steaming Analysis (SSA) model, consist of two models; model 1- Emissions Impact and model 2-Economic Impact. The input variable used for the two models are distances, speeds, ship sizes (container vessels and bulk carrier), physical and operational characteristics of the ship are used to estimate slow steaming impact across distances and fleets. The output results from model 1 are used as input variables for model 2 to determine the economic impact.

1.6 Scope of the study

The study focused on the emission and economic impact on container vessels and bulk carrier. Four trade routes and also the trade relations between Ghana and three other countries were considered. The countries are the United Kingdom (UK), United Arab Emirates (UAE) and China. Other vessels for example oil tankers, chemical tankers and so on were not considered for the study. A range of speeds from 16.6 to 10knots for 2012 Global Average Speed (GAS) and from 20 to 10knots for High Baseline (HBL) speed scenario were considered. A detailed economic analysis is beyond the study.

1.7 Organisation of the research

This thesis is composed of five chapters organised in the following order; Chapter one introduces the topic and commences by providing a background information on the topic, followed by the, aims and objectives, justification of the study, problem statement/motivation, the research methodology, scope of the study and organisation of the research. Chapter two is a literature review on the impact of speed reduction as a short-term measure. Chapter three describes the methodology used for the study to quantify the impact of speed reduction. Chapter four is a case study on the trade routes for container vessels and bulk carrier trade with respect to Ghana and finally chapter five concludes and provides recommendation for future studies.

CHAPTER TWO – LITERATURE REVIEW

2.1 Chapter Overview

The literature review focuses on speed reduction and its impact on trade and emissions. The chapter also looks at the importance of impact assessments to States, Ghana's international trade and economy, the eight criteria to consider in an impact assessment and finally a short qualitative analysis on documents addressing the EEXI, CII submitted to IMO.

2.2 Speed reduction

Slow steaming is a strategy used to reduce emissions from ships by focusing on the energy used in propulsion and the resulting emissions through lowering the speed of the ship during its operations (APEC, 2019). To monitor the benefit of using slow steaming is basically observing the normal speed used and the lowered speed of the same ship for a voyage or distance. Accepting slow steaming as a measure to reduce the emissions of CO_2 from ships will imply having a trade-off between the reduction of emissions and the longer time for transportation (Lee et al., 2015). These two options need to be balanced to meet the patience of cargo owners in the shipping industry. Speed reduction is a decision on the operational side of the vessel where alterations are not required, however, this would mean increasing the number of vessels or transport work to cater for the same volume of cargo (Psaraftis & Zis, 2021). Lee et al., 2015 indicate that when the speed of the vessel is reduced, drag is lowered, which can result in a 10% speed reduction with 15 to 20% of savings on fuel consumption. Furthermore, they indicate that, as a result of the shipping industry adopting speed reduction the increase in transport time will lead to a trade-off in cost between fuel and other operational cost. According to Cariou (2011), when the speed of vessels is reduced, emissions from international shipping is estimated to be lowered by 10 to 30% over the last decade.

In 2050, shipping is expected to double its account of 90% of all freight transport and with this increase it is important for shipping to be more energy-efficient and also reduce its contribution to GHG emissions to 50% compared to 2008 level (IMO, 2018). Tillig et al. (2020) applied a "shipCLEAN" model to a case study of a container carrier on a Pacific Ocean route, the results revealed how vessel speed reduction serves as an economic motivation when fuel prices are high. This deduction indicates the importance of ships adopting speed reduction in order to save on fuel cost when prices are high. In addition to benefits of savings on fuel price as a positive impact on bunker from speed reduction, (Medina et al. (2020) as cited by (Ronen, 2011; Kim, 2014; Wang et al., 2019a, 2019b) indicates that the daily fuel consumption (ton/day) of a ship is approximately proportional to the third power of the sailing speed. They further expressed that if the ships operational speed is reduced (slow steaming) in a given liner shipping service, the bunker consumption and costs also decreases. However, lowering operational speed usually leads to increasing of other transportation costs like introduction of more ships to maintain capacity required from the liner shipping services, inventory costs, insurance, maintenance or crew cost (Notteboom & Verninmen, 2009).

From the APEC (2019) study the impact of speed reduction depends on the type of cargo carried by the vessel, for cargos that is not perishable the impact of slow steaming is small and on the other hand, if the cargo carried is perishable, the impact of slow speed reduction may result in using other faster means of transportation. This shift could lead to high emissions of GHG (APEC, 2019), from other means of transportation like rail, road and air. Speed reduction if adopted can yield both economic and environmental benefits, however, Maloni et al. (2013) indicates that the implementation of slow steaming in container shipping to improve fuel efficiency and reduce GHG emissions is not well appreciated by shippers because of the increase in inventory cost. The increase is due to the longer transit time. Furthermore, through a study to quantify the costs and benefits of slow steaming, Maloni et al. (2013) used the Asian-North American trade lane to estimate impacts under different vessel speeds, volumes and fuel prices. The results showed that extra slow steaming as vessel speed, produced the most benefit with 20% in total cost and 43% CO_2 emission reduction.

Chang & Chang (2013) carried out a study to investigate the fuel consumption and corresponding CO_2 emissions of capsize, panamax, supramax and handysize dry bulk carriers. They used a Cost of Averting a Ton of CO_2eq Heating (CATCH) model to evaluate the cost efficiency of speed reduction. The results obtained from the study was that, fuel consumption is reduced by 27.1%, 48.8% and 60.3% and CO_2 emissions by 19%, 36% and 51% with reduced speeds of 10%, 20% and 30% respectively. Furthermore, Chang & Chang (2013), reveals that with a minimum of nine vessels in service, and an average operational speed of 14.53 knots with one call in port a week may lead to one, two and four vessels to be added with speed reductions of 10%, 20% and 30% respectively.

Also, Wijnolst and Wergeland (1997) and Stopford (1999) states that when the speed of a vessel is decreased by 2 to 3 knots below the design speed, the daily fuel consumption of cargo fleet may be halved. This indicates that when the operational speed of vessels is reduced, a huge impact of reduction is achieved on fuel consumption. A challenge with decreased cargo quantity transported by ships can be solved by increasing the number of ships serving this purpose (Notteboom & Vernimmen, 2009; Cariou, 2011). However, when the number of ships are increased using speed reduction as a measure helps to reduce CO_2 emissions to a reasonable amount (Corbett et al., 2009).

2.2.1 Economic impact of speed reduction

Speed reduction has the potential of impacting on total cost generated by shippers, which can equally have an impact on the economy of a country. One of the key elements of the cost involved in doing trade is transport cost. In maritime transport, fuel takes 50% of the operating cost of a vessel and transport cost is approximately 10% of the total cost generated (Smith et al., n.d). When savings are made in these costs, the total cost generated from trade increases which is beneficial to shippers and their economy. When transit time is extended due to speed reduction, the possibility of an increase in logistics cost of shippers is high (APEC, 2019). The practice of using speed reduction as a measure by ship operators to reduce the cost of fuel consumption is predominantly done when prices for bunker is high. According to the APEC (2019) study, using speed reduction became a normal practice after the experience of the economic crisis in 2008.

2.2.2 Environmental impact of slow steaming

Operating ships at reduced speeds is used as a measure to save energy, which is known as slow steaming (Zincir et al., 2019). The practice of speed reduction has become a predominant tool for improving the energy efficiency of commercial ships by fuel consumption reduction which leads to less cost of operation (Cariou, 2011). Speed redcution was used by Maersk lines for container vessels, and later the practice transferred to other types of ships (Corbett, 2009). To support Cariou (2011) statement, Degiuli et al. (2021) state that speed reduction can be used as a means of optimizing operations of new ships as well as reducing CO_2 emissions from ships in operations. The Mediterranean Sea has around 30,000 vessels conducting business which produces emissions greater than 64 million tons of CO_2 in 2016 (Degiuli et al., 2021). They further stated that a major portion of CO_2 and SO_2 emissions are from container vessels in the Mediterranean Sea. For all analyzed sea states of their research, Degiuli et al. (2021), obtained around 31% for savings in fuel consumption and CO_2 emissions. The impact of speed reduction on the environment is mostly beneficial due to the reduced consumption of fuel oil.

2.3 The importance of impact assessment

Some of the requirements of the impact assessment on States is the need for the assessment to be quantified and related to the normal variations in transport cost, trade or gross domestic product (GDP) (IMO, 2018). Additionally, the initial impact assessment is required to evaluate if the measure chosen is likely to result in disproportionately negative impacts and how these effects could be solved. The impact assessment on States need to be carried out considering methodologies and approaches which deals with conflicting objectives under trade-off environment (IMO, 2018) and also consider using multiple criteria decision making tools to forecast the simple Cost/Benefit analysis models (MEPC 76-INF.68). These relevant requirements will yield beneficial results for States in terms of how to manage their maritime transport sector to adjust to the upcoming short-term measure. Another importance is to provide understanding and forecast the potential negative impacts which may arise. Another benefit is to ensure the IMO measure attains its goal, as well as, taking into account relevant implementation and compliance cost which might occur.

According to Psaraftis & Zis (2020), a difference among the short-term measures are the "prescriptive measures" and "goal-based measures", which both aims to reach the 2030 target. The goal-based measures allow the ship owner to make a choice without giving the means, but the prescriptive specifies the means (Psaraftis & Zis, 2020). The ship owners have the option of choosing any means to obtain reduction of emissions, either by using technical or operational means. The technical means includes hull shape optimization, use of more efficient engines, energy recuperation devices and alternative fuels. The EEXI is also another goal-base measure which uses Engine Power Limit (EPL) as a technical measure to reduce GHG emissions.

Psaraftis & Zis (2020), carried out a study to investigate some potential negative impacts. They listed undesirable degradation of the quality of cargo, increase in-transit inventory cost, cargo shifts to the other modes of transport, higher freight rates, decrease in product FOB prices and/or increase in product CIF prices, higher lifecycle GHG emissions and difficulty to finance retrofitting of old ships or investment in new ships. From their methodology they looked at how fleet, port connectivity, main trading partners, distance and freight rates as factors will influence these impacts. For a ship to achieve reduction in carbon intensity indicator (CII) to meet the 2030 target, ship owners can take action in two levels (Psaraftis & Zis, 2020). The operational/logistics level which includes speed reduction implementation, perform speed optimization and/or optimized routing, applying proper management of fleet, improve ship capacity utilization and better coordination with ports, any of these measures leads to CO_2 and carbon intensity reduction (Psaraftis & Zis, 2020). The technical measures available as options for the ship owner to choose from includes, purchasing a new ship, scrapping/selling an old one, retrofit to reduce resistance (such as bulbous bow, propellers), engine retrofit (derating) to reduce power, energy saving devices installation like the waste heat recovery (WHR), a device to limit engine power, switch to electric/hybrid propulsion, alternative fuels and the use of better hull coatings to reduce resistance.

2.4 Ghana's international trade and economy

The country relies on maritime transport for large cargo trade. Alternatives to transport cargo by train or air is possible, however, most shippers might not opt for this means because it is more expensive. Ghana as a developing country has trade lines from most European countries either by exporting or importing products across the oceans (EPA, 2020). Furthermore, the report states that as part of the Ghana's Economic Partnership Agreement (EPA), the European Union (EU) gives duty-free, quota-free opportunities to Ghana's exports to the EU. Ghana reciprocates this good gesture with gradual reduction in tariffs to zero for 78% of the country's import from the EU by 2029 (EPA, 2020). These agreements are beneficial to the economy of Ghana and majority will be done via ships, since the country depends on maritime transport for the movement of goods, which are either imported or export from and to the national ports located in Tema and Takoradi (Tsikata et al., 2008). In terms of cargo throughput for the seaports of Ghana, the port of Tema was 14.47 million metric tonnes (mt) representing 68% and 6.96 million mt representing 32% for the total seaborne trade of the country (Ghana Shipper's Authority, 2017). Ghana deals in agricultural, non-agricultural products, intermediary goods and machinery importation and exportation. And the conduct of these trade supports the development and growth of the country.

In 1991, the country imported goods worth USD 1,318 million than was imported in 1990 which was worth USD 1,204.96 million, which is an increase of 9.4% difference in imports (Okyere, 2020). Furthermore, Okyere (2020) indicate an improvement in import trade over the years for Ghana. The expansion of the import market signifies that the economy is expanding, this is evidenced with the increase in total import of USD 6753.68 million in 2006 than the USD 5347.31 million obtained in 2005, representing a 26.3% rate in growth (Okyere, 2020). There was also a significant increase in total imports in 2011 indicating 46.2%, USD 15968.40 million compared to USD 10922.11 million in 2010 (Okyere, 2020). For exports, according to the WTO (2012), there was an increase in exports from USD 635 million in 1986 to USD 14,377 million in 2011, which represents an average yearly export increase of 70% over the period (WTO (2012) as cited by Okyere, 2020).

With these progress and increase in trade, it is important to conduct an impact assessment of speed reduction on the ships facilitating the carriage of goods in fulfilling trade relation between Ghana and other countries. And also, what will be the effect on the country's economy and environment. More specifically, this dissertation will focus on container and bulk transport trade for Ghana. To address this challenge, the dissertation is aimed at using a model to investigate the potential impact of the short-term measure, that is speed reduction on container and bulk vessels trade for Ghana. The economic and environmental impact of speed reduction will be the focus.

2.5 The eight criteria considered for impact assessment

Countries nearer to locations with high economic activities benefit the most from trade. Redding & Venables (2002) conducted a study to draw out the implications of small and isolated economies location away from the center of economic activities and how these economies are deprived of benefits. The growth of an economy currently in our global world depends on distance and isolation. This implies that a good access to markets is valuable for development of a country. Redding & Venables (2002) state that access can be from two sources, the proximity to countries which bring good access to export markets. And secondly, the extent to which the home market provides alternatives to exports. These source of market access according to the Redding & Venables (2002) are not available to remote and small countries.

Another important consideration is how these economies have access to other countries which supply intermediate and capital goods. The remoteness and level of economic growth might hinder the supply and as well increase the price of the goods. The literature studied the direct effects of distance on economic interactions, particularly the cost of making trade across space. The study reveals that using a gravity trade model to estimate the bilateral trade flows of one hundred or more countries, the elasticity of trade flows with respect to distance is around -0.9 to -1.5 (Redding & Venables, 2002). These figures indicate that volumes of trade decline steeply with distance and also geography matters greatly for economic interaction between countries.

The different cost involved in doing trade is what leads to the decrease of economic interactions. The costs of time in transit, insurance and freight rates are important costs to consider in maritime transport. Shipping cost on short or heavily used routes are usually low. This low cost of shipping is as a result of the closeness of the countries involved and also the relative low cost of transport of the goods traded (Redding & Venables, 2002). Taking all bilateral trade flows where data is available the median Cost, Insurance and Freight/Free Onboard (CIF/FOB) ratio is 1.28, and for the value of goods shipped, transport and insurance cost amounted to 28% (Redding & Venables, 2002). According to Hummels (1999b) and Limao & Venables (2001) when distance over which goods are shipped increases, freight rate costs around 20% (as cited by Redding & Venables 2002). The authors further indicate that countries sharing common borders reduce the cost of transporting goods and to transport goods overland between these close countries is 7 times more expensive compared to sea transport.

A number of studies carried out to discover the effect of geographical remoteness on the economy of a country have focused on developed than developing countries (Lu, 2020). The developmental level of some countries located together like South and North Korea, Democratic Republic of the Congo and the Republic of Congo and the United States and Mexico are not the same. From this understanding, Lu (2020), states that the evidence of this large economic developmental difference between these countries, geographical remoteness could not be a reason. To confirm this statement, the author carried out further investigation into the industry-level gravity model of international trade, provided a theoretical framework to demonstrate the effect of geographical remoteness on OECD and non-OECD countries and quantile regression analysis. Lu (2020), concludes that geographical remoteness is not a disadvantage to countries in terms of development.

With respect to the effect of slow steaming on the cargo value and type, the owner of the cargo needs to accept that the transportation time will increase slightly. Wiesmann (2010), conducted a study on the voyage between Asia and Europe and discovered that reducing the voyage speed from 27 to 22 knots will increase the voyage time by 3 to 4 days. Depending on the goods carried and the voyage time added due to slow steaming, the cargo owner might change the transport mode. And this change may lead to an increase in the costs for “goods in progress” (Wiesmann, 2010, p.50)

From the carrier’s perspective, the carrier may be required to change the trade schedule and in order to maintain normal service on a particular trade route, additional ships may be added to the fleet (APEC, 2019). According to Wiesman (2010), the introduction of slow steaming is driven by the carriers, for the reason been that they gain more from the large fuel consumption reductions. However, when the capital and operating costs of the ship are considered the benefit to the carrier may be invalid. Slow steaming is not suitable for all services and during all times of vessel operations. With the change in speeds to adjust to various condition during operation, it is not possible to make a general statement concerning the overall cost of reduction potential of slow steaming (Wiesmann, 2010).

From the proposal of document ISWG-GHG 7/2/8, States which depend more on maritime transport benefits more with respect to emissions and economic gains from the goal base measure. With an identified suitable speed, transport cost can be reduced. Furthermore, document 7/2/8 indicates that when transport cost is reduced, States which depend more on the importation of food may be in advantage compared to other States when food security is considered. On disaster response, document ISWG-GHG 7/2/11, indicates the support provided by international shipping to SIDs when there is a disaster. The document proposes for some ship types and sizes serving SIDs and LDCs to be exempted in the short-term but not permanently. With the challenges of climate change on these countries it is important for this consideration to be taken note of when the IMO decides in 2023. Also, in considering cost-effectiveness, document ISWG-GHG 7/2/12 indicates that the ship owner is free to take the most cost-effective option to improve the ships energy efficiency. Because the measure is goal based, the decision lies with the owner of the ship.

2.6 Qualitative analysis- systematic literature review

Japan and Norway submitted document (ISWG 6/2), an initial impact assessment of EEXI which was conducted in accordance with the procedure set out in MEPC.1/Circ.885. The document concludes that the proposed EEXI has positive impacts on reduction of GHG emissions and voyage cost, and that the potential negative impact could be avoided when the overall transport cost is reduced. The shortfall of the impact assessment is that it did not consider quantitative analysis on transport cost or potential economic impacts. The countries proposed that in order to avoid any potential disproportionately negative impacts, the required EEXI need to be set at a suitable limit for each category of ship type and size but not applying a fixed rate of reduction for all ships. The countries further proposed that the required EEXI need to meet the contribution of at least 40% reduction in carbon intensity as targeted for 2030 and practically possible without leading to increase in cost or major technical challenges.

2.6.1 Impact of EEXI on ships

The EEXI requires that ships in existence are to improve their performance in energy efficiency. The measure is goal-based and to meet the requirement any option can be adopted for example ships can improve energy efficiency or opt for an alternative fuel once that is valid. The option of engine power limit (EPL) permits ships to be operated at maximum engine power for normal operation to meet the requirement (ISWG-GHG 6/2). This was followed by a statement from Japan in document MEPC74/INF.23 that the original maximum continuous rating (MCR) of the engine may be made use of when operators encounter severe weather conditions. Ships can also choose energy efficiency devices or alternative fuel. With the option of energy saving devices the ship maintains its design speed performance with a lesser engine power for low fuel consumption and as a result the ship improves efficiency with no effect on performance negatively (ISWG-GHG 6/2).

An option of alternative fuels like liquefied natural gas (LNG), bio-fuels or hydrogen, these options depend solely on capacity to supply them, their availability and carbon factors. In spite of these challenges ships can reduce CO_2 emissions simply as well as improving the EEXI (less CO_2 per transport work) and at the same time maintain same operational practice.

2.6.2 Impact on emissions

The EEXI under MARPOL Annex VI is a mandatory requirement and ships which fall under it also have to meet the existing survey and certification scheme for Energy Efficiency Design Index (EEDI) requirements. Options chosen by ships will require the ships to improve the EEXI at least to the required level (ISWG-GHG 6/2). The document continues that the quantity of emissions reduced is dependent on the level of the required EEXI, which can be accurately estimated once there is an agreement on the required level of the EEXI. The document further indicates that when the required EEDI is set to the reference line proposed in document ISWG-GHG 5/4 a 10 to 20% reduction in the average EEDI is expected. Also, if the EEDI reduced leads to similar reduction in operations, carbon intensity may be reduced by approximately 4% in 2030 when the requirement for the reference line is set (ISWG-GHG 6/2).

The document ISWG-GHG 7/2/8 submitted to the 7th Intersessional Meeting of the Working Group on Reduction of GHG Emissions from Ships by Greece, Japan, Norway and ICS considered additional information on the impact assessment of the goal-based energy efficiency improvement measure on existing ships. The countries carried out an analysis focusing on the impact of slow steaming on transport cost, with the assumption that existing ships would opt for EPL to comply with the EEXI requirement. From the analysis, the study indicates that when energy efficiency of ships is improved to meet the least level of compliance to the EEXI requirement negative impacts on transport cost will be avoided. On the other hand, the study states that there could be other impacts linked with the additional days of voyage when EPL is implemented to comply with the EEXI requirement. This change in number of days do affect the global supply chain. The document also concluded that the implementation of EPL with the assumption of all ships making that choice will lead to reduced ship running cost because of the reduced fuel cost.

CHAPTER THREE- METHODOLOGY

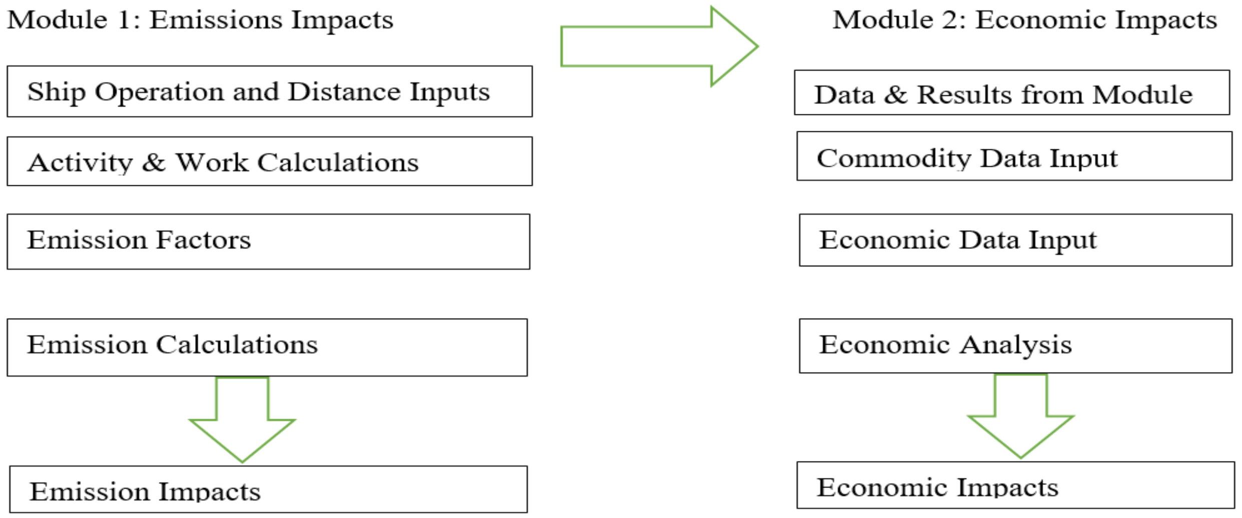
3.1 Chapter overview

In order to accomplish the aim and objectives of this study the SSA model will be applied to the study. The objective of the model is to help investigate the impact of speed reduction on Ghana's maritime trade. The values obtained for the case study of Ghana for the 2012 GAS scenario are presented as tables in the appendix.

3.2 Slow Steaming Analysis Model.

The SSA model considers a nation trading partners, the commodities imported and exported, characteristics of the ships involved in the trade and routes plied by the ships. The potential benefits and impacts from speed reduction are peculiar to these combinations which are specific to the economy of a particular country (APEC, 2019). The SSA model consists of two models; the emissions impact as model 1 and the economic impact as model 2. These two models allow the following parameters as input variables: distances, speeds, ship sizes for container vessels and bulk carriers, the physical and operational characteristics which helps to estimate the impact of slow steaming. Figure 2 shows an illustration of the SSA model.

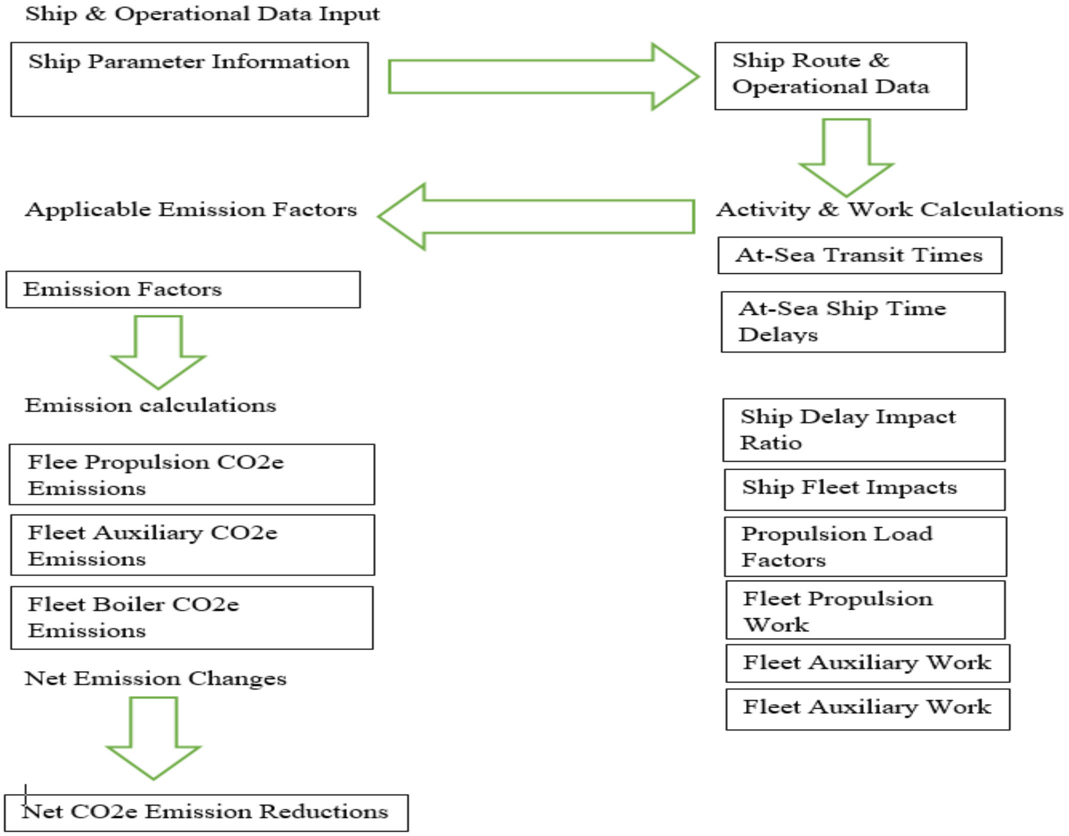
Figure 2: SSA Model.



Source: APEC study 2019.

The obtained outcome from model 1 indicates impacts on additional time for sailing, the need for addition of ships to augment population of a fleet and the percentage change in carbon dioxide equivalent (CO_2e). These impacts are obtained from the combination of ship type, size and distance. The results obtained from model 1, in addition to cargo time delay, GDP impact, interest cost, depreciation and insurance cost are used as input variables for model 2. The model is designed using Microsoft Excel. Figure 3 shows an illustration of the interaction between module 1.

Figure 3: SSA Model, module 1.



Source: APEC 2019 Study.

For the ship & route operational data input, the model uses a delay tolerance for arrival as a factor (in hours). This helps to set a time which is acceptable for delay with respect to the arrival of the ship. A period of 48 hours was used, which implies that when ships arrive before 48 hours there will not be a need for ships to be added to the fleet operating on a particular route. This tolerance cannot be set to zero, this will imply that for every minute of delay there will be a need for an additional ship to the fleet. The model gives an expression of the change in emissions from a baseline speed through reduced speeds for various distances and vessel type and size. With such wide range of reduced speeds, policy makers will be able to make decisions based on the broad options available from the model.

3.3 Module 1: emission impacts.

The Emission Impact model worksheet consists of two tabs for emission analysis from the routes, ship size and type chosen. The first is the ship and emission factor (EF) parameters and second, the analysis matrices worksheet.

1. Ship and Emission factor (EF) parameters: In this worksheet, the following parameters are provided as inputs, container vessel and bulk carrier sizes, average rated maximum speed, propulsion power rating, engine type, operational parameters for auxiliary engines and boilers, EF for GHG and global warming potential (GWP) factors.
2. Analysis matrices: The following are the variables provided as inputs in this worksheet; the number of ships, distances, baseline speeds, incremental speed reduction and the lowest reduced speed. The parameters used for the ship and EF are shown in appendix 1 and 2.

3.3.1 Ship and emission factor parameters worksheet.

The description of the ship parameter inputs used in this matrix is provided as follows:

1. Ship types: for this study, container vessels and dry bulk carrier were specified.
2. Ship sizes: container vessel sizes of 3000, 4000 and 5000 twenty-foot equivalent unit (TEU) were used for the routes considered. The bulk type of ship used for the chosen route is handymax.
3. Average maximum rated speeds (knots): the average maximum rated speeds for various ship type and size combination were obtained from the 4th IMO GHG study.
4. Percentage of maximum draft: these values indicate the maximum draft percentage; the ship is operating at for the scenario considered. For this study, an assumption of 100% or fully laden is used.
5. Hull fouling factor: this factor indicates the extra work done by the propulsion engine with respect to the state of the hull. The values used in the 4th IMO GHG study is the same used for this study (IMO, 2020).

6. Route type: there are two options to choose from, the “at-sea” or “coastal”. The “at-sea” conditions are used for this study because of the effect of the weather on the ships in this condition (APEC, 2019).
7. Weather impact factor: the value to use depends on the route type selected. For the at-sea condition the value used is 15% and coastal is 10%. Taking into account the average weather impact on propulsion engine loads, these values are the same used in the 4th IMO GHG study (IMO, 2020).
8. Average propulsion power ratings (kw): following how the category of ship was chosen for average maximum rated speed, the averages for the propulsion power were obtained for each ship size and type combination.
9. Engine type: two primary engine types were considered for propulsion power, the slow speed diesel (SSD) and the medium speed diesel (MSD) engines. The type of engine is important because every type has different emission factors and this can be changed to different configuration for ship, fuel or engine (APEC, 2019). The IMO defines SSD as engines rated less than 130 revolutions per minute (rpm) and MSD as engines rated at 130 to less than 2000 rpm (MARPOL Annex VI, Reg. 13).
10. At-sea average auxiliary loads (kw): these figures represent the average load for the auxiliary engines when the ship is operating at-sea. The loads used in this study and the table provided are data from the 4th IMO GHG study (IMO, 2020).
11. At-sea average boiler loads (kw): these are the average load of the boiler system when the ship is operating at-sea.
12. At-sea global speed averages (GSA), (knots): these values represent the baseline speeds ships were travelling at before the implementation of the strategy on slow steaming. To determine these speeds, one option is using the information published on the global fleet for ship type and size categories in the 3rd IMO GHG study for 2012 (IMO, 2014).
13. At-sea published speeds (knots): for this study, the published speeds applied in the APEC study was used. These speeds provide the greatest ranges of speed regimes for analysis (APEC, 2019).

Under the emission factor input grid, the input values for EF of propulsion engines, auxiliary engines and boilers were provided. Emission estimates for CO_2, N_2O and CH_4 were used. The GWP values used were one for CO_2, 298 for N_2O and 25 for CH_4.

3.3.2 Analysis matrices worksheet

The first parameter which is set, is the minimum slow steaming speed in knots. The value used is 10 knots. According to the APEC (2019) study, 10 knots is not a real speed used by ships globally, however, this provides a wide range of speeds and also helps to observe the impact of slow steaming over various lower speeds. The analysis matrices consist of 13 matrices which provides good explanation of the impacts in various steps.

Matrix 1: Ship & Route operational data.

The input for the ship and route operational data for each ship type and size combination are provided in this sheet. Data collected and parameters are shown in appendix 3 and 4. Appendix 4 shows the baseline and operational inputs for the 2012 GAS scenario. The description of the ship fleet and distance travelled at sea is provided as follows:

1. Number of ships: the number of ships or size of the fleet operating on the selected route and distances are provided. For the ship type and size combinations these are the number of ships deployed. The 4000TEU had 6 ships, the 5000TEU had 15 ships, the 6000TEU had 10 ships and the bulk had 5 ships which is an assumption.
2. Distance 1-Shortest distance (nm): this is the shortest distance which is covered within a particular route. For the selected routes, the shortest distance is between 200 to 600nm.
3. Distance 5-Longest distance (nm): this is the longest distance for each route considered. The longest distance is between 5000 to 13000nm.
4. Distance 2 to 4 (nm): these are the distances in between the shortest and longest distances. This helps to compare the results of the economic and environmental impact of the operations of the ships within the selected routes.

The description of the baseline speed and operational inputs required is provided as follows:

1. Global speed average (GSA), in knots: this helps to select the baseline speed for the various scenarios in order to calculate the benefits from slow steaming. The two scenarios used were:

a. high baseline speed scenario, with speeds ranging from 20 to 10 knots.

b. 2012 annual average speeds from IMO 2014 scenario with speed ranging from 16.3 to 10 knots.

2. GSA-X, in knots: these speeds are reducing speeds from the GSA speed. Ten incremental speeds from GSA-1 to GSA-10 were observed.

3. Slow Down Increment (knots): for each ship type and size combination, the slow down increment is set to end with 10 knots as the lowest slow steaming value.

4. Arrival Delay Tolerance (hours): the time delay tolerance is set for the arrival of the ship due to slow steaming. A forty-eight (48) hours' time period is used for the ship type and size combinations, this implies that when the delay is less than 48 hours there is no need for ships to be added to the fleet. This value cannot be set to zero, reason been that the scenario becomes unrealistic (APEC, 2019).

MATRIX 2: At-Sea Ship Transit Times.

The at-sea transit times are calculated in this matrix. For these calculations, the operations of the ship during maneuvering, at-anchorage, at-berth and so on are not considered. Slow steaming usually has less impact in such operations of the ship and the distances covered during such operations are less significant when compared to operations of the ship at-sea (APEC, 2019). The following formula is used:

$$\text{Transit times}_{\text{GSA-X}} = \text{Distance \# divided by Speed}_{\text{GSA-X}}$$

Example, for 2012 GSA model. 18.4 (GSA in hours) = 300 (Distance 1) / 16.3 (GSA in knots)

The Transit Times $_{\text{GSA-X}}$ are the at-sea transit times for the baseline GSA speeds and reduced speeds from GSA-1 to GSA-10 divided by their corresponding distance from 1 to 5.

Distance # are the values for the distances from 1 to 5 for the various ship type and size combinations selected.

Speed $_{\text{GSA-X}}$ are the at-sea transit baseline speeds and reduced speeds from GSA-1 to GSA-10 in knots.

MATRIX 3: Ship Time Delays.

The calculations for the delay in time between the baseline GSA speed and the slow steaming reduced speed from GSA-1 to GSA-10 is done in this matrix. This is done over the at-sea transit for each ship type and size combinations for distances 1 to 5. The following equation is used:

$$\text{Time delay}_{\text{GSA-X}} = \text{Time}_{\text{GSA-X}} - \text{Time}_{\text{GSA}}$$

Example for 2012 GSA model. 0.8 (GSA1 in hours) = 19.2 (GSA-1 in hours) – 18.4 (GSA in hours)

Time delay $_{\text{GSA-X}}$ are the time changes as a result of slow steaming for reducing speeds GSA-1 to GSA-10 subtracted from the GSA for distances 1 to 5.

Time $_{\text{GSA-X}}$ are the values for the at-sea transit time for speeds from GSA-1 to GSA-10 for distances 1 to 5 in hours.

Time $_{\text{GSA}}$ are the at-sea transit time for GSA speeds for their specific distances in hours.

MATRIX 4: Ship Delay Impact Ratios.

For each ship type and size combinations and distances (1 to 5), the ship delay impact ratio between the baseline GSA speed state and the slow steaming reduced speeds (GSA 1 to GSA 10) is calculated. The following equation is used:

$\text{Ship Delay Impact Ratio}_{\text{GSA-X}} = \text{Time}_{\text{GSA-X}} / (\text{Time}_{\text{GSA}} + \text{Arrival Delay Tolerance})$

Example for 2012 GSA model, distance 2. 1.02 (GSA 6 as ratio) = 220.5 (GSA-6) * (168.7 (GSA in hours) + 48(Arrival Delay Tolerance in hours)).

Ship Delay Impact Ratio $_{\text{GSA-X}}$ are the values obtained from the at-sea transit time per ship for each GSA divided by the sum of the same value and the arrival delay tolerance.

Arrival Delay Tolerance are the values set for the delay as a result of slow steaming. The value used in the model is 48 hours. This is done for all speeds from GSA to GSA-10.

MATRIX 5: Ship Fleet Impacts.

For the at-sea transit for each ship type and size combination for distance 1 to 5, the fleet impact for estimating the required number of additional ships between the GSA conditions and the slow steaming reduced speeds from GSA-1 to GSA-10 is calculated in this matrix. The following equation is applied.

$$\text{Ship Fleet Impact}_{\text{GSA-X}} = \text{Ship Delay Impact Ratio}_{\text{GSA-X}} * \text{Number of Ships}_{\text{GSA-X}}$$

Example for 2012 GSA model, distance 2. 15 (GSA 5(# of ships)) = 15 (number of ships for 5000TEU) * 1.00(GSA 5 as ratio)

The Ship Delay Impact Ratio $_{\text{GSA-X}}$ is rounded to the nearest integer. Ship Fleet Impact $_{\text{GSA-X}}$ are the values for the number of ships required to maintain the normal frequency of the operations of the fleet for a particular route. It is the product of the ship delay ratios for each speed and the number of ships deployed for each ship size and type combination. This is done for all the 5 distances considered for each combination.

MATRIX 6: Propulsion Engine Load Factors

For the at-sea transit for each ship type and size combination, the propulsion engine load factors (LF) for the baseline GSA speed condition and the reduced speeds due to slow steaming from GSA-1 to GSA-10 are calculated under this matrix. The values are the same for distance 1 to 5. The propulsion LF is dependent on the percent draft of the ship, the propeller curve, weather and hull conditions. The values used are the same as applied in the 3rd IMO GHG study (IMO, 2014). The equation used is as follows.

Propulsion Engine $\text{LF}_{\text{GSA-X}} =$ [(Percent of Draft) ^0.66*(GSA-X/Avg. Max Rated Speed) ^3] / [(1-Weather Impact Variable) *(1-Hull Fouling Variable)]

Example for 2012 GSA, distance 1. 0.44 = ((100%^0.66) *(16.3/23.3) ^3) / (1-15%)*(1-9%))

Propulsion Engine $\text{LF}_{\text{GSA-X}}$ – represents loads on propulsion engine (dimensionless).

Percent of draft – represents percent of draft the ship is operating on.

GSA-X – is the baseline GSA speeds and reduced speeds from GSA-1 to GSA-10 (knots).

Avg. Max Rated Speed – is the propulsion engine maximum rated speed for each ship type and size combination (knots).

Weather Impact Factor – is the factor that takes into consideration the impact on the propulsion engine and the power required when the ship is at-sea or coastal conditions.

Hull Fouling Factor – is the factor that takes into consideration the power required for propulsion depending on the state of the hull.

MATRIX 7: Fleet Propulsion Engine Work.

For the at-sea transit for each ship type and size combination, the energy consumed or the work done by the propulsion engine for the baseline GSA speed conditions and the reduced speeds as a result of slow steaming from GSA-1 to GSA-10 are calculated under this matrix. The values are the same for distances 1 to 5. The following equation is used, which is similar to that used in the 3rd IMO GHG study (IMO, 2014).

Fleet Propulsion Engine Work $_{\text{GSA-X}}$ = [Ship Fleet Impact $_{\text{GSA-X}}$ * Transit Time $_{\text{GSA-X}}$ * Avg Prop Power Rating * Propulsion LF $_{\text{GSA-X}}$]

Example for 2012 GSA, distance 1. 1,731,332kwh = 0.44 (ratio) * 6 (no. of ships) * 18.4hours * 35,421kw.

Fleet Propulsion Engine Work $_{\text{GSA-X}}$ - work done by the propulsion engine for baseline GSA speeds and the reduced speeds for slow steaming from GSA-1 to GSA-10 for the distances from 1 to 5 (kilowatts per hour, kwh).

MATRIX 8: Fleet Auxiliary Engine Work

For the at-sea transit for each ship type and size combination, the energy consumed or the work done by the auxiliary engine for the baseline GSA speed conditions and the reduced speeds as a result of slow steaming from GSA-1 to GSA-10 are calculated under this matrix. The values are the same for distances 1 to 5. The following equation is used, which is similar to that used in the 3rd IMO GHG study (IMO, 2014).

Fleet Auxiliary Engine Work $_{\text{GSA-X}}$ = Ship Fleet Impact $_{\text{GSA-X}}$ * Transit Time $_{\text{GSA-X}}$ * At-sea Avg Auxiliary Load.

Example for 2012 GSA, distance 1. 154,601kwh = 6(no. of ships) * 18.4hours * 1,400kw.

Fleet Auxiliary Engine Load $_{\text{GSA-X}}$ – these are the values obtained for work done by the auxiliary engines for the baseline GSA speed and the reduced speeds for slow steaming from GSA-1 to GSA-10, for distances 1 to 5 (kwh).

At-sea Avg Auxiliary Load – these are the values for the average power load of the auxiliary systems when the ships are operating at-sea (kw). According to the APEC (2019) study, the model does not consider ships using shaft generators when the ship is operated at-sea.

Matrix 9: Fleet Boiler Work

For the at-sea transit for each ship type and size combination, the energy consumed or the work done by the boiler for the baseline GSA speed conditions and the reduced speeds as a result of slow steaming from GSA-1 to GSA-10 are calculated under this matrix. The values are the same for distances 1 to 5. For the boiler operations, the APEC study proposed the use of a LF of 0.25. The reason for this input is that at that LF, the waste heat recovery stops working and this is where the boilers start operations (APEC, 2019). The study further indicated that a discussion was carried out during a Vessel Boarding Program, and the outcome is that the value of this LF is between main engine loads of 20% to 25%. For both container and bulk carriers the value is set to 0.25. The following equation is used, which is similar to that used in the 3rd IMO GHG study (IMO, 2014).

Fleet Boiler Work $_{\text{GSA-X}}$ = Ship Fleet Impact $_{\text{GSA-X}}$ * Transit Times $_{\text{GSA-X}}$ * At-sea Avg Boiler Load.

Example for 2012 GSA, distance 1 (Bulk carrier, handymax). 8,263kwh = 5 * 25.4hours * 65kw.

Fleet Boiler Work $_{\text{GSA-X}}$ - these are the values obtained for work done by the boiler for the baseline GSA speed and the reduced speeds for slow steaming from GSA-1 to GSA-10, for distances 1 to 5 (kwh).

At-sea Avg Boiler Load – these are the values for the average power load of the auxiliary systems when the ships are operating at-sea (kw).

Matrix 10: Fleet Propulsion Engine CO2e Emissions.

For the at-sea transit for each ship type and size combination, the fleet propulsion CO_2e emissions for the baseline GSA speed conditions and the reduced speeds as a result of slow steaming from GSA-1 to GSA-10 are calculated under this matrix. The CO_2e emissions is the sum of CO_2e emissions of CO_2, N_2O and CH_4, their GHG EF multiplied by their GWP, this allows the GHGs to be normalized. The values applied are same as that used in the 3rd IMO GHG study. The following equation is used.

Fleet Propulsion Engine CO_2e Emissions $_{GSA\text{-}X} = \sum$ (Fleet Propulsion Engine $_{GSA\text{-}X}$ * EF_i * GWP_i * LAF $_{GSA\text{-}X}$) / 1,000,000.

Example for 2012 GSA, distance 1. 472 = sum (1,731,332kwh * 0.44 * 616.538) / 1,000,000.

Fleet Propulsion Engine CO_2e Emission $_{GSA\text{-}X}$ - For the at-sea transit for each ship type and size combination, the fleet propulsion CO_2e emissions for the baseline GSA speed conditions and the reduced speeds as a result of slow steaming from GSA-1 to GSA-10 are calculated under this matrix. This is done for distance 1 to 5 (tonnes).

EF_i – these values represent the EF of the type of engine whether SSD or MSD propulsion and its GHG_i (CO2, N2O and CH4) (g GHG_i/kwh).

Load Adjustment factor (LAF) – the LAF used in the 3rd IMO GHG study was used to adjust the emissions with respect to the engine load factor.

GWP_i – the global warming potential (CO_2e/GHG_i)

1,000,000 – is used to convert grams to tonnes.

Matrix 11: Fleet Auxiliary Engine CO_2e Emissions.

For the at-sea transit for each ship type and size combination, the fleet auxiliary engine CO_2e emissions for the baseline GSA speed conditions and the reduced speeds as a result of slow steaming from GSA-1 to GSA-10 are calculated under this matrix. The same method used for CO_2e emission estimates for the fleet propulsion is applied in this matrix. The following equation is used for the calculation.

Fleet Auxiliary Engine CO_2e Emissions $_{GSA-X}$ = ∑ (Fleet Auxiliary Work $_{GSA-X}$ * EF_i * GWP_i) / 1,000,000

Example for 2012 GSA, distance 1. 111 = sum (154,601kwh * 717.928) / 1,000,000.

Fleet Auxiliary Engine CO_2e Emissions $_{GSA-X}$ - the CO_2e emissions represents the sum of the emissions for each GHG_i for baseline GSA speeds and the reduced speeds from GSA-1 to GSA-10 for distances 1 to 5 (tonnes)

EF_i – these are values for the MSD auxiliary engines emission factors and their corresponding GHG_i (CO_2, N_2O and CH_4) (GHG_i/kwh).

Matrix 12 – Fleet Boiler CO_2e Emissions.

For the at-sea transit for each ship type and size combination, the fleet boiler CO_2e emissions for the baseline GSA speed conditions and the reduced speeds as a result of slow steaming from GSA-1 to GSA-10 are calculated under this matrix. The same method used for CO_2e emission estimates for the fleet propulsion is applied in this matrix. The following equation is used for the calculation.

Fleet boiler CO_2e Emissions $_{GSA-X}$ = ∑ (Fleet Boiler Works $_{GSA-X}$ * EF_i * GWP_i) / 1,000,000.

Example for 2012 GSA, distance 1(Bulk carrier, handymax). 8 = sum (8263kwh * 964.652) / 1,000,000.

Fleet boiler CO_2e Emissions $_{GSA-X}$ - the CO2e emissions represents the sum of the emissions for each GHG_i for baseline GSA speeds and the reduced speeds from GSA-1 to GSA-10 for distances 1 to 5 (tonnes).

EF_i – these are values for the MSD auxiliary engines EF and their corresponding GHG_i (CO2, N2O and CH4) (GHG_i/kwh).

Matrix 13: Net Fleet CO_2e Emissions Changes.

For the at-sea transit for each ship type and size combination, the net fleet CO_2e emissions compared with the baseline GSA speed conditions and the reduced speeds as a result of slow steaming from GSA-1 to GSA-10 are calculated under this matrix. This is done for distances 1 to 5. The following equation is used for the calculation:

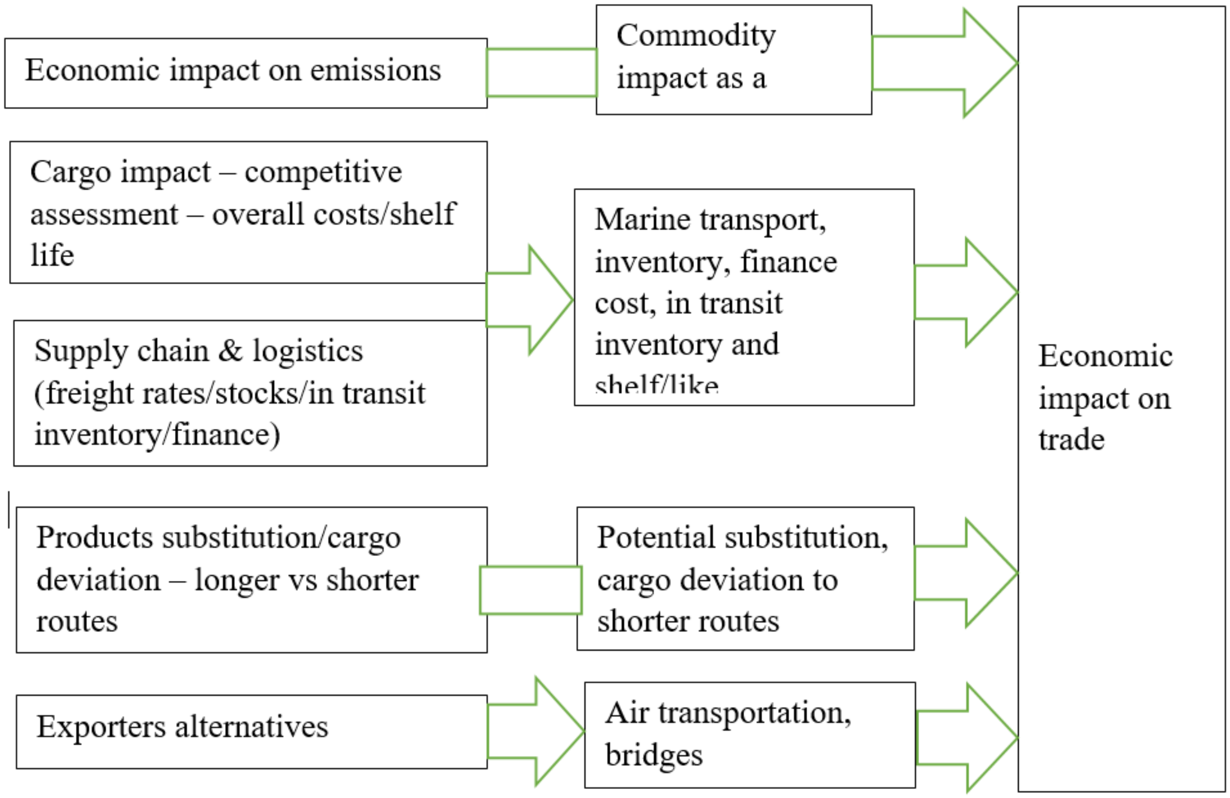
Net Fleet CO_2e Emissions $_{\text{GSA-X}}$ = [(Fleet Propulsion CO2e Emissions $_{\text{GSA-X}}$ + Fleet Auxiliary CO2e Emissions $_{\text{GSA-X}}$ + Fleet boiler CO2e Emissions $_{\text{GSA-X}}$) – (Fleet Propulsion CO2e Emissions $_{\text{GSA}}$ + Fleet Auxiliary CO2e Emissions $_{\text{GSA}}$ + Fleet boiler CO2e Emissions $_{\text{GSA}}$)] / [Fleet Propulsion CO2e Emissions $_{\text{GSA}}$ + Fleet Auxiliary CO2e Emissions $_{\text{GSA}}$ + Fleet boiler CO2e Emissions $_{\text{GSA}}$].

Example for 2012 GSA, distance 1. -25.9% = (432-583) / 583.

Net Fleet CO2e Emissions $_{\text{GSA-X}}$ – these are values obtained from the net CO_2e emissions for the reduced speeds compared with the baseline GSA speed for distances 1 to 5 (tonnes). Results reading negative under this matrix indicates reduction whiles positive figures indicate increase in emission.

3.4 Slow steaming analysis model (SSA), module 2 – economic impacts.

Figure 4: SSA model, module 2 – economic impacts.



Source: APEC 2019 study.

The procedure for calculating the economic impact is explained in this section. There are four worksheet tabs for the economic impact model:

1. Environmental Inputs: the table from module 1 for the vessel speeds from GSA to GSA-10 with the ship size categories are transferred to module 2.
2. Selected Routes Liners: inputs for the container vessels trade routes are provided, with the economies and ports of origin and destination, the product or commodity to be analyzed and its category, the FOB value, weight, value per kg, the service and vessel characteristics are also provided. These data were sourced from the following websites: UN Comtrade, TrendEconomy and World Integrated Trade Solutions (WITS).

3. Selected Routes Bulk: inputs for the bulk vessel trade route are provided, with the economies and ports of origin and destination, the product or commodity to be analyzed and its category, the FOB value, weight, value per kg, the service and vessel characteristics are also provided.
4. Economic Impact Matrix: inputs for the GDP of the economies analyzed, yearly export volume in kilograms, the annual export value in USD $, economies and ports of origin and destination, commodities at level 4 harmonized code (HS), interest, depreciation, insurance and impact cost of delay as a result of additional time is provided in this matrix. Also the distances and the range of speed for each scenario is provided in this tab.

3.4.1 Environmental inputs to the economic impact model (Module 2)

The size of ship categories for container vessels and bulk carriers and the speeds, that is the GSA are used as inputs for the module 2 – economic impacts. The table of values used for the ship & operational data in the emission impact excel file in the analysis matrices is transferred to the environmental tab in the economic impact model.

For all the services provided by the fleet of the companies on the various routes the total time for each voyage is calculated. The total voyage time includes the time in intermediate ports and the total time spent in the ports. The information for the reduced speeds is obtained from the "Environmental Inputs" tab. The average time in port spent by vessel according to the UNCTAD Review of Maritime Transport report is 1.37 days. The following equations are used:

1. Total time in port = average time in port * number of ports
2. Total time = transit time + total time in port

Calculations for the total time for the voyage is done for the range of speeds from the GSA to GSA-10.

Selected Routes Bulk Worksheet

The selected bulk trade route is provided in this worksheet. The equation used in calculating the delay for the different speeds is provided below. The information for the reduced speeds used is obtained from the "Environmental Inputs" tab.

Transit Times $_{\text{GSA-X}}$ = Distance # / Speed $_{\text{GSA-X}}$

3.4.2 Economic impact worksheet.

This worksheet contains four matrices, three for the container vessels trade and one for the bulk carrier trade. Information on time delay at different speeds is the same as on the "Selected Routes Liner" and "Selected Routes Bulk" tabs. In this tab, calculations for the percentage of the GDP of the economy exporting the products is used to analyze the economic impact on each commodity in trade and route used. The economic impact or the additional expenses shippers are likely to incur for extra days of travel is related to three variables interest, depreciation and insurance cost. The parameters used to estimate the impact on an economy as a result of slow steaming are expressed as follows:

1. Time delay: due to slow steaming the number of days or hours of delay which will take place before the cargo arrives at the destination port. This is compared with the total voyage days of the vessels current speed. The assumptions for the various speeds of the vessel determines the time delay, when changes are effected to the GSA the voyage time also changes accordingly.
2. GDP: the impact on the total GDP is dependent on the rate at which products exported are reduced. The equation for calculating this impact is:

GDP Impact = Commodity total export value / Economy GDP

3. Interest cost: this provides the cost involved as impact due to each hour or day of delay for the product traded. It is assumed to be 5% for this analysis. The equation used is:

Interest cost = (Export Value * Interest rate) * (Time delay/365.25).

4. Depreciation cost: for this analysis an assumption of 10% for container cargo, 30% for perishable products and 5% for bulk cargo is used. The equation used is:

Depreciation cost = (Export value * Depreciation rate) * (Time delay/365.25)

5. Insurance cost: according to the APEC, 2019 study, the percentage used in economic analysis is 2%. The equation used is:

Insurance cost = (Export value * insurance rate) * (Time delay/365.25)

All the steps and obtained values described in the methodology for the 2012 GAS scenario for the study are shown in the Appendices.

CHAPTER 4 – Case study for the four routes.

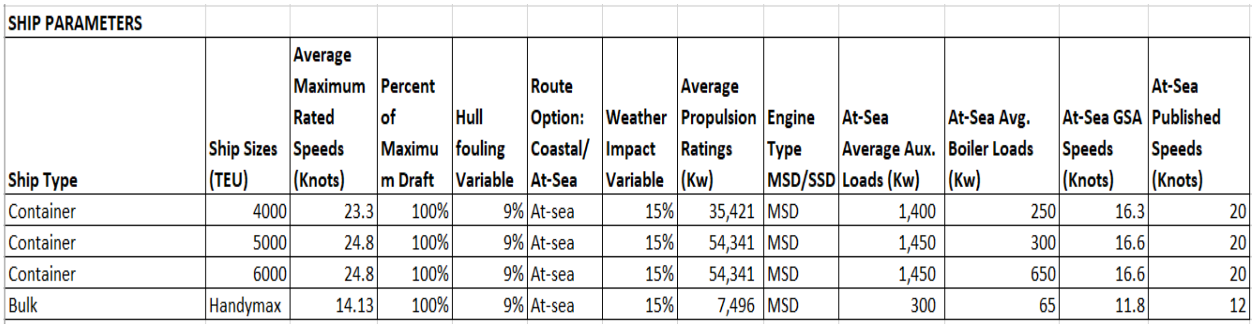
4.1 Chapter overview

This chapter will explain the emission and economic impact for the four trade routes selected for the case study. The four routes analyzed are the United Kingdom (UK) to Ghana, China to Ghana, United Arab Emirates (UAE) to Ghana for container vessels and Ghana to China route for the bulk carrier. The SSA model will be applied to these routes to investigate the emission and economic impact on the fleet operating on these routes.

4.2 Ship Parameters

The characteristics of the vessels, trade routes, ports called and service rotations will be provided in tables and figures. The average propulsion ratings, at-sea average auxiliary and boiler loads and the published speeds for each ship type and size are provided in table 1. These values are obtained from the 4th IMO GHG study and these were used for the analysis. The number of ships operating on the routes provided are obtained from the CMA CGM and Maersk shipping line webpages.

Table 1: Ship Parameters.



SHIP PARAMETERS

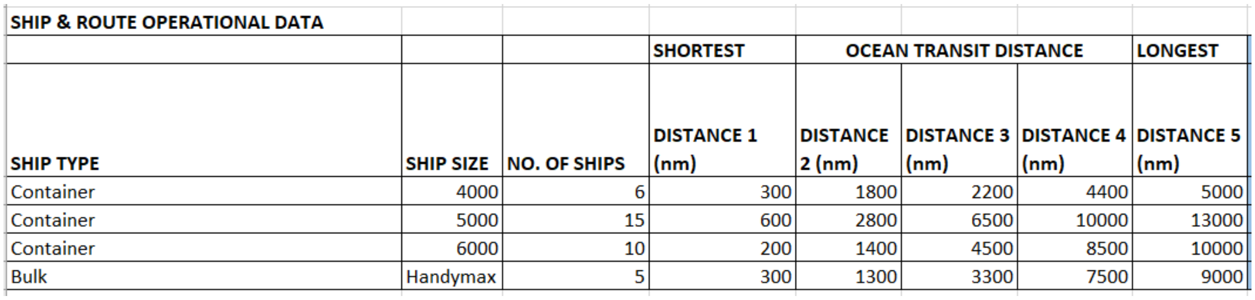
Ship Type	Ship Sizes (TEU)	Average Maximum Rated Speeds (Knots)	Percent of Maximum Draft	Hull fouling Variable	Route Option: Coastal/ At-Sea	Weather Impact Variable	Average Propulsion Ratings (Kw)	Engine Type MSD/SSD	At-Sea Average Aux. Loads (Kw)	At-Sea Avg. Boiler Loads (Kw)	At-Sea GSA Speeds (Knots)	At-Sea Published Speeds (Knots)
Container	4000	23.3	100%	9%	At-sea	15%	35,421	MSD	1,400	250	16.3	20
Container	5000	24.8	100%	9%	At-sea	15%	54,341	MSD	1,450	300	16.6	20
Container	6000	24.8	100%	9%	At-sea	15%	54,341	MSD	1,450	650	16.6	20
Bulk	Handymax	14.13	100%	9%	At-sea	15%	7,496	MSD	300	65	11.8	12

From the routes provided by the shipping line webpages, a range of distances are covered from shortest, intermediate or ocean transit and longest to help observe the impact of slow steaming across these distances. For the 4,000TEU with 6 ships the distance range is from 300nm to 5000nm; the 5,000TEU with 15 ships the distance range is from 600nm to 13,000nm; the 6,000TEU with 10 ships the distance range is from 200nm to 10,000nm and for the handymax with 5 ships the distance range is from 300nm to 9,000nm.

4.2.1 Number of ships for each fleet

Table 2 shows the values used in the analysis for both the 2012 GAS and High Baseline (HBL) speed scenario.

Table 2: Results for number of ships and distances considered.

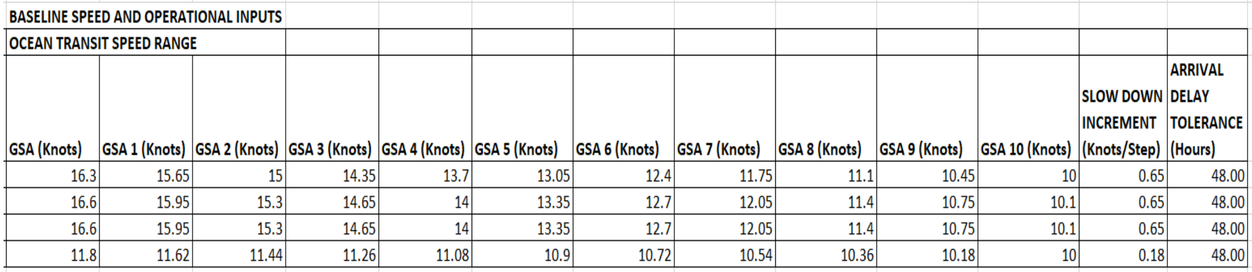


SHIP & ROUTE OPERATIONAL DATA							
			SHORTEST	OCEAN TRANSIT DISTANCE			LONGEST
SHIP TYPE	SHIP SIZE	NO. OF SHIPS	DISTANCE 1 (nm)	DISTANCE 2 (nm)	DISTANCE 3 (nm)	DISTANCE 4 (nm)	DISTANCE 5 (nm)
Container	4000	6	300	1800	2200	4400	5000
Container	5000	15	600	2800	6500	10000	13000
Container	6000	10	200	1400	4500	8500	10000
Bulk	Handymax	5	300	1300	3300	7500	9000

4.2.2 Selected speed ranges (GAS and HBL)

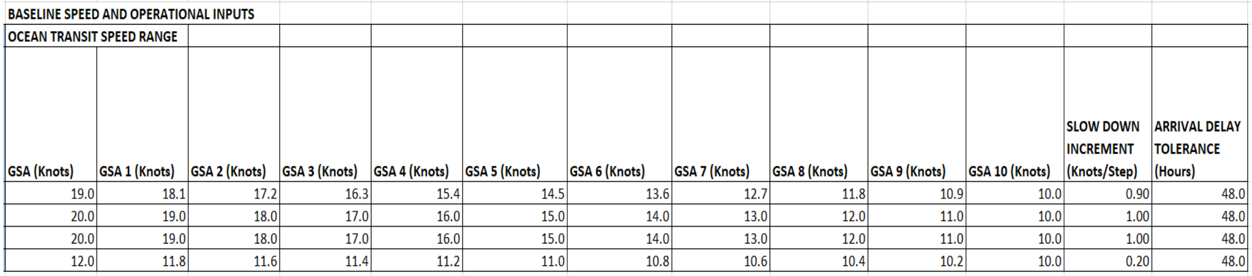
To observe the impact of slow steaming on the fleet deployed in each route a speed range for the 2012 GAS and HBL speed scenario are provided. The 2012 GAS scenario speed range is from 16.6 to 10knots and the HBL scenario speed range is from 20 to 10knots. For the routes provided, each ship or fleet moves from one port to another before arriving at the destination port to deliver cargo. The results for the values used for speed ranges for the 2012 GAS and HBL speed scenarios are shown in table 3 and 4.

Table 3: Speed ranges for 2012 GAS scenario



BASELINE SPEED AND OPERATIONAL INPUTS												
OCEAN TRANSIT SPEED RANGE												
GSA (Knots)	GSA 1 (Knots)	GSA 2 (Knots)	GSA 3 (Knots)	GSA 4 (Knots)	GSA 5 (Knots)	GSA 6 (Knots)	GSA 7 (Knots)	GSA 8 (Knots)	GSA 9 (Knots)	GSA 10 (Knots)	SLOW DOWN INCREMENT (Knots/Step)	ARRIVAL DELAY TOLERANCE (Hours)
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	10	0.65	48.00
16.6	15.95	15.3	14.65	14	13.35	12.7	12.05	11.4	10.75	10.1	0.65	48.00
16.6	15.95	15.3	14.65	14	13.35	12.7	12.05	11.4	10.75	10.1	0.65	48.00
11.8	11.62	11.44	11.26	11.08	10.9	10.72	10.54	10.36	10.18	10	0.18	48.00

Table 4: Speed ranges for HBL speed scenario

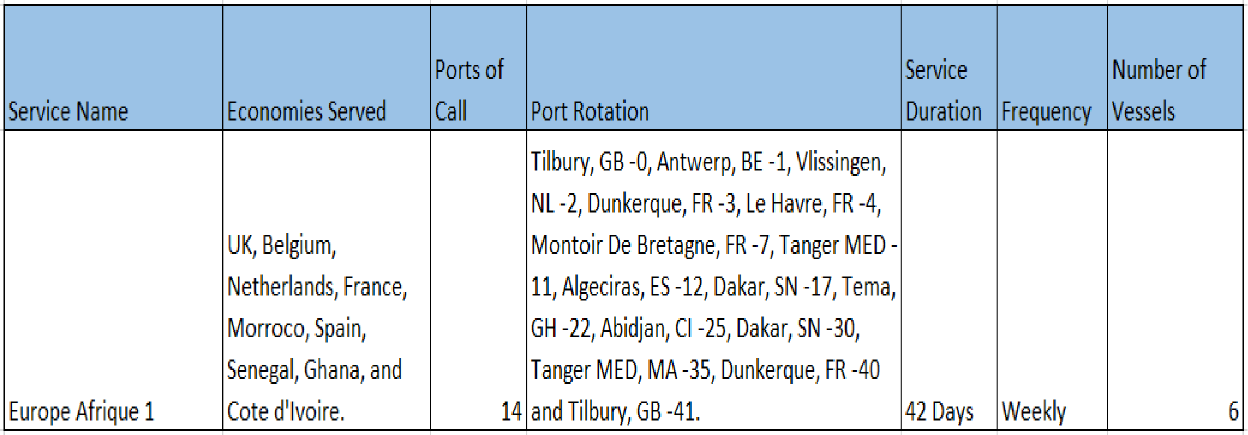


BASELINE SPEED AND OPERATIONAL INPUTS												
OCEAN TRANSIT SPEED RANGE												
GSA (Knots)	GSA 1 (Knots)	GSA 2 (Knots)	GSA 3 (Knots)	GSA 4 (Knots)	GSA 5 (Knots)	GSA 6 (Knots)	GSA 7 (Knots)	GSA 8 (Knots)	GSA 9 (Knots)	GSA 10 (Knots)	SLOW DOWN INCREMENT (Knots/Step)	ARRIVAL DELAY TOLERANCE (Hours)
19.0	18.1	17.2	16.3	15.4	14.5	13.6	12.7	11.8	10.9	10.0	0.90	48.0
20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.0	0.20	48.0

4.3 Route 1 - Tilbury, United Kingdom to Tema, Ghana

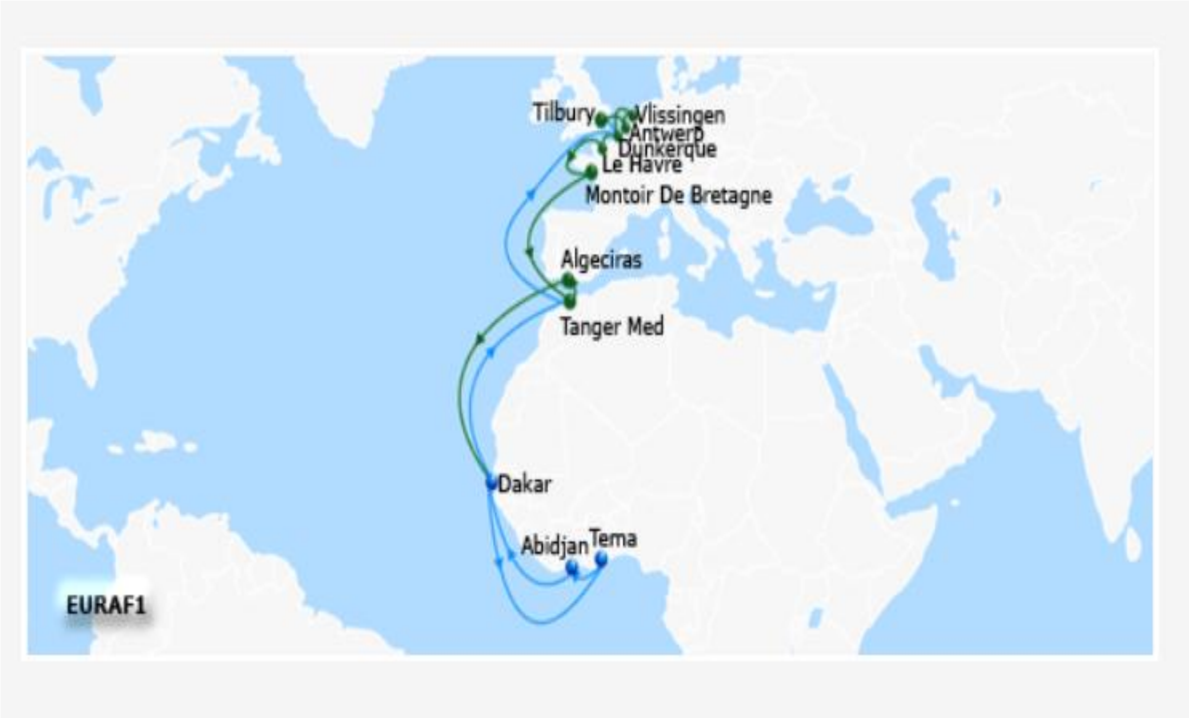
Table 5, 6 and figure 5 represents the characteristics of the Great Britain Service (EURAF 1), the CMA CGM group shipping line deploys 6 vessels in total. As presented in the following trade, transporting goods in EURAF 1 service from Tilbury, Great Britain is not a direct route. The vessel calls to the ports of Antwerp, Vlissingen, Dunkerque, Le Havre, Montoir De Bretagne, Tanger MED, Algeciras, Dakar, Tema and Abidjan before arriving at final destination for the cargo to be delivered. The distance between the ports are obtained from Ports.com.

Table 5: Europe Afrique 1(EURAF 1) Characteristics



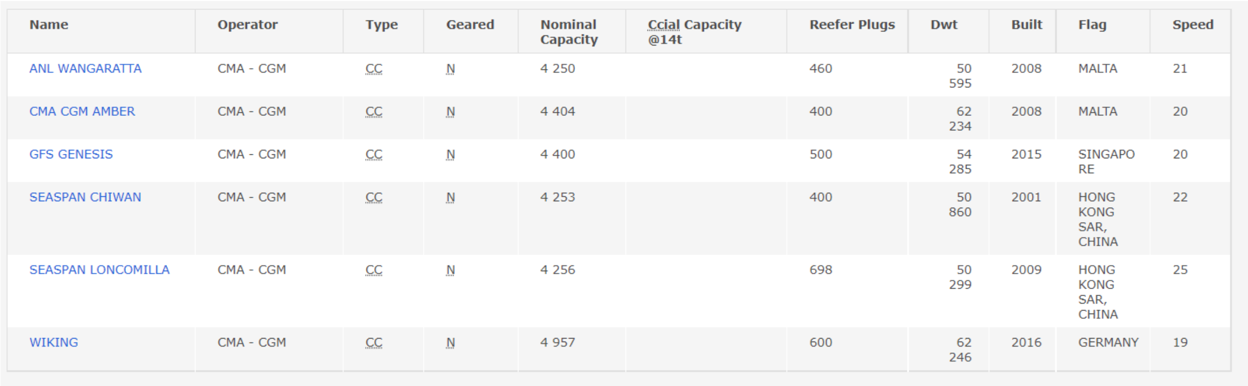
Service Name	Economies Served	Ports of Call	Port Rotation	Service Duration	Frequency	Number of Vessels
Europe Afrique 1	UK, Belgium, Netherlands, France, Morroco, Spain, Senegal, Ghana, and Cote d'Ivoire.	14	Tilbury, GB -0, Antwerp, BE -1, Vlissingen, NL -2, Dunkerque, FR -3, Le Havre, FR -4, Montoir De Bretagne, FR -7, Tanger MED - 11, Algeciras, ES -12, Dakar, SN -17, Tema, GH -22, Abidjan, CI -25, Dakar, SN -30, Tanger MED, MA -35, Dunkerque, FR -40 and Tilbury, GB -41.	42 Days	Weekly	6

Figure 5: EURAF 1 Service Rotation



Ref.: https://www.cma-cgm.com/products-services/line-services/flyer/EURAF1

Table 6: Vessel Characteristics for Tibury, Great Britain to Tema, Ghana.



Name	Operator	Type	Geared	Nominal Capacity	Ccial Capacity @14t	Reefer Plugs	Dwt	Built	Flag	Speed
ANL WANGARATTA	CMA - CGM	CC	N	4 250		460	50 595	2008	MALTA	21
CMA CGM AMBER	CMA - CGM	CC	N	4 404		400	62 234	2008	MALTA	20
GFS GENESIS	CMA - CGM	CC	N	4 400		500	54 285	2015	SINGAPORE	20
SEASPAN CHIWAN	CMA - CGM	CC	N	4 253		400	50 860	2001	HONG KONG SAR, CHINA	22
SEASPAN LONCOMILLA	CMA - CGM	CC	N	4 256		698	50 299	2009	HONG KONG SAR, CHINA	25
WIKING	CMA - CGM	CC	N	4 957		600	62 246	2016	GERMANY	19

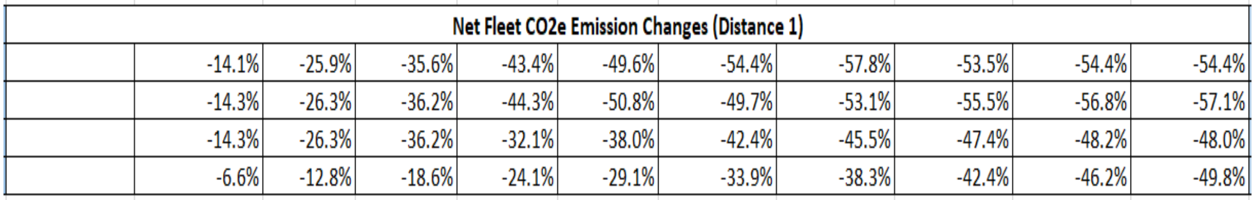
Ref.: https://www.cma-cgm.com/products-services/line-services/flyer/EURAF1

4.3.1 Emission impact analysis.

For the ship type and size combinations for the 4000TEU container vessels trade, the ships operating on this route covers a distance of 10,430 nm. To analyze the emissions impact from the vessels in this route, a range of distances were considered. The shortest distance is 300nm, the intermediate distances are 1,800nm, 2,200nm and 4,400nm and the longest distance is 5,000nm. The speed range is from 16.3 to 10knots with reducing intervals of 0.65, which is a suitable range to investigate the impact across a wide range of speeds. The analysis is carried out through the 13 matrices explained in the methodology for the five distances from 300nm to 5,000nm. Calculations for the propulsion, auxiliary and boilers are tabulated to provide the work done for the 6 ships in the fleet for this route.

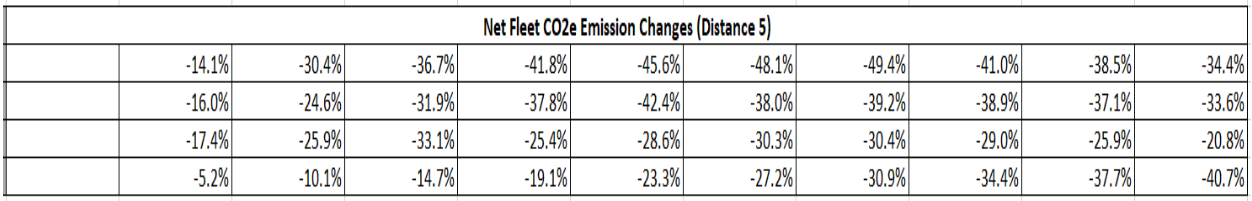
From these tabulations the percentage of net fleet CO_2e emissions changes is provided in matrix 13. For distance 1, which is the shortest, the emissions benefits obtained ranges from -14.1% to -54.4% which corresponds to the speed reduction from 16.3 to 10 knots. This indicates that for this distance as the speed reduces, the emission benefits also increase. For example, at a reduced speed of 13.05 knots, a percentage reduction of -49.6% is gained in emissions. For the longest distance which is 5,000nm, the benefits obtained ranges from -14.1% to -34.3% which corresponds to the speed reduction from 16.3 to 10knots. An important observation is that as the speed reduces for the longest distance, the benefits obtained in emissions decrease. This indicates that slower speeds for longer distances could yield less benefits which is as a result of the additional ships required to augment the fleet. Table 7 and 8 shows the illustration of the results obtained for distance 1 and 5 for the 2012 GAS scenario.

Table 7: Illustration for Distance 1 for the 2012 GSA Scenario.



Net Fleet CO2e Emission Changes (Distance 1)										
	-14.1%	-25.9%	-35.6%	-43.4%	-49.6%	-54.4%	-57.8%	-53.5%	-54.4%	-54.4%
	-14.3%	-26.3%	-36.2%	-44.3%	-50.8%	-49.7%	-53.1%	-55.5%	-56.8%	-57.1%
	-14.3%	-26.3%	-36.2%	-32.1%	-38.0%	-42.4%	-45.5%	-47.4%	-48.2%	-48.0%
	-6.6%	-12.8%	-18.6%	-24.1%	-29.1%	-33.9%	-38.3%	-42.4%	-46.2%	-49.8%

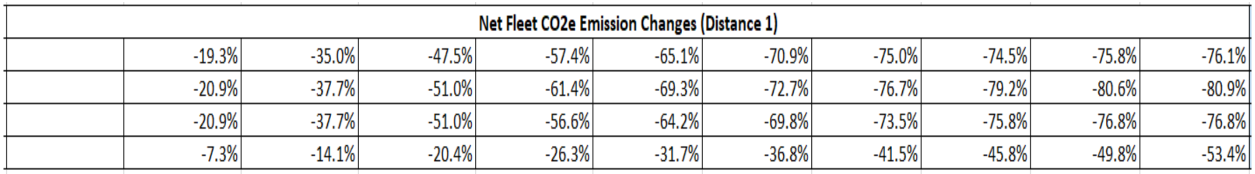
Table 8: Illustration for Distance 5 for the 2012 Global Average Speed Scenario.



Net Fleet CO2e Emission Changes (Distance 5)										
	-14.1%	-30.4%	-36.7%	-41.8%	-45.6%	-48.1%	-49.4%	-41.0%	-38.5%	-34.4%
	-16.0%	-24.6%	-31.9%	-37.8%	-42.4%	-38.0%	-39.2%	-38.9%	-37.1%	-33.6%
	-17.4%	-25.9%	-33.1%	-25.4%	-28.6%	-30.3%	-30.4%	-29.0%	-25.9%	-20.8%
	-5.2%	-10.1%	-14.7%	-19.1%	-23.3%	-27.2%	-30.9%	-34.4%	-37.7%	-40.7%

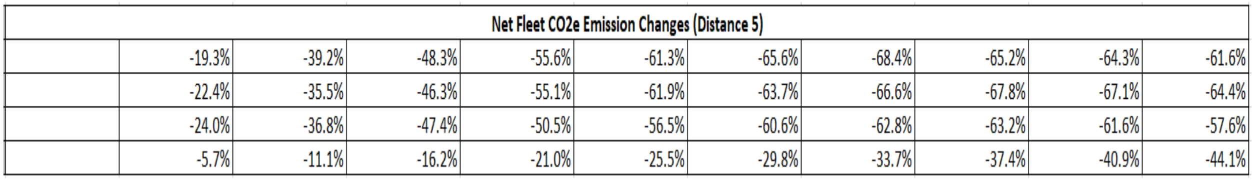
To further examine the impact of speed reduction on the fleet operating on this route, the same analysis is conduct for the HBL speed scenario. The speed range considered in this scenario is from 19.0 to 10knots with reduction intervals of 0.90. The same tabulation is carried out through the 13 matrices with this range of speeds. This is to help compare the emission benefits with the 2012 GAS scenario. For distance 1, which is the shortest distance, the emission benefits obtained ranges from -19.3% to -76.1% which corresponds to the reduced speeds from 19 to 10knots. This indicates that for this distance as speed reduces, the emission benefits increase. At a reduced speed of 14.5knots, a percentage of -65.1% is gained in emissions. For the longest distance 5,000nm, the benefits obtained ranges from -19.3% to -61.6% which corresponds to the speed range from 19 to 10knots. Similar to the 2012 GAS scenario, it is observed that as the speed reduces for the longest distance the benefits obtained in emissions reduction decrease. The same conclusion can be deduced that slower speeds for the EURAF1 route which serves Ghana, could yield less benefits. The result of this less benefit is from the additional ships required to maintain the frequency of the fleet on this route. Table 9 and 10 shows the illustration of the results obtained for distance 1 and 5 for the HBL speed scenario.

Table 9: Illustration for Distance 1 for the High Baseline Speed Scenario.



Net Fleet CO2e Emission Changes (Distance 1)										
	-19.3%	-35.0%	-47.5%	-57.4%	-65.1%	-70.9%	-75.0%	-74.5%	-75.8%	-76.1%
	-20.9%	-37.7%	-51.0%	-61.4%	-69.3%	-72.7%	-76.7%	-79.2%	-80.6%	-80.9%
	-20.9%	-37.7%	-51.0%	-56.6%	-64.2%	-69.8%	-73.5%	-75.8%	-76.8%	-76.8%
	-7.3%	-14.1%	-20.4%	-26.3%	-31.7%	-36.8%	-41.5%	-45.8%	-49.8%	-53.4%

Table 10: Illustration for Distance 5 for the High Baseline Speed Scenario.

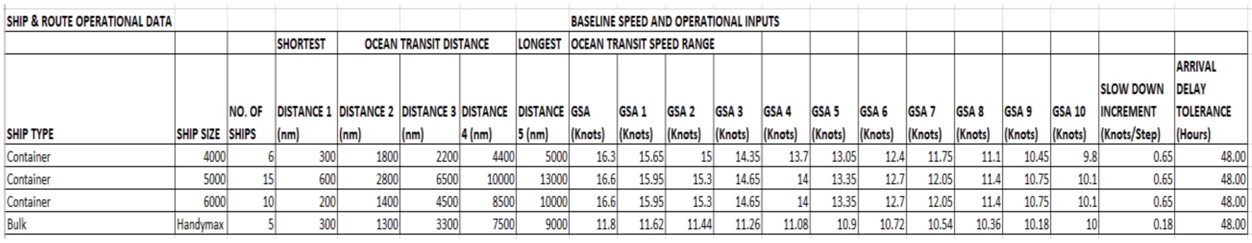


Net Fleet CO2e Emission Changes (Distance 5)										
	-19.3%	-39.2%	-48.3%	-55.6%	-61.3%	-65.6%	-68.4%	-65.2%	-64.3%	-61.6%
	-22.4%	-35.5%	-46.3%	-55.1%	-61.9%	-63.7%	-66.6%	-67.8%	-67.1%	-64.4%
	-24.0%	-36.8%	-47.4%	-50.5%	-56.5%	-60.6%	-62.8%	-63.2%	-61.6%	-57.6%
	-5.7%	-11.1%	-16.2%	-21.0%	-25.5%	-29.8%	-33.7%	-37.4%	-40.9%	-44.1%

4.3.2 Economic impact analysis.

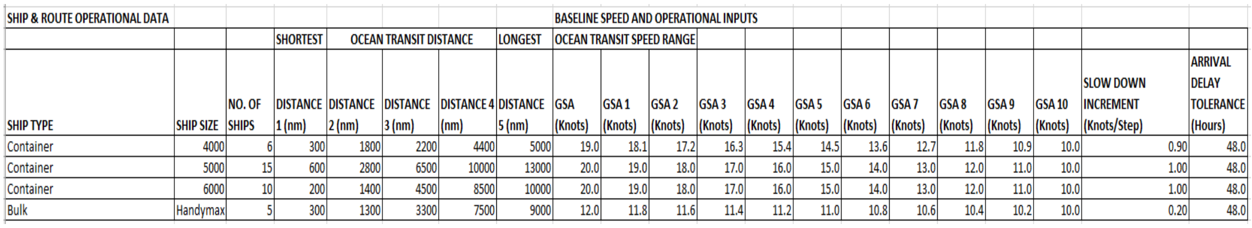
After obtaining the results for the emission benefits, the values for the ship and route operational data in model 1 is transferred as input parameters to model 2 for the economic impact assessment. In model 2, the values are presented in the environmental inputs matrix. Table 11 shows the values used for the analysis. The values used for the HBL speed scenario are also shown in table 12. The same values in tables 1, 2, 3 and 4 are used for all the routes considered.

Table 11: Ship and route operational data for 2012 GAS scenario.



SHIP & ROUTE OPERATIONAL DATA								BASELINE SPEED AND OPERATIONAL INPUTS												
			SHORTEST	OCEAN TRANSIT DISTANCE			LONGEST	OCEAN TRANSIT SPEED RANGE												
SHIP TYPE	SHIP SIZE	NO. OF SHIPS	DISTANCE 1 (nm)	DISTANCE 2 (nm)	DISTANCE 3 (nm)	DISTANCE 4 (nm)	DISTANCE 5 (nm)	GSA (Knots)	GSA 1 (Knots)	GSA 2 (Knots)	GSA 3 (Knots)	GSA 4 (Knots)	GSA 5 (Knots)	GSA 6 (Knots)	GSA 7 (Knots)	GSA 8 (Knots)	GSA 9 (Knots)	GSA 10 (Knots)	SLOW DOWN INCREMENT (Knots/Step)	ARRIVAL DELAY TOLERANCE (Hours)
Container	4000	6	300	1800	2200	4400	5000	16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	0.65	48.00
Container	5000	15	600	2800	6500	10000	13000	16.6	15.95	15.3	14.65	14	13.35	12.7	12.05	11.4	10.75	10.1	0.65	48.00
Container	6000	10	200	1400	4500	8500	10000	16.6	15.95	15.3	14.65	14	13.35	12.7	12.05	11.4	10.75	10.1	0.65	48.00
Bulk	Handymax	5	300	1300	3300	7500	9000	11.8	11.62	11.44	11.26	11.08	10.9	10.72	10.54	10.36	10.18	10	0.18	48.00

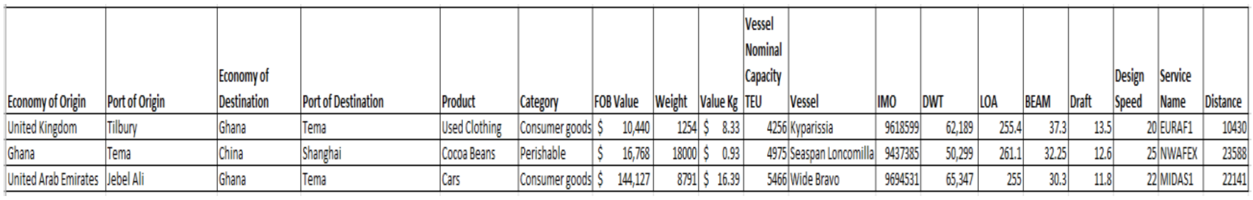
Table 12: Ship and route operational data for HBL speed scenario.



SHIP & ROUTE OPERATIONAL DATA								BASELINE SPEED AND OPERATIONAL INPUTS												
			SHORTEST	OCEAN TRANSIT DISTANCE			LONGEST	OCEAN TRANSIT SPEED RANGE												
SHIP TYPE	SHIP SIZE	NO. OF SHIPS	DISTANCE 1 (nm)	DISTANCE 2 (nm)	DISTANCE 3 (nm)	DISTANCE 4 (nm)	DISTANCE 5 (nm)	GSA (Knots)	GSA 1 (Knots)	GSA 2 (Knots)	GSA 3 (Knots)	GSA 4 (Knots)	GSA 5 (Knots)	GSA 6 (Knots)	GSA 7 (Knots)	GSA 8 (Knots)	GSA 9 (Knots)	GSA 10 (Knots)	SLOW DOWN INCREMENT (Knots/Step)	ARRIVAL DELAY TOLERANCE (Hours)
Container	4000	6	300	1800	2200	4400	5000	19.0	18.1	17.2	16.3	15.4	14.5	13.6	12.7	11.8	10.9	10.0	0.90	48.0
Container	5000	15	600	2800	6500	10000	13000	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
Container	6000	10	200	1400	4500	8500	10000	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	1.00	48.0
Bulk	Handymax	5	300	1300	3300	7500	9000	12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.0	0.20	48.0

The other data required for investigating the economic impact are the FOB value, category (examples, perishable, consumable or high value), weight, value per kg, vessel nominal capacity, design speed and distance. This information is obtained from Ports.com, CMA CGM and Maersk shipping line webpages. The values used are presented in table 13 for the 2012 GAS and the HBL speed scenario.

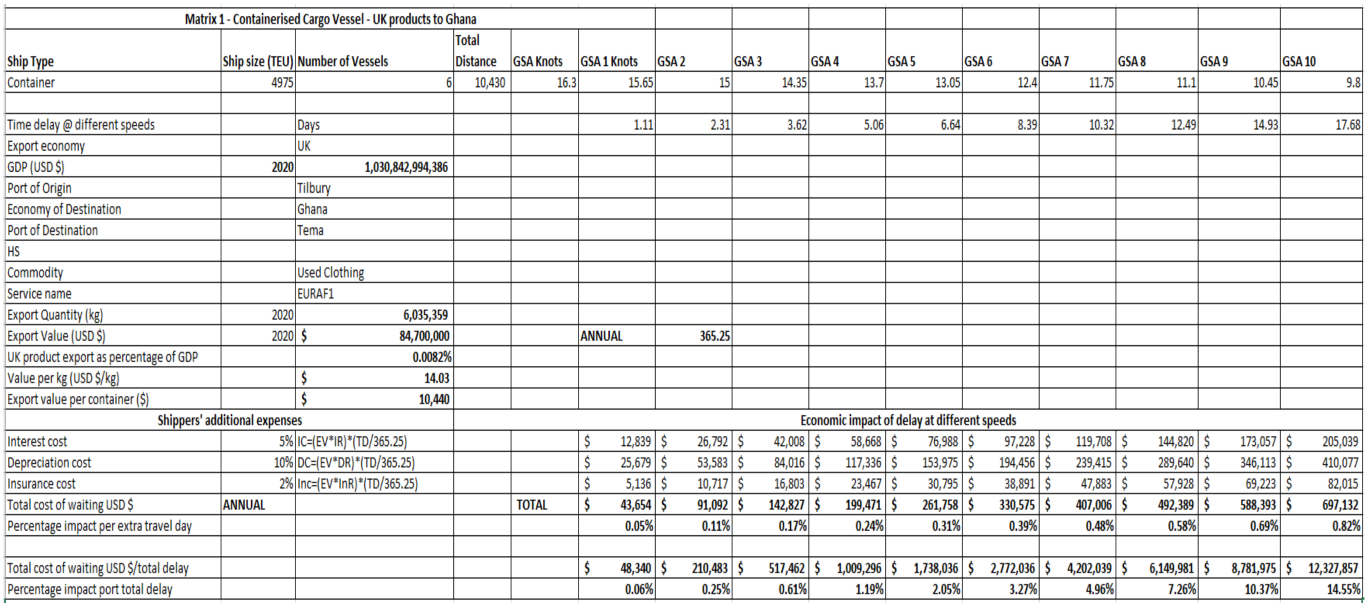
Table 13: Data used for the economic impact analysis.



Economy of Origin	Port of Origin	Economy of Destination	Port of Destination	Product	Category	FOB Value	Weight	Value Kg	Vessel Nominal Capacity TEU	Vessel	IMO	DWT	LOA	BEAM	Draft	Design Speed	Service Name	Distance
United Kingdom	Tilbury	Ghana	Tema	Used Clothing	Consumer goods	$ 10,440	1254	$ 8.33	4256	Kyparissia	9618599	62,189	255.4	37.3	13.5	20	EURAF1	10430
Ghana	Tema	China	Shanghai	Cocoa Beans	Perishable	$ 16,768	18000	$ 0.93	4975	Seaspan Loncomilla	9437385	50,299	261.1	32.25	12.6	25	NWAFEX	23588
United Arab Emirates	Jebel Ali	Ghana	Tema	Cars	Consumer goods	$ 144,127	8791	$ 16.39	5466	Wide Bravo	9694531	65,347	255	30.3	11.8	22	MIDAS1	22141

The GDP of the export country, export value and quantity are obtained from OEC and UN Comtrade webpages. The results for values used for the GAS and HBL speed scenario are shown in table 14 and 15. According to the APEC study (2019), the super slow steaming for container vessels is 15 knots, however, 10 knots are used as the extreme low case for the GAS range. From the OEC (n.d) data, in 2019, the UK exported USD 757M to Ghana. The products exported were railroad ties, used clothing and pesticides. Ghana on the other hand exported products such as crude petroleum, processed fish and tropical fruits to the UK. Used clothing as a percentage of GDP represents 0.0082%. When speed is reduced from 16.3 to 10 knots under the GAS scenario, an addition of 1.11 to 17.68 transit days is made to the EURAF1 service. This increase in transit days will lead to an additional cost ranging from 0.05% to 0.82% for each extra travel day of delay for used clothing exported to Ghana in 2019. At 13.05 knots, the time differential will be 6.64 days and 0.31% additional cost per day.

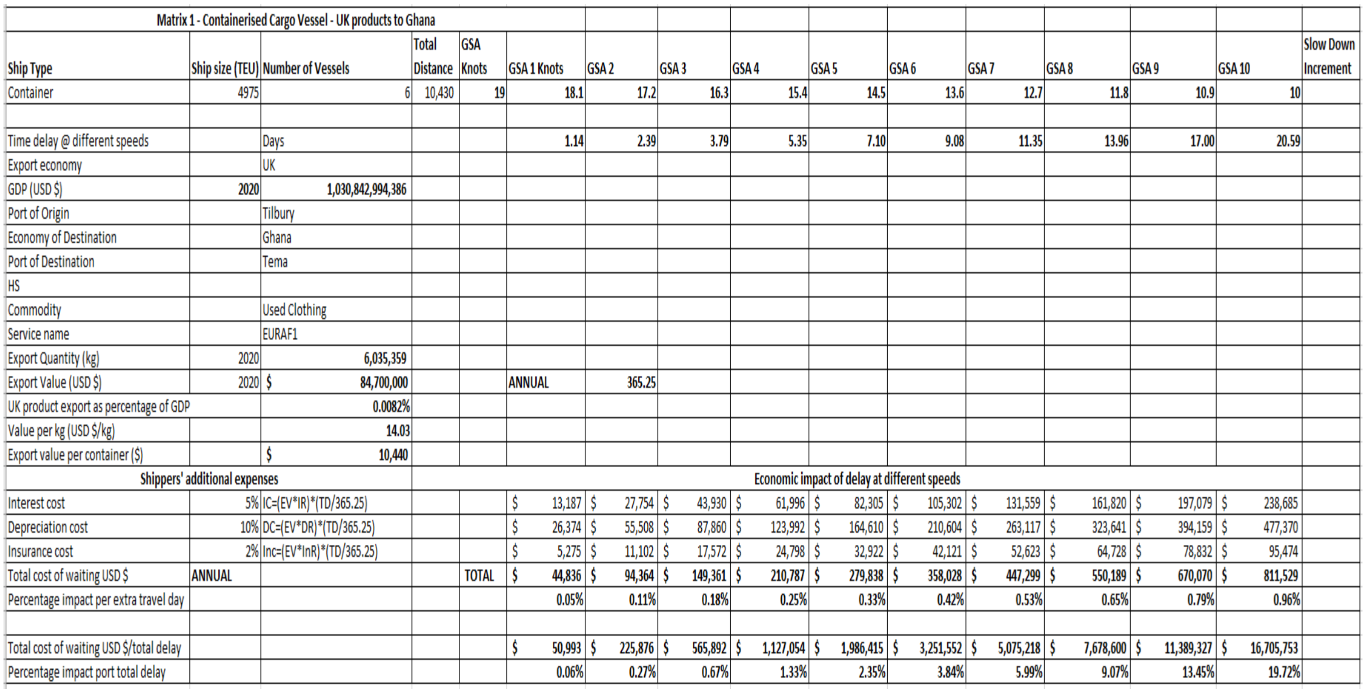
Table 14: Economic impact for 2012 GAS speed scenario.



Matrix 1 - Containerised Cargo Vessel - UK products to Ghana														
Ship Type	Ship size (TEU)	Number of Vessels	Total Distance	GSA Knots	GSA 1 Knots	GSA 2	GSA 3	GSA 4	GSA 5	GSA 6	GSA 7	GSA 8	GSA 9	GSA 10
Container	4975	6	10,430	16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8
Time delay @ different speeds		Days			1.11	2.31	3.62	5.06	6.64	8.39	10.32	12.49	14.93	17.68
Export economy		UK												
GDP (USD $)	2020	1,030,842,994,386												
Port of Origin		Tilbury												
Economy of Destination		Ghana												
Port of Destination		Tema												
HS														
Commodity		Used Clothing												
Service name		EURAF1												
Export Quantity (kg)	2020	6,035,359												
Export Value (USD $)	2020	$ 84,700,000			ANNUAL	365.25								
UK product export as percentage of GDP		0.0082%												
Value per kg (USD $/kg)		$ 14.03												
Export value per container ($)		$ 10,440												
Shippers' additional expenses			Economic impact of delay at different speeds											
Interest cost	5%	IC=(EV*IR)*(TD/365.25)			$ 12,839	$ 26,792	$ 42,008	$ 58,668	$ 76,988	$ 97,228	$ 119,708	$ 144,820	$ 173,057	$ 205,039
Depreciation cost	10%	DC=(EV*DR)*(TD/365.25)			$ 25,679	$ 53,583	$ 84,016	$ 117,336	$ 153,975	$ 194,456	$ 239,415	$ 289,640	$ 346,113	$ 410,077
Insurance cost	2%	Inc=(EV*InR)*(TD/365.25)			$ 5,136	$ 10,717	$ 16,803	$ 23,467	$ 30,795	$ 38,891	$ 47,883	$ 57,928	$ 69,223	$ 82,015
Total cost of waiting USD $	ANNUAL			TOTAL	$ 43,654	$ 91,092	$ 142,827	$ 199,471	$ 261,758	$ 330,575	$ 407,006	$ 492,389	$ 588,393	$ 697,132
Percentage impact per extra travel day					0.05%	0.11%	0.17%	0.24%	0.31%	0.39%	0.48%	0.58%	0.69%	0.82%
Total cost of waiting USD $/total delay					$ 48,340	$ 210,483	$ 517,462	$ 1,009,296	$ 1,738,036	$ 2,772,036	$ 4,202,039	$ 6,149,981	$ 8,781,975	$ 12,327,857
Percentage impact port total delay					0.06%	0.25%	0.61%	1.19%	2.05%	3.27%	4.96%	7.26%	10.37%	14.55%

When speed is reduced from 20 to 10 knots under the high baseline speed scenario, an addition of 1.14 to 20.59 transit days is made to the EURAF1 service. This increase in transit days will lead to an additional cost ranging from 0.05% to 0.96% for each extra travel day of delay for used clothing exported to Ghana in 2019. At 16.3 knots, the time differential will be 3.79 days and 0.18% additional cost per day.

Table 15: Economic impact for HBL speed scenario.



Matrix 1 - Containerised Cargo Vessel - UK products to Ghana															
Ship Type	**Ship size (TEU)**	**Number of Vessels**	**Total Distance**	**GSA Knots**	**GSA 1 Knots**	**GSA 2**	**GSA 3**	**GSA 4**	**GSA 5**	**GSA 6**	**GSA 7**	**GSA 8**	**GSA 9**	**GSA 10**	**Slow Down Increment**
Container	4975	6	10,430	**19**	**18.1**	**17.2**	**16.3**	**15.4**	**14.5**	**13.6**	**12.7**	**11.8**	**10.9**	**10**	
Time delay @ different speeds		Days			**1.14**	**2.39**	**3.79**	**5.35**	**7.10**	**9.08**	**11.35**	**13.96**	**17.00**	**20.59**	
Export economy		UK													
GDP (USD $)	**2020**	**1,030,842,994,386**													
Port of Origin		Tilbury													
Economy of Destination		Ghana													
Port of Destination		Tema													
HS															
Commodity		Used Clothing													
Service name		EURAF1													
Export Quantity (kg)	2020	**6,035,359**													
Export Value (USD $)	2020	**$ 84,700,000**			**ANNUAL**	**365.25**									
UK product export as percentage of GDP		**0.0082%**													
Value per kg (USD $/kg)		**14.03**													
Export value per container ($)		**$ 10,440**													
Shippers' additional expenses			**Economic impact of delay at different speeds**												
Interest cost	5%	IC=(EV*IR)*(TD/365.25)			$ 13,187	$ 27,754	$ 43,930	$ 61,996	$ 82,305	$ 105,302	$ 131,559	$ 161,820	$ 197,079	$ 238,685	
Depreciation cost	10%	DC=(EV*DR)*(TD/365.25)			$ 26,374	$ 55,508	$ 87,860	$ 123,992	$ 164,610	$ 210,604	$ 263,117	$ 323,641	$ 394,159	$ 477,370	
Insurance cost	2%	Inc=(EV*InR)*(TD/365.25)			$ 5,275	$ 11,102	$ 17,572	$ 24,798	$ 32,922	$ 42,121	$ 52,623	$ 64,728	$ 78,832	$ 95,474	
Total cost of waiting USD $	**ANNUAL**			**TOTAL**	**$ 44,836**	**$ 94,364**	**$ 149,361**	**$ 210,787**	**$ 279,838**	**$ 358,028**	**$ 447,299**	**$ 550,189**	**$ 670,070**	**$ 811,529**	
Percentage impact per extra travel day					**0.05%**	**0.11%**	**0.18%**	**0.25%**	**0.33%**	**0.42%**	**0.53%**	**0.65%**	**0.79%**	**0.96%**	
Total cost of waiting USD $/total delay					**$ 50,993**	**$ 225,876**	**$ 565,892**	**$ 1,127,054**	**$ 1,986,415**	**$ 3,251,552**	**$ 5,075,218**	**$ 7,678,600**	**$ 11,389,327**	**$ 16,705,753**	
Percentage impact port total delay					**0.06%**	**0.27%**	**0.67%**	**1.33%**	**2.35%**	**3.84%**	**5.99%**	**9.07%**	**13.45%**	**19.72%**	

Figure 6: Economic Impact as a Percentage of Trade Value: Used clothing, UK to Ghana, High Baseline Speed Scenario.

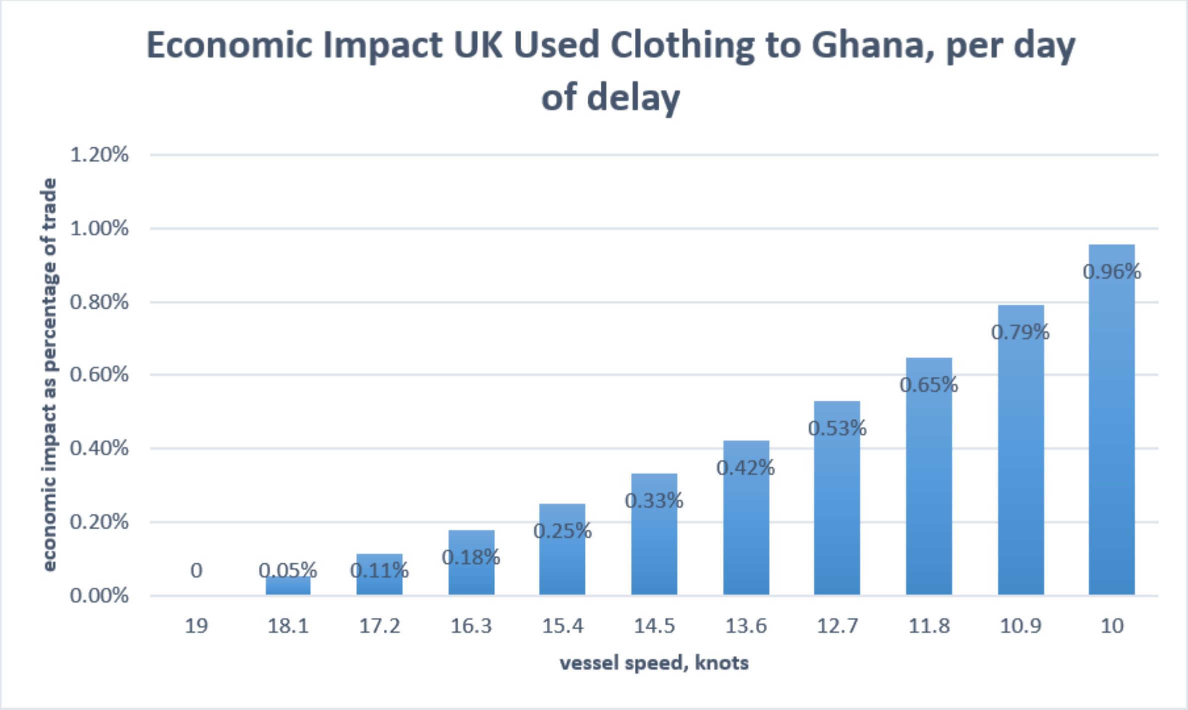
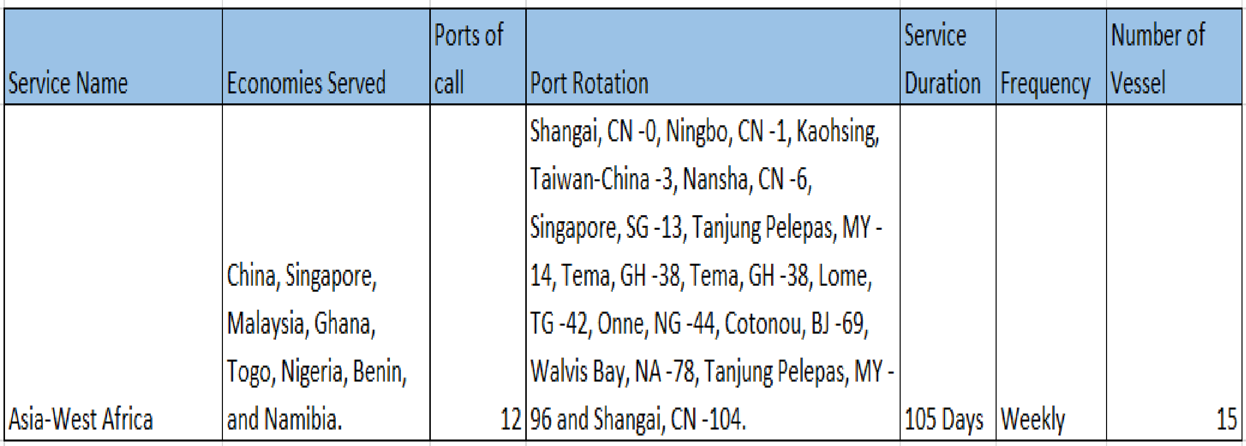


Figure 6 indicates that the economic impact per day of delay over 2019 for UK used clothing export trade value to Ghana is around 0.05% per day, when speed is reduced from 20 to 19 knots. For the 2012 GAS Scenario, applying slow steaming from 16.3 to 10 knots will add 1.11 to 17.68 additional transit days on the EURAF1 service. This will lead to an additional cost ranging from 0.05% to 0.96% per extra travel day of delay for all used clothing exported to Ghana in 2019.

4.4 Route 2 – Tema, Ghana to Shanghai, China.

The New Africa Express (NWAFEX) route was selected for the emission and economic impact analysis, where 15 vessels are deployed by CMA-CGM Group Shipping line. The vessels move from Shanghai, China and calls to 12 ports before arriving at the final destination for the cargo to be delivered. The voyage covers a total distance of 23,588 nautical miles (nm). Table 16, 17 and figure 6 presents the characteristics of the NWAFEX service.

Table 16: New Africa Express (NWAFEX) Characteristics.



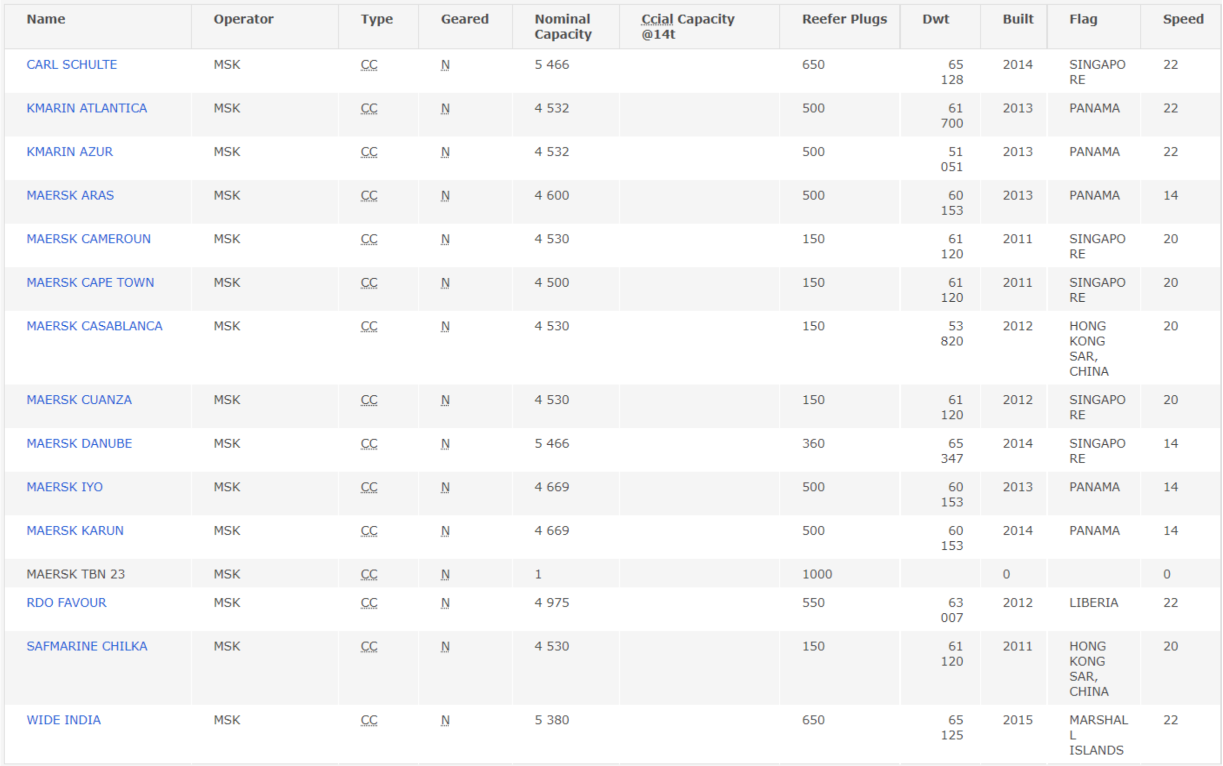
Service Name	Economies Served	Ports of call	Port Rotation	Service Duration	Frequency	Number of Vessel
Asia-West Africa	China, Singapore, Malaysia, Ghana, Togo, Nigeria, Benin, and Namibia.	12	Shangai, CN -0, Ningbo, CN -1, Kaohsing, Taiwan-China -3, Nansha, CN -6, Singapore, SG -13, Tanjung Pelepas, MY -14, Tema, GH -38, Tema, GH -38, Lome, TG -42, Onne, NG -44, Cotonou, BJ -69, Walvis Bay, NA -78, Tanjung Pelepas, MY -96 and Shangai, CN -104.	105 Days	Weekly	15

Ref.: https://www.cma-cgm.com/products-services/line-services/flyer/NWAFEX

Figure 7: New Africa Express (NWAFEX) Service Rotation.

Ref.: https://www.cma-cgm.com/products-services/line-services/flyer/NWAFEX

Table 17: Vessel Characteristics for Tema, Ghana to China, Shanghai.



Name	Operator	Type	Geared	Nominal Capacity	Ccial Capacity @14t	Reefer Plugs	Dwt	Built	Flag	Speed
CARL SCHULTE	MSK	CC	N	5 466		650	65 128	2014	SINGAPORE	22
KMARIN ATLANTICA	MSK	CC	N	4 532		500	61 700	2013	PANAMA	22
KMARIN AZUR	MSK	CC	N	4 532		500	51 051	2013	PANAMA	22
MAERSK ARAS	MSK	CC	N	4 600		500	60 153	2013	PANAMA	14
MAERSK CAMEROUN	MSK	CC	N	4 530		150	61 120	2011	SINGAPORE	20
MAERSK CAPE TOWN	MSK	CC	N	4 500		150	61 120	2011	SINGAPORE	20
MAERSK CASABLANCA	MSK	CC	N	4 530		150	53 820	2012	HONG KONG SAR, CHINA	20
MAERSK CUANZA	MSK	CC	N	4 530		150	61 120	2012	SINGAPORE	20
MAERSK DANUBE	MSK	CC	N	5 466		360	65 347	2014	SINGAPORE	14
MAERSK IYO	MSK	CC	N	4 669		500	60 153	2013	PANAMA	14
MAERSK KARUN	MSK	CC	N	4 669		500	60 153	2014	PANAMA	14
MAERSK TBN 23	MSK	CC	N	1		1000		0		0
RDO FAVOUR	MSK	CC	N	4 975		550	63 007	2012	LIBERIA	22
SAFMARINE CHILKA	MSK	CC	N	4 530		150	61 120	2011	HONG KONG SAR, CHINA	20
WIDE INDIA	MSK	CC	N	5 380		650	65 125	2015	MARSHALL ISLANDS	22

Ref.: https://www.cma-cgm.com/products-services/line-services/flyer/NWAFEX

4.4.1 Emission impact analysis for route 2.

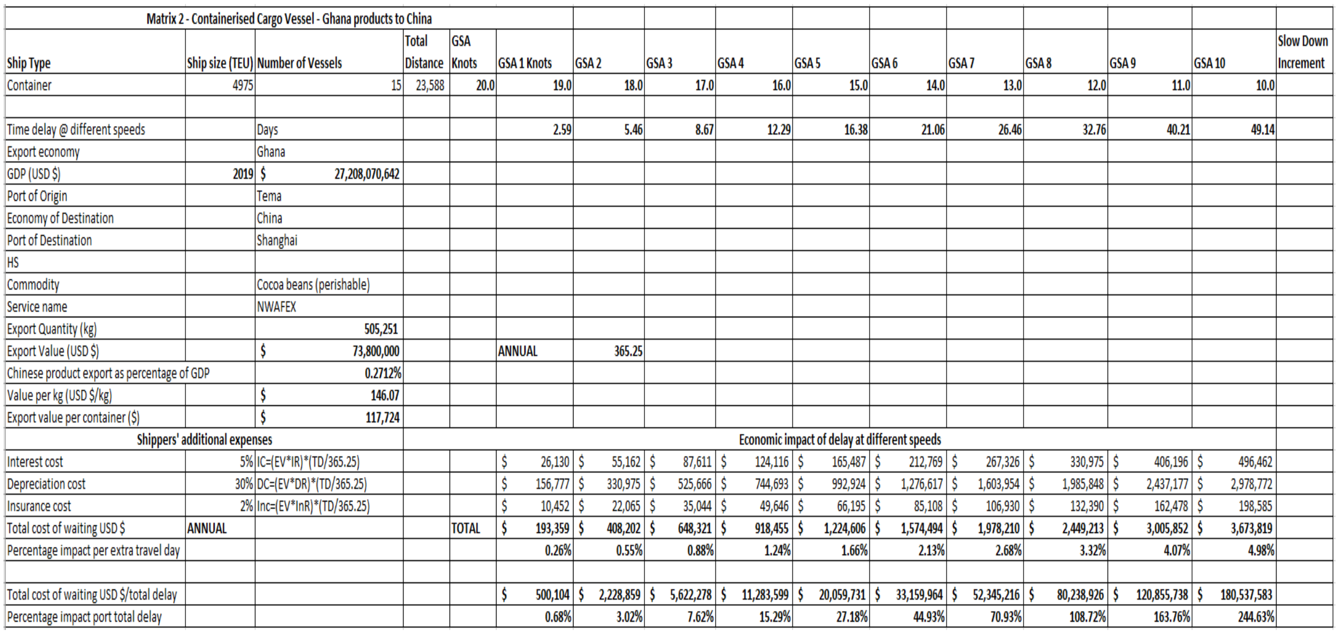
For the ship type and size combinations for the 5,000TEU container vessels trade, the ships operating on this route covers a distance of 23,588nm. To analyze the emissions impact on this route, a range of distances were considered. The shortest distance is 600nm, the intermediate distances are 2,800nm, 6,500nm and 10,000nm and the longest distance is 13,000nm. The speed range is from 16.6 to 10knots with reducing intervals of 0.65. The analysis is carried out through the 13 matrices for the five distances from 600nm to 13,000nm. Calculations for the propulsion, auxiliary and boilers are tabulated to provide the work done for the 15 ships in the fleet for this route is also provided in excel. From these tabulations the percentage of net fleet CO2e emissions changes is provided in matrix 13. For distance 1, which is the shortest, the emissions benefits obtained ranges from -14.3% to -57.1% which corresponds to the speed reduction from 16.6 to 10 knots. This indicates that for this distance as the speed reduces, the emission benefits also increase. For example, at a reduced speed of 13.35 knots, a percentage reduction of -50.8% is gained in emissions. For the longest distance which is 13,000nm, the benefit obtained ranges from -20.9% to -80.9% which corresponds to the speed reduction from 16.6 to 10knots. Table 7 and 8 shows the illustration of the results obtained for distance 1 and 5 for the 2012 GAS scenario.

To further examine the impact of speed reduction on the fleet operating on this route, the same analysis is conduct for the HBL speed scenario. The speed range considered in this scenario is from 20.0 to 10knots with reduction intervals of 1.00. The same tabulation is carried out through the 13 matrices with this range of speeds. This is to help compare the emission benefits with the 2012 GAS scenario. For distance 1, which is the shortest distance, the emission benefits obtained ranges from -20.9% to -80.9% which corresponds to the reduced speeds from 20.0 to 10knots. This indicates that for this distance as speed reduces, the emission benefit increase. At a reduced speed of 15knots, a percentage of -69.3% is gained in emissions. For the longest distance 13,000nm, the benefits obtained ranges from -22.4% to -64.4% which corresponds to the speed range from 20 to 10knots. Table 9 and 10 shows the illustration of the results obtained for distance 1 and 5 for the High Baseline Speed (HBL) scenario.

4.4.2 Economic impact analysis for route 2.

In 2019, China exported an amount of USD 4.35Bn worth of products to Ghana. Coated flat-rolled iron, rubber footwear and pesticides were the main products exported. Ghana exported USD 2.67Bn worth of product to China on the other hand and the main products involved were crude petroleum, manganese and cocoa beans. The export of cocoa beans represented 0.2712% of Ghana's GDP. When the speed of the vessels involved in this trade are reduced from 20 to 10 knots for the HBL speed scenario, additional transit days of 2.59 to 49.14 is going to be added from Ghana to China in the NWAFEX service. This additional added transit days will result in additional cost ranging from 0.26% to 4.98% per extra travel day of delay on this route. With an average speed of 16 knots, the additional time is 12.29 days and an added cost of 0.57%.

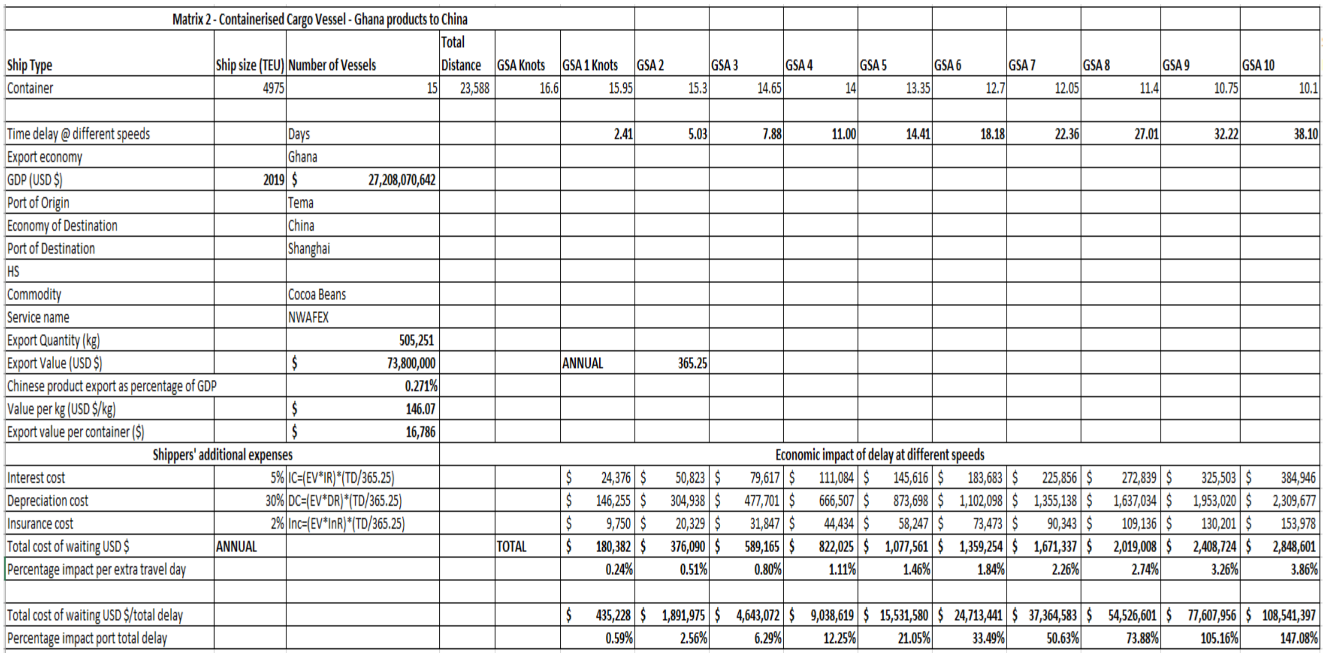
Table 18: Economic impact for HBL speed scenario for route 2.



Matrix 2 - Containerised Cargo Vessel - Ghana products to China															
Ship Type	Ship size (TEU)	Number of Vessels	Total Distance	GSA Knots	GSA 1 Knots	GSA 2	GSA 3	GSA 4	GSA 5	GSA 6	GSA 7	GSA 8	GSA 9	GSA 10	Slow Down Increment
Container	4975	15	23,588	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	
Time delay @ different speeds		Days			2.59	5.46	8.67	12.29	16.38	21.06	26.46	32.76	40.21	49.14	
Export economy		Ghana													
GDP (USD $)	2019	$ 27,208,070,642													
Port of Origin		Tema													
Economy of Destination		China													
Port of Destination		Shanghai													
HS															
Commodity		Cocoa beans (perishable)													
Service name		NWAFEX													
Export Quantity (kg)		505,251													
Export Value (USD $)		$ 73,800,000			ANNUAL	365.25									
Chinese product export as percentage of GDP		0.2712%													
Value per kg (USD $/kg)		$ 146.07													
Export value per container ($)		$ 117,724													
Shippers' additional expenses			Economic impact of delay at different speeds												
Interest cost	5%	IC=(EV*IR)*(TD/365.25)			$ 26,130	$ 55,162	$ 87,611	$ 124,116	$ 165,487	$ 212,769	$ 267,326	$ 330,975	$ 406,196	$ 496,462	
Depreciation cost	30%	DC=(EV*DR)*(TD/365.25)			$ 156,777	$ 330,975	$ 525,666	$ 744,693	$ 992,924	$ 1,276,617	$ 1,603,954	$ 1,985,848	$ 2,437,177	$ 2,978,772	
Insurance cost	2%	Inc=(EV*InR)*(TD/365.25)			$ 10,452	$ 22,065	$ 35,044	$ 49,646	$ 66,195	$ 85,108	$ 106,930	$ 132,390	$ 162,478	$ 198,585	
Total cost of waiting USD $	ANNUAL			TOTAL	$ 193,359	$ 408,202	$ 648,321	$ 918,455	$ 1,224,606	$ 1,574,494	$ 1,978,210	$ 2,449,213	$ 3,005,852	$ 3,673,819	
Percentage impact per extra travel day					0.26%	0.55%	0.88%	1.24%	1.66%	2.13%	2.68%	3.32%	4.07%	4.98%	
Total cost of waiting USD $/total delay					$ 500,104	$ 2,228,859	$ 5,622,278	$ 11,283,599	$ 20,059,731	$ 33,159,964	$ 52,345,216	$ 80,238,926	$ 120,855,738	$ 180,537,583	
Percentage impact port total delay					0.68%	3.02%	7.62%	15.29%	27.18%	44.93%	70.93%	108.72%	163.76%	244.63%	

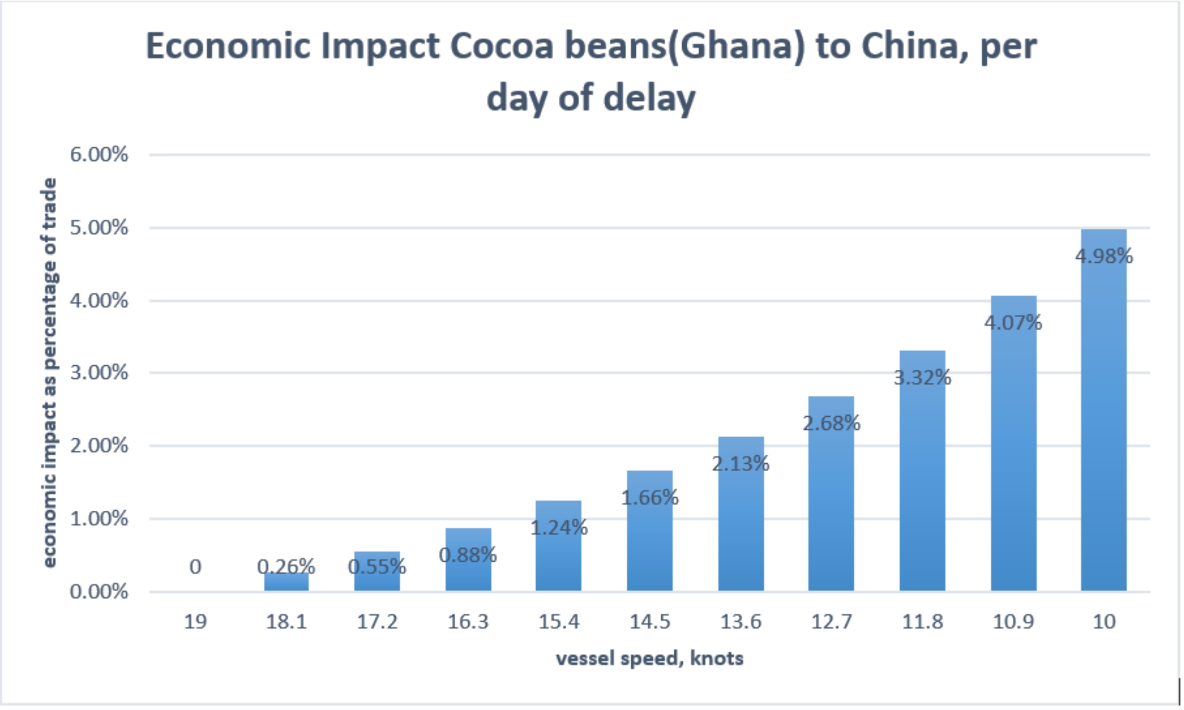
When the speed of the vessels involved in this trade are reduced from 16.6 to 10 knots for the GAS scenario, additional transit days of 2.41 to 38.10 is going to be added from Ghana to China in the NWAFEX service. This additional added transit days will result in additional cost ranging from 0.24% to 3.86% per extra travel day of delay on this route. With an average speed of 14.65 knots, the additional time is 7.88 days and an added cost of 0.80%.

Table 19: Economic impact for 2012 GAS speed scenario for route 2.



Matrix 2 - Containerised Cargo Vessel - Ghana products to China														
Ship Type	Ship size (TEU)	Number of Vessels	Total Distance	GSA Knots	GSA 1 Knots	GSA 2	GSA 3	GSA 4	GSA 5	GSA 6	GSA 7	GSA 8	GSA 9	GSA 10
Container	4975	15	23,588	16.6	15.95	15.3	14.65	14	13.35	12.7	12.05	11.4	10.75	10.1
Time delay @ different speeds		Days			2.41	5.03	7.88	11.00	14.41	18.18	22.36	27.01	32.22	38.10
Export economy		Ghana												
GDP (USD $)	2019	$ 27,208,070,642												
Port of Origin		Tema												
Economy of Destination		China												
Port of Destination		Shanghai												
HS														
Commodity		Cocoa Beans												
Service name		NWAFEX												
Export Quantity (kg)		505,251												
Export Value (USD $)		$ 73,800,000			ANNUAL	365.25								
Chinese product export as percentage of GDP		0.271%												
Value per kg (USD $/kg)		$ 146.07												
Export value per container ($)		$ 16,786												
Shippers' additional expenses			Economic impact of delay at different speeds											
Interest cost	5%	IC=(EV*IR)*(TD/365.25)			$ 24,376	$ 50,823	$ 79,617	$ 111,084	$ 145,616	$ 183,683	$ 225,856	$ 272,839	$ 325,503	$ 384,946
Depreciation cost	30%	DC=(EV*DR)*(TD/365.25)			$ 146,255	$ 304,938	$ 477,701	$ 666,507	$ 873,698	$ 1,102,098	$ 1,355,138	$ 1,637,034	$ 1,953,020	$ 2,309,677
Insurance cost	2%	Inc=(EV*InR)*(TD/365.25)			$ 9,750	$ 20,329	$ 31,847	$ 44,434	$ 58,247	$ 73,473	$ 90,343	$ 109,136	$ 130,201	$ 153,978
Total cost of waiting USD $	ANNUAL			TOTAL	$ 180,382	$ 376,090	$ 589,165	$ 822,025	$ 1,077,561	$ 1,359,254	$ 1,671,337	$ 2,019,008	$ 2,408,724	$ 2,848,601
Percentage impact per extra travel day					0.24%	0.51%	0.80%	1.11%	1.46%	1.84%	2.26%	2.74%	3.26%	3.86%
Total cost of waiting USD $/total delay					$ 435,228	$ 1,891,975	$ 4,643,072	$ 9,038,619	$ 15,531,580	$ 24,713,441	$ 37,364,583	$ 54,526,601	$ 77,607,956	$ 108,541,397
Percentage impact port total delay					0.59%	2.56%	6.29%	12.25%	21.05%	33.49%	50.63%	73.88%	105.16%	147.08%

Figure 8: Economic Impact as a Percentage of Trade Value: Cocoa beans, Ghana to China, High Baseline Speed Scenario.

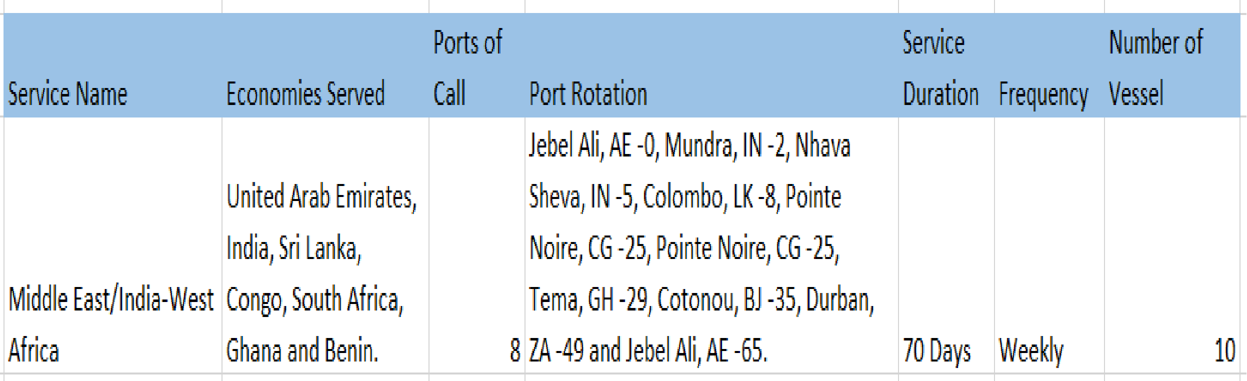


Cocoa beans have the tendency of going bad when not properly preserved, taking this into consideration and the increase in transit days as a result of slow steaming, the depreciation is assumed to be 30%. With the 2012 GAS scenario, slow steaming from 16.3 to 10 knots will create a delay range from 2.41 to 38.10 days in transit from Ghana to China in the NWAFEX service. This increase in transit days will result in an additional cost range from 0.24% to 3.86% per extra travel day of delay on this route and trade. For the HBL speed scenario, the total increase in the voyage transit time ranges from 2.59 to 49.14 days and economic impact per day of delay from 0.26% to 4.98%, which when multiplied by the number of days will generate an impact of 0.68% to 244.63% of cocoa beans exports for 2019.

4.5 Route 3 - Jebel Ali, United Arab Emirates to Tema, Ghana.

To analyze the emission and economic impact on this route, the Middle East/India-West Africa Service was selected which CMA CGM group deployed 10 vessels to provide a weekly service. For this service, the vessel sails from Jebel Ali, UAE, visits 8 ports before arriving at its destination. The voyage covers a total distance of 22,141 nautical miles (nm). Table 20, 21 and figure 7 presents the characteristics of the MIDAS 1 service route.

Table 20: Midas Loop 1 (MIDAS 1) Characteristics.



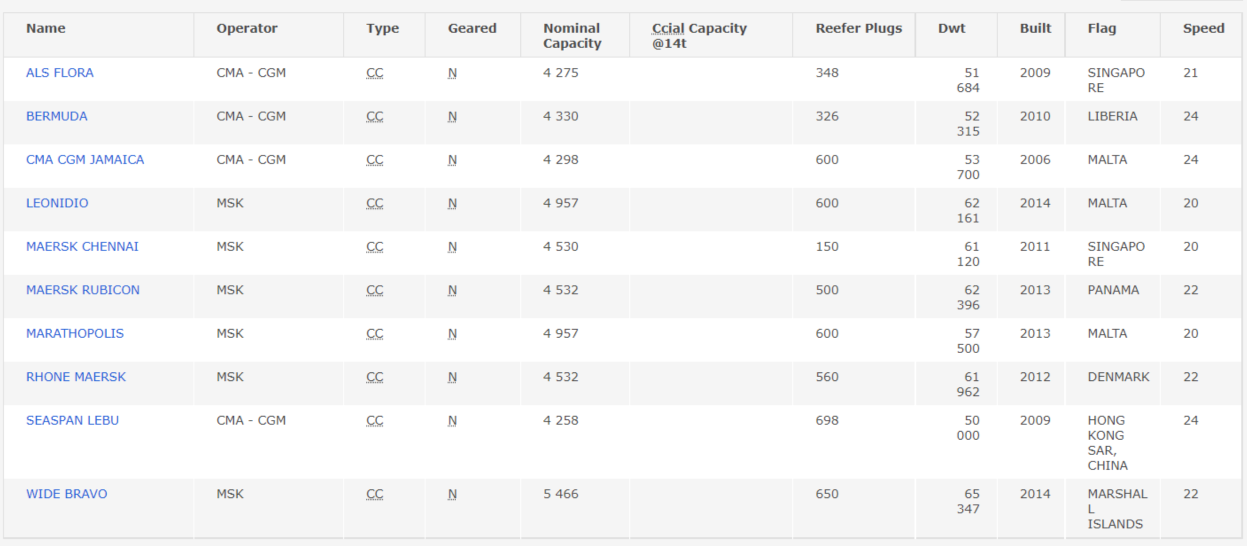
Service Name	Economies Served	Ports of Call	Port Rotation	Service Duration	Frequency	Number of Vessel
Middle East/India-West Africa	United Arab Emirates, India, Sri Lanka, Congo, South Africa, Ghana and Benin.	8	Jebel Ali, AE -0, Mundra, IN -2, Nhava Sheva, IN -5, Colombo, LK -8, Pointe Noire, CG -25, Pointe Noire, CG -25, Tema, GH -29, Cotonou, BJ -35, Durban, ZA -49 and Jebel Ali, AE -65.	70 Days	Weekly	10

Ref.: https://www.cma-cgm.com/products-services/line-services/flyer/MIDAS1

Figure 9: Middle East/India-West Africa Service Rotation.

Ref.: https://www.cma-cgm.com/products-services/line-services/flyer/MIDAS1

Table 21: Vessel characteristics for Middle East/India-West Africa Service Rotation.



Name	Operator	Type	Geared	Nominal Capacity	Ccial Capacity @14t	Reefer Plugs	Dwt	Built	Flag	Speed
ALS FLORA	CMA - CGM	CC	N	4 275		348	51 684	2009	SINGAPORE	21
BERMUDA	CMA - CGM	CC	N	4 330		326	52 315	2010	LIBERIA	24
CMA CGM JAMAICA	CMA - CGM	CC	N	4 298		600	53 700	2006	MALTA	24
LEONIDIO	MSK	CC	N	4 957		600	62 161	2014	MALTA	20
MAERSK CHENNAI	MSK	CC	N	4 530		150	61 120	2011	SINGAPORE	20
MAERSK RUBICON	MSK	CC	N	4 532		500	62 396	2013	PANAMA	22
MARATHOPOLIS	MSK	CC	N	4 957		600	57 500	2013	MALTA	20
RHONE MAERSK	MSK	CC	N	4 532		560	61 962	2012	DENMARK	22
SEASPAN LEBU	CMA - CGM	CC	N	4 258		698	50 000	2009	HONG KONG SAR, CHINA	24
WIDE BRAVO	MSK	CC	N	5 466		650	65 347	2014	MARSHALL ISLANDS	22

4.5.1 Emission impact analysis for route 3.

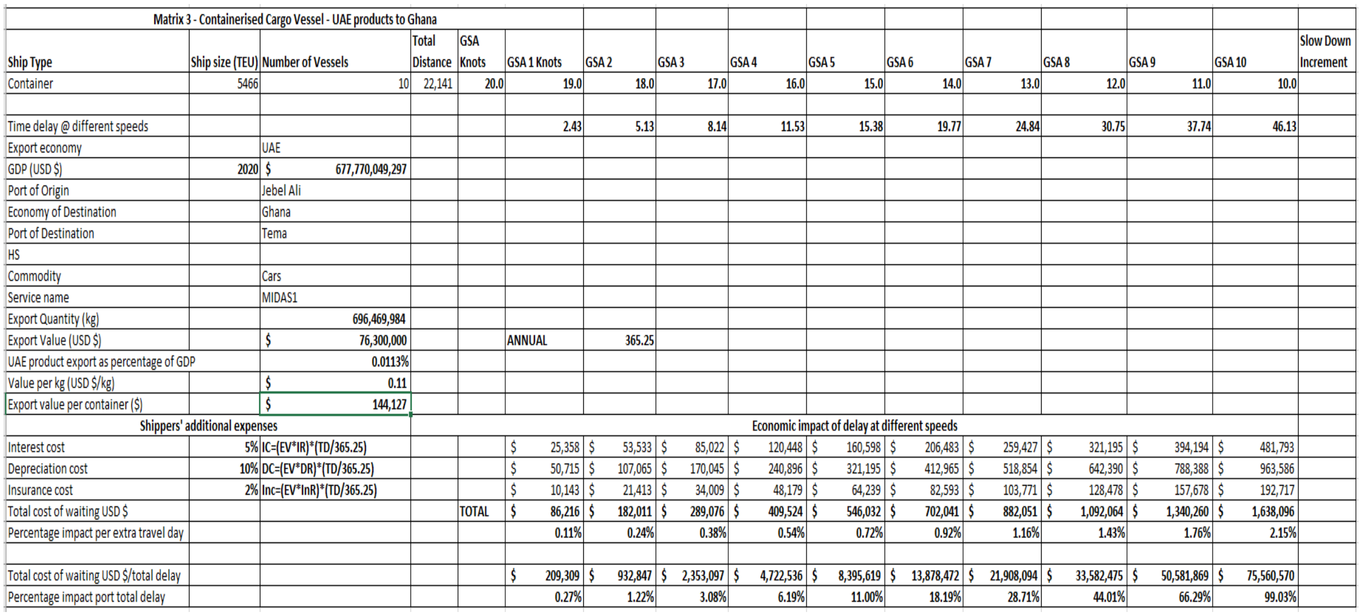
For the ship type and size combinations for the 6,000TEU container vessels trade, the ships operating on this route covers a distance of 22,141nm. To analyze the emissions impact from the vessels in this route, a range of distances were considered. The shortest distance is 200nm, the intermediate distances are 1,400nm, 4,500nm and 8,500nm and the longest distance is 10,000nm. The speed range is from 16.6 to 10knots with reducing intervals of 0.65. The analysis is carried out through the 13 matrices for the five distances from 200nm to 10,000nm. Calculations for the propulsion, auxiliary and boilers are tabulated to provide the work done for the 10 ships in the fleet for this route. From these tabulations the percentage of net fleet CO_2e emissions changes is provided in matrix 13 in the excel file. For distance 1, which is the shortest, the emissions benefits obtained ranges from -14.3% to -48.0% which corresponds to the speed reduction from 16.6 to 10 knots. This indicates that for this distance as the speed reduces, the emission benefits also increase. For example, at a reduced speed of 13.35 knots, a percentage reduction of -38.0% is gained in emissions. For the longest distance which is 10,000nm, the benefits obtained ranges from -17.4% to -20.8% which corresponds to the speed reduction from 16.6 to 10knots. Table 7 and 8 shows the illustration of the results obtained for distance 1 and 5 for the 2012 GAS scenario.

To further examine the impact of speed reduction on the fleet operating on this route, the same analysis is conduct for the HBL speed scenario. The speed range considered in this scenario is from 20.0 to 10knots with reduction intervals of 1.00. The same tabulation is carried out through the 13 matrices with this range of speeds. This is to help compare the emission benefits with the 2012 GAS speed scenario. For distance 1, which is the shortest distance, the emission benefits obtained ranges from -20.9% to -76.8% which corresponds to the reduced speeds from 20.0 to 10knots. This indicates that for this distance as speed reduces, the emission benefits increase. At a reduced speed of 15knots, a percentage of -64.2% is gained in emissions. For the longest distance 10,000nm, the benefits obtained ranges from -24.0% to -57.6% which corresponds to the speed range from 20 to 10knots. Table 9 and 10 shows the illustration of the results obtained for distance 1 and 5 for the HBL speed scenario.

4.5.2 Economic impact analysis for route 3.

In 2019, the UAE exported USD 330M worth of products to Ghana, among these products, cars, refined petroleum and delivery trucks were the main products and Ghana on the other hand exported products worth USD 1.83Bn to UAE (OEC, n.d). The main products exported were gold, precious metal compounds and non-fillet frozen fish. The car export from the UAE represented 0.0113% amounting to USD 76.3M of the UAE economy. With a reduced vessel speed from 20 to 10knots under the HBL speed scenario, an addition of transit days of 2.43 to 46.13 will occur. This will lead to additional cost ranging from 0.11% to 2.15% per extra travel day for cars exported from the UAE to Ghana in 2019. At an average vessel speed of 14knots, an additional transit delay of 19.77 days and cost of 0.92% may occur.

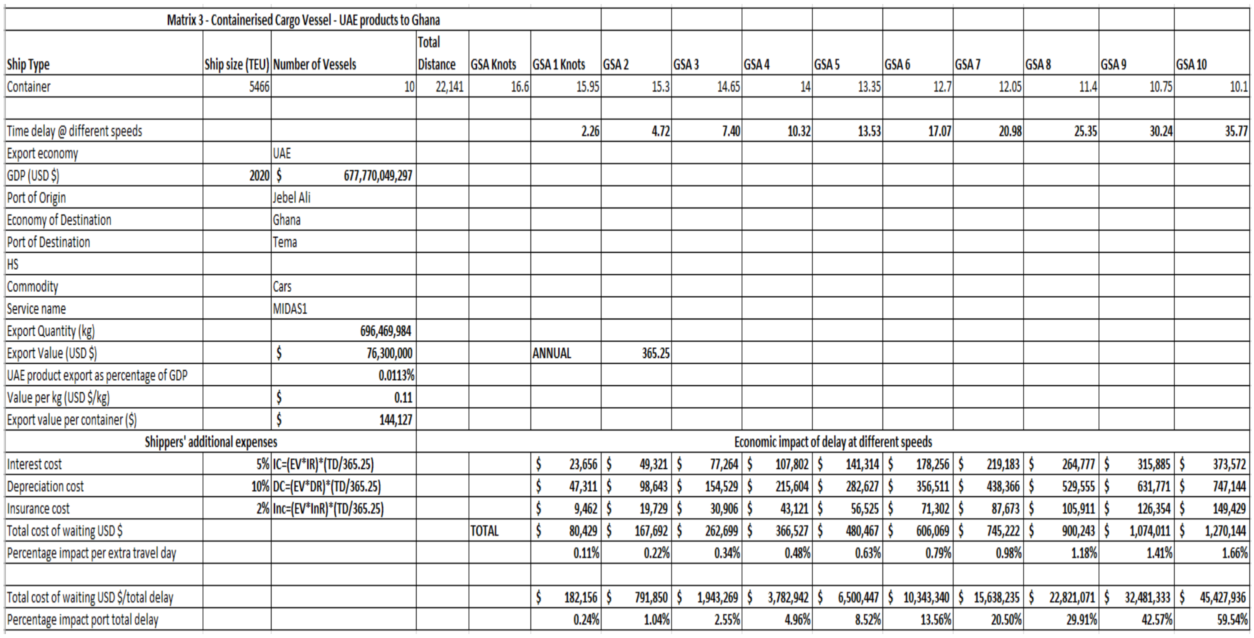
Table 22: Economic impact for HBL speed scenario.



Matrix 3 - Containerised Cargo Vessel - UAE products to Ghana															
Ship Type	Ship size (TEU)	Number of Vessels	Total Distance	GSA Knots	GSA 1 Knots	GSA 2	GSA 3	GSA 4	GSA 5	GSA 6	GSA 7	GSA 8	GSA 9	GSA 10	Slow Down Increment
Container	5466	10	22,141	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0	10.0	
Time delay @ different speeds					2.43	5.13	8.14	11.53	15.38	19.77	24.84	30.75	37.74	46.13	
Export economy		UAE													
GDP (USD $)	2020	$ 677,770,049,297													
Port of Origin		Jebel Ali													
Economy of Destination		Ghana													
Port of Destination		Tema													
HS															
Commodity		Cars													
Service name		MIDAS1													
Export Quantity (kg)		696,469,984													
Export Value (USD $)		$ 76,300,000			ANNUAL	365.25									
UAE product export as percentage of GDP		0.0113%													
Value per kg (USD $/kg)		$ 0.11													
Export value per container ($)		$ 144,127													
Shippers' additional expenses			Economic impact of delay at different speeds												
Interest cost	5%	IC=(EV*IR)*(TD/365.25)			$ 25,358	$ 53,533	$ 85,022	$ 120,448	$ 160,598	$ 206,483	$ 259,427	$ 321,195	$ 394,194	$ 481,793	
Depreciation cost	10%	DC=(EV*DR)*(TD/365.25)			$ 50,715	$ 107,065	$ 170,045	$ 240,896	$ 321,195	$ 412,965	$ 518,854	$ 642,390	$ 788,388	$ 963,586	
Insurance cost	2%	Inc=(EV*InR)*(TD/365.25)			$ 10,143	$ 21,413	$ 34,009	$ 48,179	$ 64,239	$ 82,593	$ 103,771	$ 128,478	$ 157,678	$ 192,717	
Total cost of waiting USD $				TOTAL	$ 86,216	$ 182,011	$ 289,076	$ 409,524	$ 546,032	$ 702,041	$ 882,051	$ 1,092,064	$ 1,340,260	$ 1,638,096	
Percentage impact per extra travel day					0.11%	0.24%	0.38%	0.54%	0.72%	0.92%	1.16%	1.43%	1.76%	2.15%	
Total cost of waiting USD $/total delay					$ 209,309	$ 932,847	$ 2,353,097	$ 4,722,536	$ 8,395,619	$ 13,878,472	$ 21,908,094	$ 33,582,475	$ 50,581,869	$ 75,560,570	
Percentage impact port total delay					0.27%	1.22%	3.08%	6.19%	11.00%	18.19%	28.71%	44.01%	66.29%	99.03%	

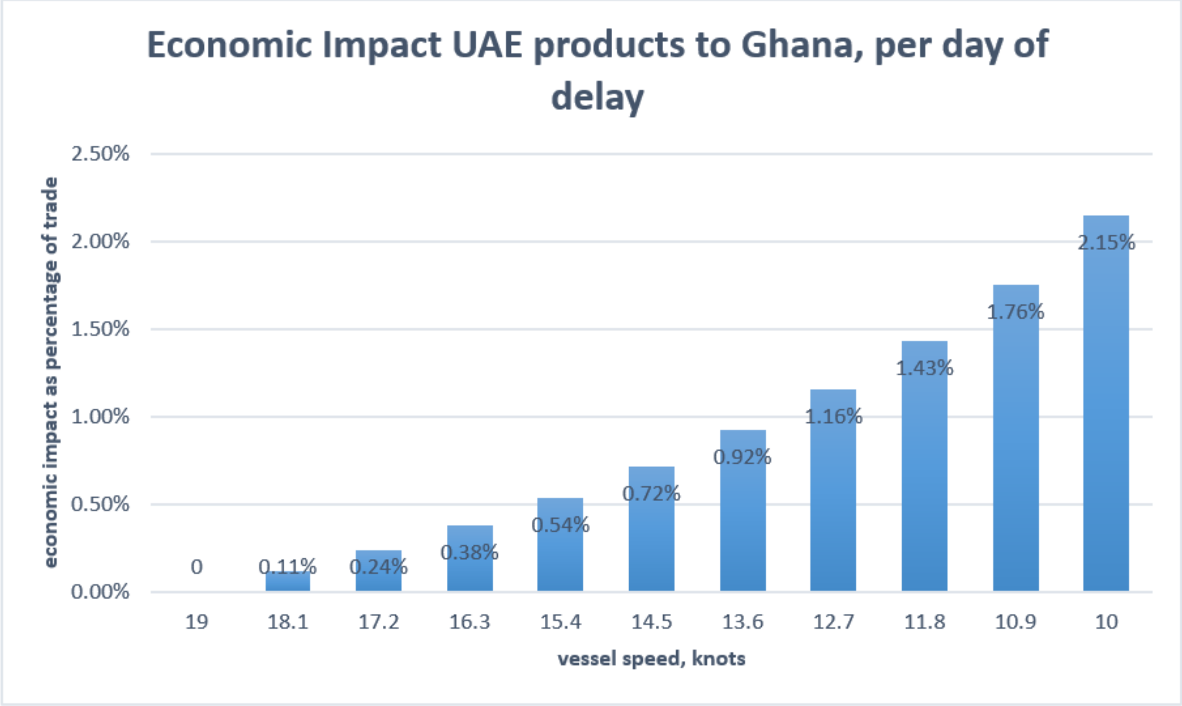
When the speed of the vessels involved in this trade are reduced from 16.6 to 10 knots for the GAS scenario, additional transit days of 2.26 to 35.77 is going to be added from UAE to Ghana in the MIDAS 1 service. This additional added transit days will result in additional cost ranging from 0.11% to 1.66% per extra travel day of delay on this route. With an average speed of 14.65 knots, the additional time is 7.40 days and an added cost of 0.34%.

Table 23: Economic impact for 2012 GAS scenario.



Matrix 3 - Containerised Cargo Vessel - UAE products to Ghana														
Ship Type	Ship size (TEU)	Number of Vessels	Total Distance	GSA Knots	GSA 1 Knots	GSA 2	GSA 3	GSA 4	GSA 5	GSA 6	GSA 7	GSA 8	GSA 9	GSA 10
Container	5466	10	22,141	16.6	15.95	15.3	14.65	14	13.35	12.7	12.05	11.4	10.75	10.1
Time delay @ different speeds					2.26	4.72	7.40	10.32	13.53	17.07	20.98	25.35	30.24	35.77
Export economy		UAE												
GDP (USD $)	2020	$ 677,770,049,297												
Port of Origin		Jebel Ali												
Economy of Destination		Ghana												
Port of Destination		Tema												
HS														
Commodity		Cars												
Service name		MIDAS1												
Export Quantity (kg)		696,469,984												
Export Value (USD $)		$ 76,300,000			ANNUAL	365.25								
UAE product export as percentage of GDP		0.0113%												
Value per kg (USD $/kg)		$ 0.11												
Export value per container ($)		$ 144,127												
Shippers' additional expenses			Economic impact of delay at different speeds											
Interest cost	5%	IC=(EV*IR)*(TD/365.25)			$ 23,656	$ 49,321	$ 77,264	$ 107,802	$ 141,314	$ 178,256	$ 219,183	$ 264,777	$ 315,885	$ 373,572
Depreciation cost	10%	DC=(EV*DR)*(TD/365.25)			$ 47,311	$ 98,643	$ 154,529	$ 215,604	$ 282,627	$ 356,511	$ 438,366	$ 529,555	$ 631,771	$ 747,144
Insurance cost	2%	Inc=(EV*InR)*(TD/365.25)			$ 9,462	$ 19,729	$ 30,906	$ 43,121	$ 56,525	$ 71,302	$ 87,673	$ 105,911	$ 126,354	$ 149,429
Total cost of waiting USD $				TOTAL	$ 80,429	$ 167,692	$ 262,699	$ 366,527	$ 480,467	$ 606,069	$ 745,222	$ 900,243	$ 1,074,011	$ 1,270,144
Percentage impact per extra travel day					0.11%	0.22%	0.34%	0.48%	0.63%	0.79%	0.98%	1.18%	1.41%	1.66%
Total cost of waiting USD $/total delay					$ 182,156	$ 791,850	$ 1,943,269	$ 3,782,942	$ 6,500,447	$ 10,343,340	$ 15,638,235	$ 22,821,071	$ 32,481,333	$ 45,427,936
Percentage impact port total delay					0.24%	1.04%	2.55%	4.96%	8.52%	13.56%	20.50%	29.91%	42.57%	59.54%

Figure 10: Economic Impact as a Percentage of Trade Value: Cars, UAE to Ghana, High Baseline Speed Scenario.



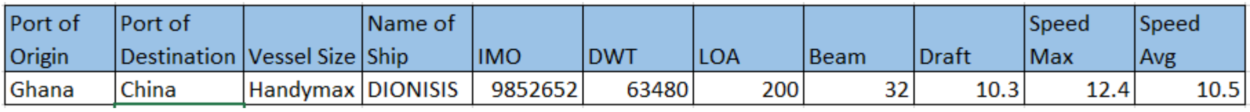
For the HBL speed scenario, slow steaming from 19 to 10 knots will lead to a delay range from 2.43 to 46.13 days in transit days. This delay will result in additional cost ranging from 0.11% to 2.15% per extra travel day of delay. The obtained results when multiplied by the number of days will yield an economic impact of 0.27% to 99.03%.

Bulk Carrier Trade Route.

4.6 Route 4 – Ghana to China trade route.

One trade flow for the dry bulk trade was selected, which is from Ghana to China. The trade route and the characteristics of the vessel selected for the route is described in table 24, 25 and figure 11.

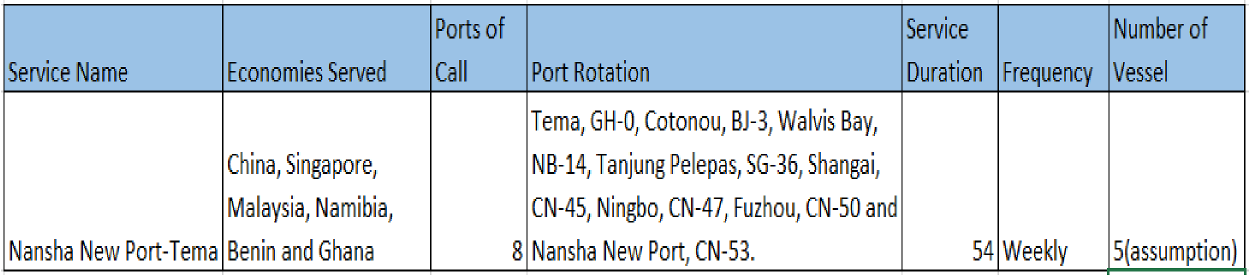
Table 24: Dry Bulk Vessel Characteristics.



Port of Origin	Port of Destination	Vessel Size	Name of Ship	IMO	DWT	LOA	Beam	Draft	Speed Max	Speed Avg
Ghana	China	Handymax	DIONISIS	9852652	63480	200	32	10.3	12.4	10.5

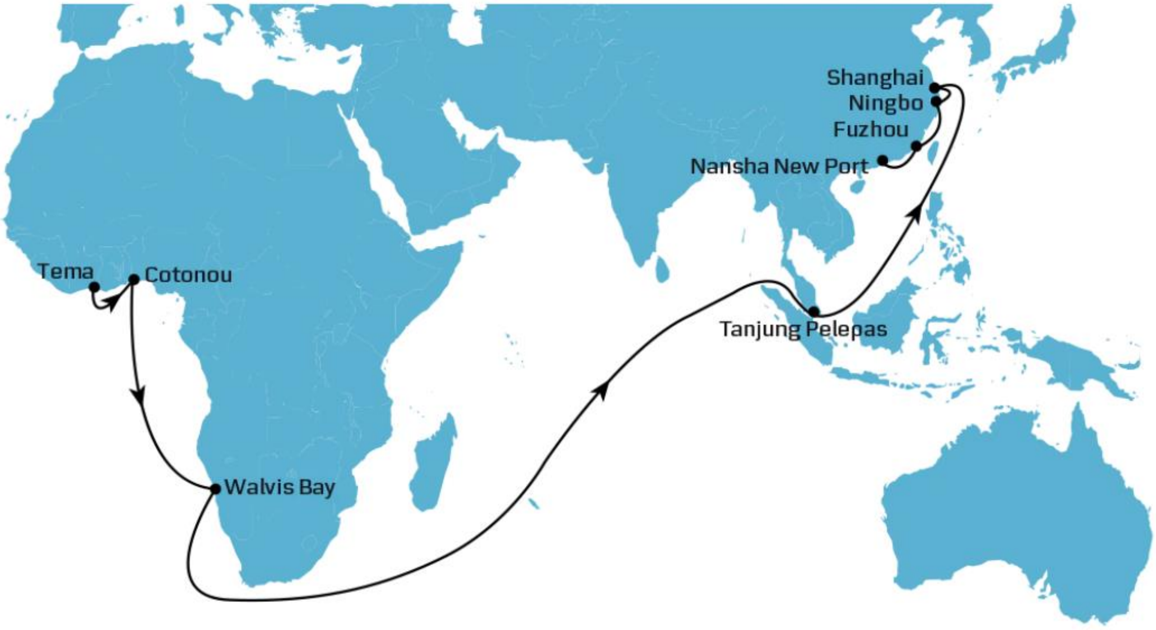
Source: https://www.vesselfinder.com/ports/GHTEM001

Table 25: FEW3 eastbound characteristics.



Service Name	Economies Served	Ports of Call	Port Rotation	Service Duration	Frequency	Number of Vessel
Nansha New Port-Tema	China, Singapore, Malaysia, Namibia, Benin and Ghana	8	Tema, GH-0, Cotonou, BJ-3, Walvis Bay, NB-14, Tanjung Pelepas, SG-36, Shangai, CN-45, Ningbo, CN-47, Fuzhou, CN-50 and Nansha New Port, CN-53.	54	Weekly	5(assumption)

Figure 11: FEW3 eastbound service rotation.



Source: https://www.maersk.com/local-information/shipping-from-africa-to-asia-pacific/few3-eastbound

4.6.1 Emission impact analysis – route 4.

For the ship type and size combinations for the handymax bulk carrier trade, the ships operating on this route covers a distance of 11,415nm. To analyze the emissions impact from the vessels in this route, a range of distances were considered. The shortest distance is 300nm, the intermediate distances are 1,300nm, 3,300nm and 7,500nm and the longest distance is 9,000nm. The speed range is from 11.8 to 10knots with reducing intervals of 0.18. The analysis is carried out through the 13 matrices for the five distances from 300nm to 9,000nm. Calculations for the propulsion, auxiliary and boilers are tabulated to provide the work done for the 5 ships in the fleet for this route. From these tabulations the percentage of net fleet CO_2e emission changes is provided in matrix 13 in the excel file. For distance 1, which is the shortest, the emissions benefits obtained ranges from -6.6% to -49.8% which corresponds to the speed reduction from 11.8 to 10 knots. This indicates that for this distance as the speed reduces, the emission benefit also increases. For example, at a reduced speed of 10.9 knots, a percentage reduction of -29.1% is gained in emissions. For the longest distance which is 9,000nm, the benefits obtained ranges from -5.2% to -40.7%

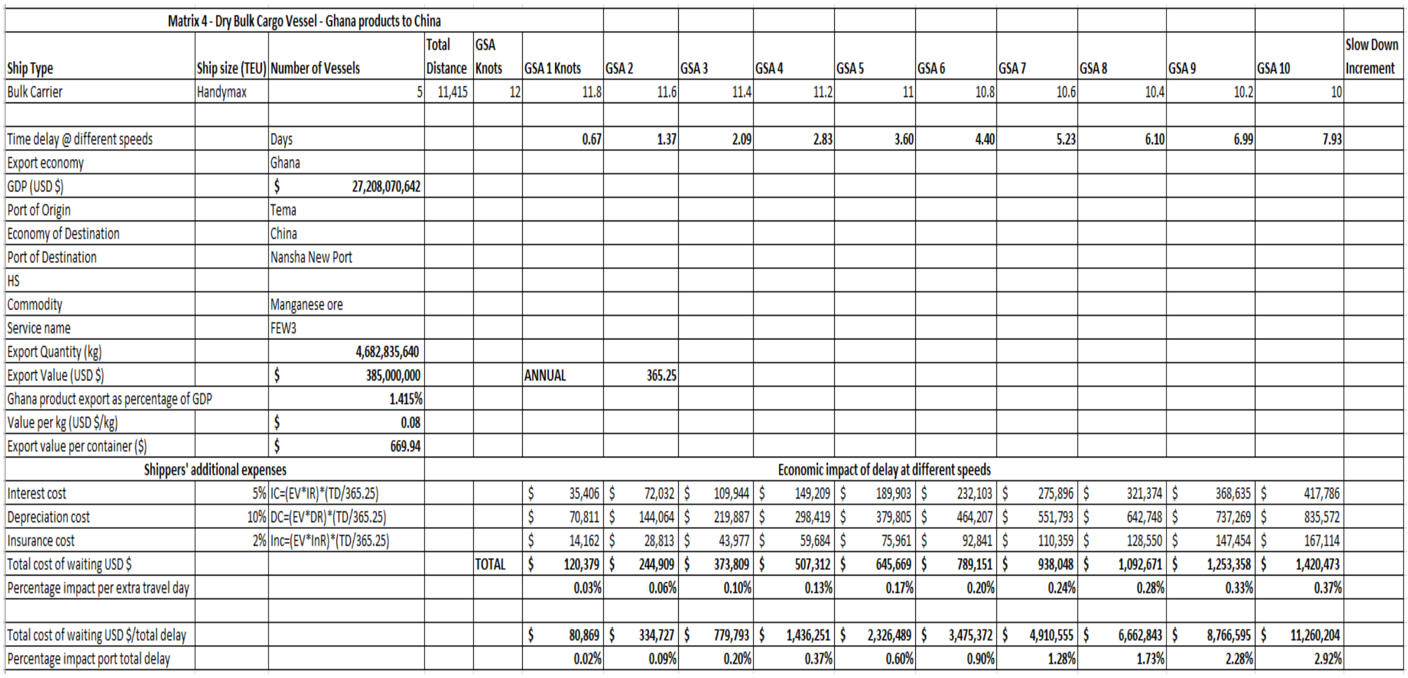
which corresponds to the speed reduction from 11.8 to 10knots. Table 7 and 8 shows the illustration of the results obtained for distance 1 and 5 for the 2012 GAS scenario.

To further examine the impact of speed reduction on the fleet operating on this route, the same analysis is conduct for the HBL speed scenario. The speed range considered in this scenario is from 12.0 to 10knots with reduction intervals of 0.20. The same tabulation is carried out through the 13 matrices with this range of speeds. This is to help compare the emission benefits with the 2012 GAS scenario. For distance 1, which is the shortest distance, the emission benefits obtained ranges from -7.3% to -53.4% which corresponds to the reduced speeds from 12.0 to 10knots. This indicates that for this distance as speed reduces, the emission benefits increase. At a reduced speed of 11.0knots, a percentage of -31.7% is gained in emissions. For the longest distance 10,000nm, the benefits obtained ranges from -5.7% to -44.1% which corresponds to the speed range from 12.0 to 10knots. Table 9 and 10 shows the illustration of the results obtained for distance 1 and 5 for the HBL scenario.

4.6.2 Economic impact analysis – route 4 – Ghana to China (Manganese ore)

Ghana exports manganese ore to China, which amounts to USD 385M of Ghana's GDP (UN Comtrade database, n.d). The economic impacts resulting from the high baseline speed scenario were evaluated from 12 to 10knots for this trade. As a result of slow steaming, the total voyage time will increase by 0.67 to 7.93 transit days and interest, depreciation and insurance will add from 0.03 to 0.37 per extra travel day for all manganese ore exports from Ghana to China in 2019.

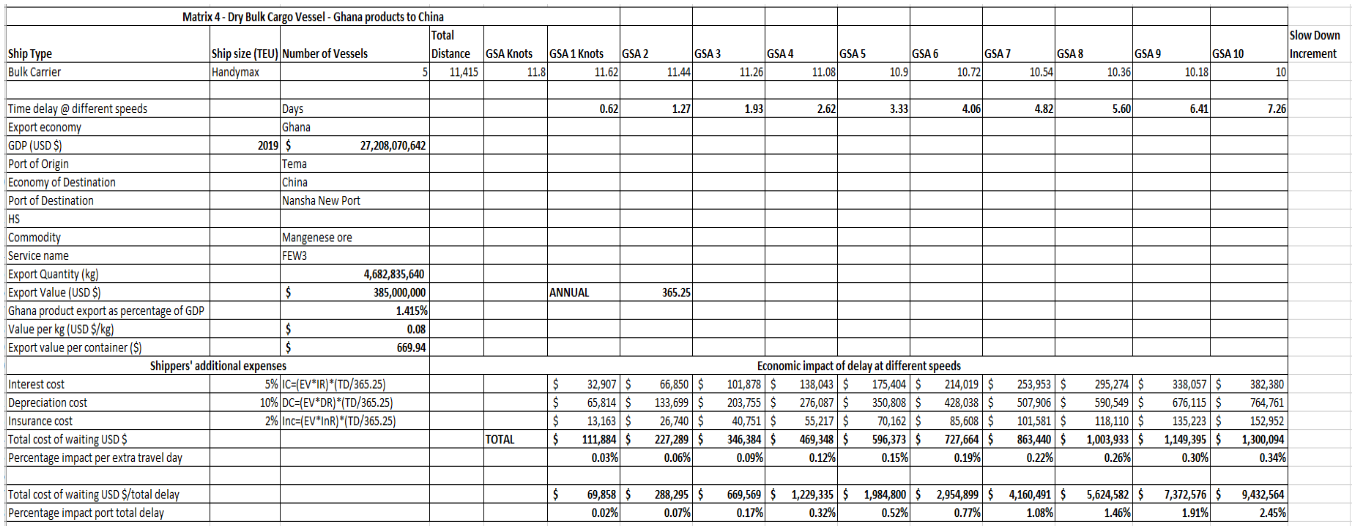
Table 26: Economic impact for HBL speed scenario.



Matrix 4 - Dry Bulk Cargo Vessel - Ghana products to China															
Ship Type	Ship size (TEU)	Number of Vessels	Total Distance	GSA Knots	GSA 1 Knots	GSA 2	GSA 3	GSA 4	GSA 5	GSA 6	GSA 7	GSA 8	GSA 9	GSA 10	Slow Down Increment
Bulk Carrier	Handymax	5	11,415	12	11.8	11.6	11.4	11.2	11	10.8	10.6	10.4	10.2	10	
Time delay @ different speeds		Days			0.67	1.37	2.09	2.83	3.60	4.40	5.23	6.10	6.99	7.93	
Export economy		Ghana													
GDP (USD $)		$ 27,208,070,642													
Port of Origin		Tema													
Economy of Destination		China													
Port of Destination		Nansha New Port													
HS															
Commodity		Manganese ore													
Service name		FEW3													
Export Quantity (kg)		4,682,835,640													
Export Value (USD $)		$ 385,000,000			ANNUAL	365.25									
Ghana product export as percentage of GDP		1.415%													
Value per kg (USD $/kg)		$ 0.08													
Export value per container ($)		$ 669.94													
Shippers' additional expenses			Economic impact of delay at different speeds												
Interest cost	5%	IC=(EV*IR)*(TD/365.25)			$ 35,406	$ 72,032	$ 109,944	$ 149,209	$ 189,903	$ 232,103	$ 275,896	$ 321,374	$ 368,635	$ 417,786	
Depreciation cost	10%	DC=(EV*DR)*(TD/365.25)			$ 70,811	$ 144,064	$ 219,887	$ 298,419	$ 379,805	$ 464,207	$ 551,793	$ 642,748	$ 737,269	$ 835,572	
Insurance cost	2%	Inc=(EV*InR)*(TD/365.25)			$ 14,162	$ 28,813	$ 43,977	$ 59,684	$ 75,961	$ 92,841	$ 110,359	$ 128,550	$ 147,454	$ 167,114	
Total cost of waiting USD $				TOTAL	$ 120,379	$ 244,909	$ 373,809	$ 507,312	$ 645,669	$ 789,151	$ 938,048	$ 1,092,671	$ 1,253,358	$ 1,420,473	
Percentage impact per extra travel day					0.03%	0.06%	0.10%	0.13%	0.17%	0.20%	0.24%	0.28%	0.33%	0.37%	
Total cost of waiting USD $/total delay					$ 80,869	$ 334,727	$ 779,793	$ 1,436,251	$ 2,326,489	$ 3,475,372	$ 4,910,555	$ 6,662,843	$ 8,766,595	$ 11,260,204	
Percentage impact port total delay					0.02%	0.09%	0.20%	0.37%	0.60%	0.90%	1.28%	1.73%	2.28%	2.92%	

When the speed of the vessels involved in this trade are reduced from 11.8 to 10 knots for the GAS scenario, additional transit days of 0.62 to 7.26 is going to be added from Ghana to China in the FEW3 service. This additional added transit days will result in additional cost ranging from 0.03% to 0.34% per extra travel day of delay on this route. With an average speed of 10.9 knots, the additional time is 3.33 days and an added cost of 0.15%.

Table 27: Economic impact for 2012 GAS scenario.



Matrix 4 - Dry Bulk Cargo Vessel - Ghana products to China															
Ship Type	Ship size (TEU)	Number of Vessels	Total Distance	GSA Knots	GSA 1 Knots	GSA 2	GSA 3	GSA 4	GSA 5	GSA 6	GSA 7	GSA 8	GSA 9	GSA 10	Slow Down Increment
Bulk Carrier	Handymax	5	11,415	11.8	11.62	11.44	11.26	11.08	10.9	10.72	10.54	10.36	10.18	10	
Time delay @ different speeds		Days			0.62	1.27	1.93	2.62	3.33	4.06	4.82	5.60	6.41	7.26	
Export economy		Ghana													
GDP (USD $)	2019	$ 27,208,070,642													
Port of Origin		Tema													
Economy of Destination		China													
Port of Destination		Nansha New Port													
HS															
Commodity		Mangenese ore													
Service name		FEW3													
Export Quantity (kg)		4,682,835,640													
Export Value (USD $)		$ 385,000,000			ANNUAL	365.25									
Ghana product export as percentage of GDP		1.415%													
Value per kg (USD $/kg)		$ 0.08													
Export value per container ($)		$ 669.94													
Shippers' additional expenses			Economic impact of delay at different speeds												
Interest cost	5%	IC=(EV*IR)*(TD/365.25)			$ 32,907	$ 66,850	$ 101,878	$ 138,043	$ 175,404	$ 214,019	$ 253,953	$ 295,274	$ 338,057	$ 382,380	
Depreciation cost	10%	DC=(EV*DR)*(TD/365.25)			$ 65,814	$ 133,699	$ 203,755	$ 276,087	$ 350,808	$ 428,038	$ 507,906	$ 590,549	$ 676,115	$ 764,761	
Insurance cost	2%	Inc=(EV*InR)*(TD/365.25)			$ 13,163	$ 26,740	$ 40,751	$ 55,217	$ 70,162	$ 85,608	$ 101,581	$ 118,110	$ 135,223	$ 152,952	
Total cost of waiting USD $				TOTAL	$ 111,884	$ 227,289	$ 346,384	$ 469,348	$ 596,373	$ 727,664	$ 863,440	$ 1,003,933	$ 1,149,395	$ 1,300,094	
Percentage impact per extra travel day					0.03%	0.06%	0.09%	0.12%	0.15%	0.19%	0.22%	0.26%	0.30%	0.34%	
Total cost of waiting USD $/total delay					$ 69,858	$ 288,295	$ 669,569	$ 1,229,335	$ 1,984,800	$ 2,954,899	$ 4,160,491	$ 5,624,582	$ 7,372,576	$ 9,432,564	
Percentage impact port total delay					0.02%	0.07%	0.17%	0.32%	0.52%	0.77%	1.08%	1.46%	1.91%	2.45%	

Figure 12: Economic Impact as a Percentage of Trade Value: Manganese ore, Ghana to China, High Baseline Speed Scenario.

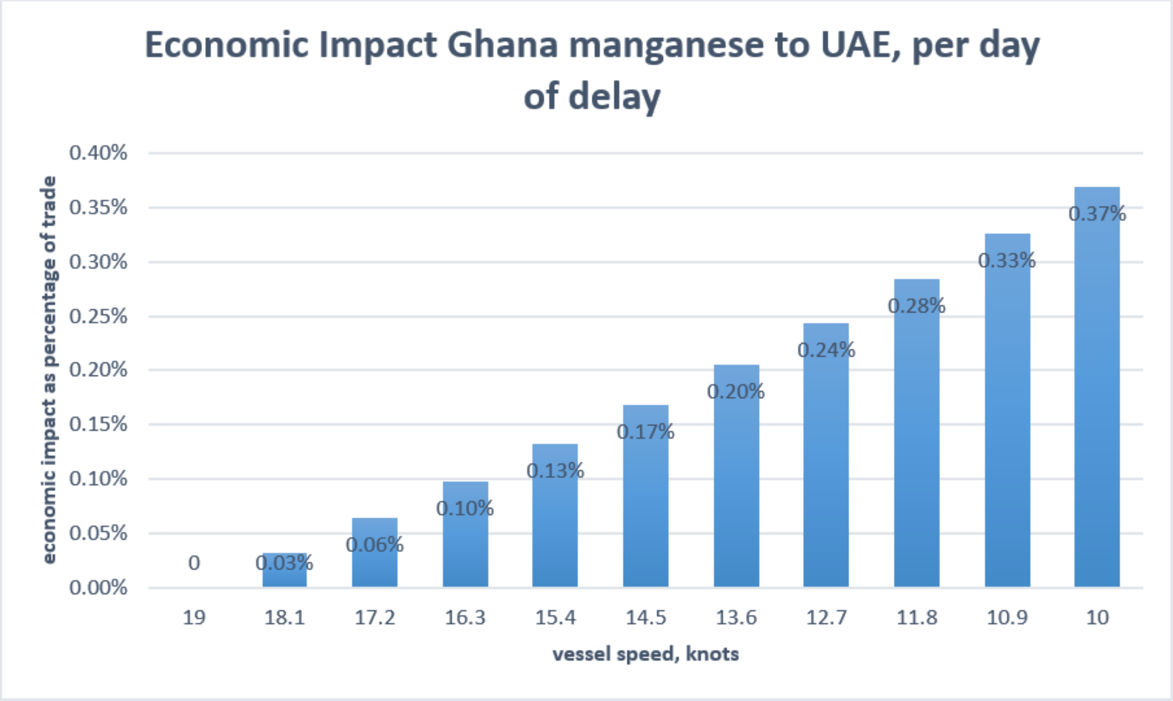


Figure 12 indicates that the economic impact per day of delay over 2019 Ghanaian manganese ore export trade value to China ranges from 0.03% per day, when reducing speed from 12 to 11.8 knots, or 0.37 per day of total value when reducing speed from 12 to 10 knots. The economic impact model was also run using the 2012 GAS Scenario. Total voyage time will increase by 0.62 to 7.26 transit days and the interest cost, depreciation and insurance will add from 0.03% to 0.37% per extra day for all manganese ore exports from Ghana to China in 2019.

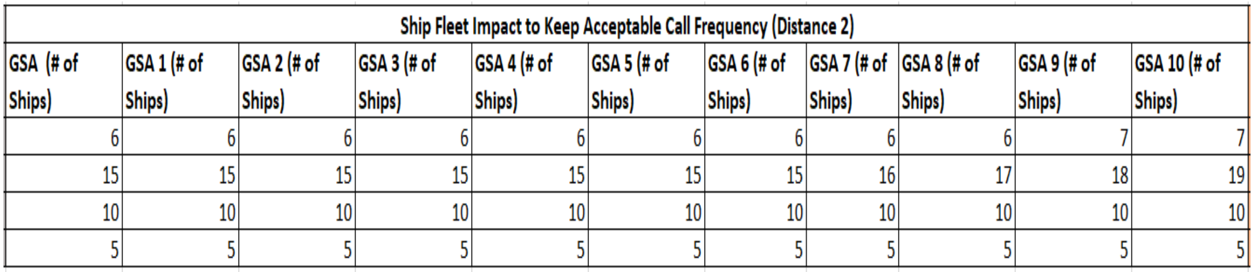
4.7 Additional ships analysis.

This section will discuss the additional ships required for distances 1, 2 and 5 and the ship type and size combinations analyzed. This will help identify the speeds at which ships will be needed to keep the frequency calls of the fleet at the ports. Presentations for the 2012 GAS and HBL speed scenario will be provided as tables as part of the discussions.

4.7.1 2012 GAS scenario for additional ships.

For distance 1, under the 2012 GAS scenario there will not be a need for additional ships to the fleet. The need for additional ships is reflected from the intermediate and the longest distances.

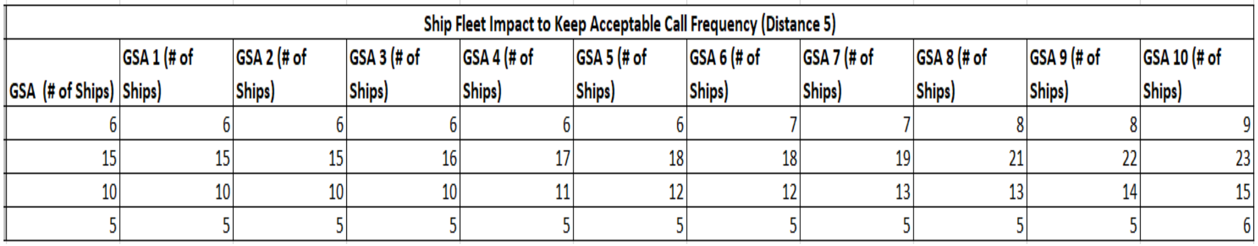
Table 28: Additional ships needed for distance 2.



Ship Fleet Impact to Keep Acceptable Call Frequency (Distance 2)										
GSA (# of Ships)	GSA 1 (# of Ships)	GSA 2 (# of Ships)	GSA 3 (# of Ships)	GSA 4 (# of Ships)	GSA 5 (# of Ships)	GSA 6 (# of Ships)	GSA 7 (# of Ships)	GSA 8 (# of Ships)	GSA 9 (# of Ships)	GSA 10 (# of Ships)
6	6	6	6	6	6	6	6	6	7	7
15	15	15	15	15	15	15	16	17	18	19
10	10	10	10	10	10	10	10	10	10	10
5	5	5	5	5	5	5	5	5	5	5

For the intermediate distances from 1800nm, additional ships will be needed at 10.45 and 10knots which are GSA 9 and 10. One ship each will be required at 10.45 and 10knots for the 4000TEU container vessels fleet. Therefore, for the UK to Ghana route trade for used cloths, an additional ship will be required at speeds 10.45 and 10knots to support the fleet to maintain call frequency. For the 5000TEU container vessels, for a distance 2800nm, additional ships will be required from speed 12.7 to 10knots which is GSA 7 to 10. The number of ships required will range from 1 to 4 as the speed reduces from 12.7 to 10knots. This also means that for the Ghana to China trade route for cocoa beans there will be a need for 1 to 4 ships as the speed reduces. And for the 6000TEU container vessels, for a distance of 1400nm, additional ships will not be required and the same applies for the handymax carrier. This implies that for the UAE to Ghana for cars and Ghana to China trade route for manganese ore there will not be a need for additional ships to maintain the call frequency.

Table 29: Additional ships needed for distance 5.



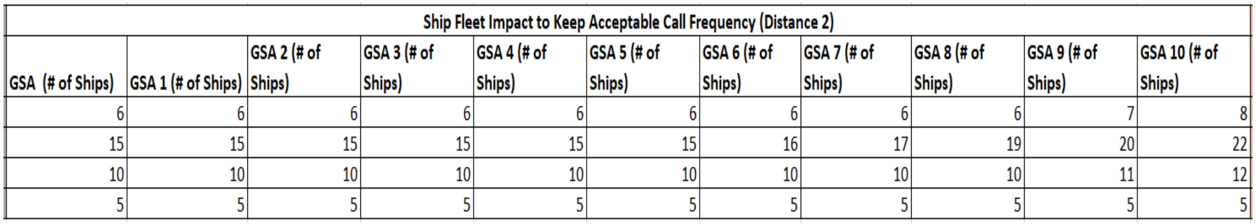
Ship Fleet Impact to Keep Acceptable Call Frequency (Distance 5)										
GSA (# of Ships)	GSA 1 (# of Ships)	GSA 2 (# of Ships)	GSA 3 (# of Ships)	GSA 4 (# of Ships)	GSA 5 (# of Ships)	GSA 6 (# of Ships)	GSA 7 (# of Ships)	GSA 8 (# of Ships)	GSA 9 (# of Ships)	GSA 10 (# of Ships)
6	6	6	6	6	6	7	7	8	8	9
15	15	15	16	17	18	18	19	21	22	23
10	10	10	10	11	12	12	13	13	14	15
5	5	5	5	5	5	5	5	5	5	6

For the intermediate distances from 5000nm, additional ships will be needed at 11.1, 10.45 and 10knots which are GSA 8, 9 and 10. One ship each will be required at 11.1, 10.45 and 2 ships at 10knots for the 4000TEU container vessels fleet. Therefore, for the UK to Ghana route trade for used cloths, an additional ship will be required at speeds 11.1, 10.45 and 10knots to support the fleet to maintain call frequency. For the 5000TEU container vessels, for a distance of 13,000nm, additional ships will be required from speed 14.65 to 10knots which is GSA 3 to 10. The number of ships required will range from 1 to 8 ships as the speed reduces from 14.65 to 10knots. This also means that for the Ghana to China trade route for cocoa beans there will be a need for 1 to 8 ships as the speed reduces. And for the 6000TEU container vessels, for a distance of 1400nm, the additional ships required will range from 1 to 5 ships from speed 14 to 10knots and for the handymax carrier trade route one ship is required at speed 10knots. This implies that for the UAE to Ghana for cars, one to 5 ships will be needed and Ghana to China trade route for manganese ore, one ship is needed as additional ships to maintain the call frequency.

4.7.2 HBL speed scenario for additional ships.

For distance 1, under the HBL speed scenario there will not be a need for additional ships to the fleet. The need for additional ships is reflected from the intermediate and the longest distances.

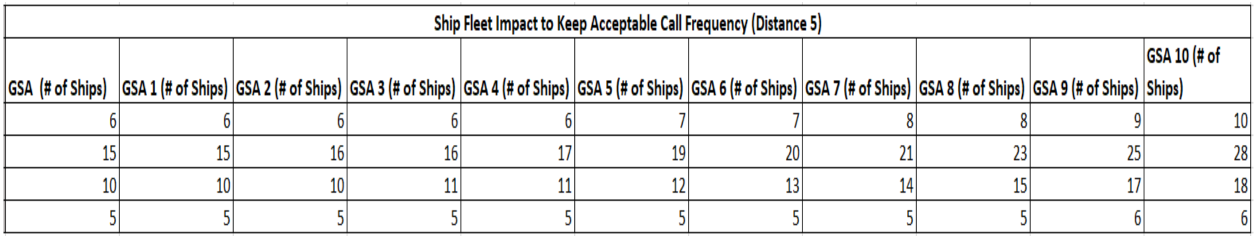
Table 30: Additional ships needed for distance 2.



Ship Fleet Impact to Keep Acceptable Call Frequency (Distance 2)										
GSA (# of Ships)	GSA 1 (# of Ships)	GSA 2 (# of Ships)	GSA 3 (# of Ships)	GSA 4 (# of Ships)	GSA 5 (# of Ships)	GSA 6 (# of Ships)	GSA 7 (# of Ships)	GSA 8 (# of Ships)	GSA 9 (# of Ships)	GSA 10 (# of Ships)
6	6	6	6	6	6	6	6	6	7	8
15	15	15	15	15	15	16	17	19	20	22
10	10	10	10	10	10	10	10	10	11	12
5	5	5	5	5	5	5	5	5	5	5

For the intermediate distances of 1800nm, additional ships will be needed at 10.45 and 10knots which are GSA 9 and 10. One ship will be required at 10.45 and 2 ships at 10knots for the 4000TEU container vessels fleet. Therefore, for the UK to Ghana route trade for used cloths, an additional ship will be required at speeds 10.45 and 10knots to support the fleet to maintain call frequency. For the 5000TEU container vessels, for a distance 2800nm, additional ships will be required from speed 14 to 10knots which is GSA 6 to 10. The number of ships required will range from 1 to 7 as the speed reduces from 14 to 10knots. This also means that for the Ghana to China trade route for cocoa beans there will be a need for 1 to 7 ships as the speed reduces. And for the 6000TEU container vessels, for a distance of 1400nm, 1 to 2 additional ships will be required and for the handymax carrier there will not be a need for additional ships. This implies that for the UAE to Ghana for cars there will be a need for 1 to 2 ships and Ghana to China trade route for manganese ore there will not be a need for additional ships to maintain the call frequency.

Table 31: Additional ships needed for distance 5.



Ship Fleet Impact to Keep Acceptable Call Frequency (Distance 5)										
GSA (# of Ships)	GSA 1 (# of Ships)	GSA 2 (# of Ships)	GSA 3 (# of Ships)	GSA 4 (# of Ships)	GSA 5 (# of Ships)	GSA 6 (# of Ships)	GSA 7 (# of Ships)	GSA 8 (# of Ships)	GSA 9 (# of Ships)	GSA 10 (# of Ships)
6	6	6	6	6	7	7	8	8	9	10
15	15	16	16	17	19	20	21	23	25	28
10	10	10	11	11	12	13	14	15	17	18
5	5	5	5	5	5	5	5	5	6	6

For the intermediate distance of 5000nm, additional ships will be needed from 14.5 to 10knots which are GSA 5 to 10. One to 4 ships will be required from speed 14.5 to 10knots for the 4000TEU container vessels fleet. Therefore, for the UK to Ghana route trade for used cloths, additional ships from 1 to 4 will be required from speeds 14.5 to 10knots to support the fleet to maintain call frequency. For the 5000TEU container vessels, for a distance of 13,000nm, additional ships will be required from speed 18 to 10knots which is GSA 2 to 10. The number of ships required will range from 1 to 13 ships as the speed reduces from 18 to 10knots. This also means that for the Ghana to China trade route for cocoa beans there will be a need for 1 to 13 ships as the speed reduces. And for the 6000TEU container vessels, for a distance of 10,000nm, the additional ships required will range from 1 to 8 ships from speed 17 to 10knots and for the handymax carrier trade route one ship each is required at speed 10.2 and 10knots. This implies that for the UAE to Ghana for cars a number of 1 to 8 ships will be needed and Ghana to China trade route for manganese ore, one to 2 ships are needed as additional ships to maintain the call frequency.

4.8 Summary of results from case study.

From the 4 routes analyzed, slow steaming will have both beneficial and unbeneficial effects depending on the speed, distances and cargo carried by the fleet in consideration. At certain speeds slow steaming will yield environmental and economic benefits for ship owners and shippers. However, when speed goes beyond certain low speeds the benefits decrease. The reason for this is the additional ships which are required to support the current fleet to maintain the normal supply of goods and services to shippers. Also when the speeds are too low the cost on transport will increase because of the time delay and bunker cost for the delay.

The shorter distance for the 4 routes considered did not result in additional ships for the fleet. And also, the size of the ship determines the need for additional ships. More ships were need as addition to the 5000TEU which covers 6500nm than the 6000TEU which covers 6500nm for distance 3. The deduction can be that when the capacity of the ship is large enough to carry required cargo, the need for additional ships is reduced.

CHAPTER 5 – CONCLUSION AND RECOMMMENDATIONS

5.1 Conclusions

The research focused on assessing the impact of speed reduction on Ghana's maritime trade when speed reduction is adopted for ships. This was done to estimate the suitable speeds at which maritime trade will not be affected. To achieve this, two models were employed using excel. The first model which is the emission model was used to calculate the total emissions in percentage. Calculations for emissions was done for four different routes and the number of ships deployed on that route and also what number of ships will be needed to meet normal call frequency. The second model which is the economic model was used to estimate the delay as a result of slow steaming and its effect on the economy of the countries involved. Two different speed ranges were investigated, the 2012 GAS and the HBL speed scenarios. The GAS scenario considered speeds ranging from 16.6 to 10knots and the HBL speed scenario considered speeds ranging from 20 to 10knots. Comparison of the two speed scenarios was conducted to give a clear understanding of the impact of speed reduction on the container vessel and bulk carrier fleet operating on the selected routes. The input data used for the calculations were obtained from the 4th IMO GHG study, CMA CGM, Maersk webpages and so on. The two models were applied to ships operating on routes serving Ghana, the United Kingdom, United Arab Emirates and China. The two ship types and sizes considered are container of 4000TEU, 5000TEU, 6000TEU and the handymax bulk carrier.

The study has shown that if slow steaming is adopted in 2023 as a short-term measure under EEXI, the impact on Ghana's trade will be dependent on the speed at which the vessels will be sailing at. In addition, at certain speeds within the selected range of 20 to 10knots, slow steaming will give environmental and economic gains. However, at too low reduced speeds the gains start to decrease due to the additional ships and delay time for the routes selected. Finally, the adoption of slow steaming for ships will be a good step to help achieve the IMO's goal of attaining emission reductions. In summary the research found the following:

a. Because the distance between Ghana and these economies are far, there could be a negative impact on the economy and environment when slow steaming is adopted. Considering the longest distance for the routes selected, there will be additional ships ranging from 1 to 8 as speed reduces.

This will mean more emissions and also an increase in transport cost. If speed is reduced for the UK to Ghana route from 16.3 to 12.4knots an increase of 0.39% is expected in insurance, depreciation and interest cost which may be absorbed by Ghanaian shippers.

b. For the Ghana to China route were cocoa beans is exported, the impact to Ghana is more due to the additional days to the voyage. When speed reduces from 16.6 to 14knots leading to additional days of 11days for the 2012 GAS scenario, an increase of 1.11% is expected in interest, insurance and depreciation cost. Cocoa beans is perishable and goes bad when not preserved well, this increase is due to the interest rate of 30% assumed for the product.

c. The impact of speed reduction on emission is more on the container vessels than the bulk carriers. The benefits in emission reduction for the container vessels were high than compared to the bulk carriers.

5.2 Recommendations

The research has shown that the SSA model can help countries know the speeds at which they can have economic and environmental benefits. This can help decision makers to settle on a suitable speed for the ships in operation and also support the efforts towards emission reductions which is a good step in saving our planet from global warming and climate change.

The following are recommended:

a. Ghana should make policy proposal to the IMO stating the effect of some slower speeds on Ghana’s maritime trade and shippers.

b. The methodology should be applied to other ship types serving Ghana to give a general overview of the impact of slower speeds on the economy and maritime stakeholders.

c. Further economic impact analysis on Ghana’s economy and products as a result of slow steaming can be carried out. The focus can be on taxes, infrastructure, employment and so on.

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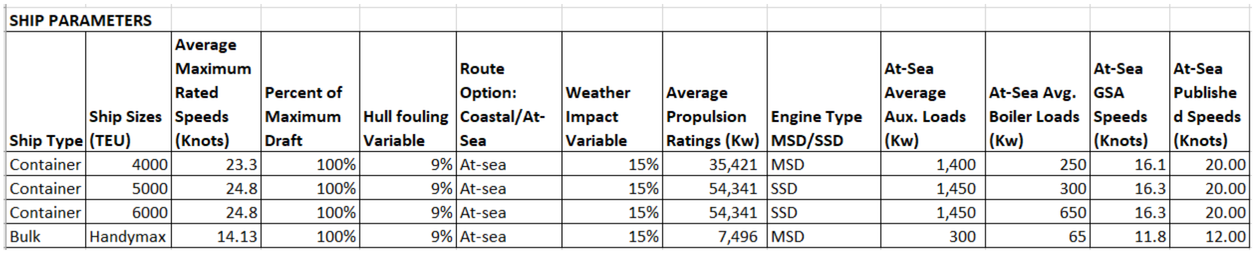
APPENDIX

The parameters for analysing slow steaming and obtained results for 2012 GAS scenario is shown in appendix 1.

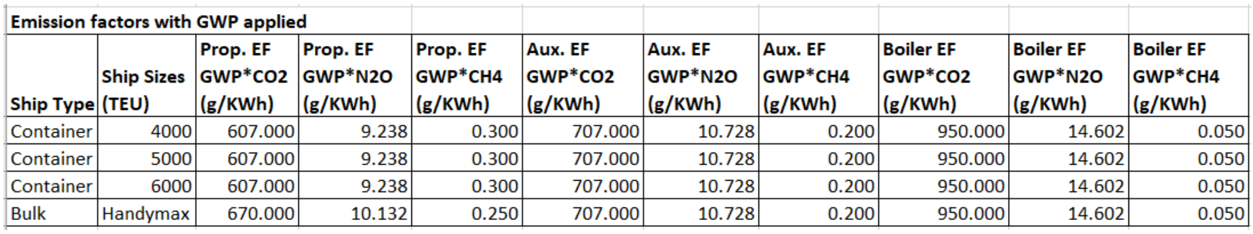
Appendix 1: Ship Parameter Inputs.



SHIP PARAMETERS												
Ship Type	**Ship Sizes (TEU)**	**Average Maximum Rated Speeds (Knots)**	**Percent of Maximum Draft**	**Hull fouling Variable**	**Route Option: Coastal/At-Sea**	**Weather Impact Variable**	**Average Propulsion Ratings (Kw)**	**Engine Type MSD/SSD**	**At-Sea Average Aux. Loads (Kw)**	**At-Sea Avg. Boiler Loads (Kw)**	**At-Sea GSA Speeds (Knots)**	**At-Sea Published Speeds (Knots)**
Container	4000	23.3	100%	9%	At-sea	15%	35,421	MSD	1,400	250	16.1	20.00
Container	5000	24.8	100%	9%	At-sea	15%	54,341	SSD	1,450	300	16.3	20.00
Container	6000	24.8	100%	9%	At-sea	15%	54,341	SSD	1,450	650	16.3	20.00
Bulk	Handymax	14.13	100%	9%	At-sea	15%	7,496	MSD	300	65	11.8	12.00

The emission factor inputs are shown in appendix 2.

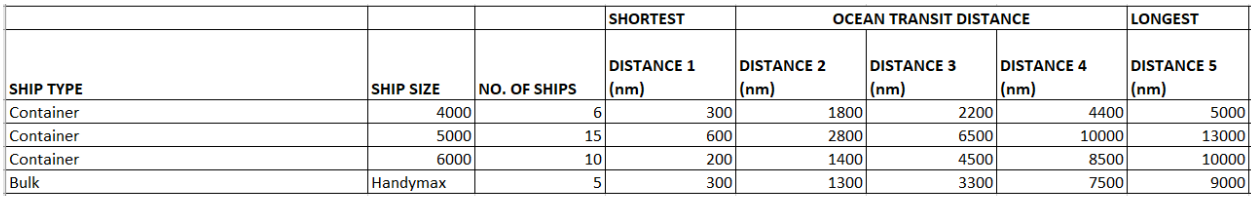
Appendix 2: Emission Factor Inputs.



Emission factors with GWP applied										
Ship Type	**Ship Sizes (TEU)**	**Prop. EF GWP*CO2 (g/KWh)**	**Prop. EF GWP*N2O (g/KWh)**	**Prop. EF GWP*CH4 (g/KWh)**	**Aux. EF GWP*CO2 (g/KWh)**	**Aux. EF GWP*N2O (g/KWh)**	**Aux. EF GWP*CH4 (g/KWh)**	**Boiler EF GWP*CO2 (g/KWh)**	**Boiler EF GWP*N2O (g/KWh)**	**Boiler EF GWP*CH4 (g/KWh)**
Container	4000	607.000	9.238	0.300	707.000	10.728	0.200	950.000	14.602	0.050
Container	5000	607.000	9.238	0.300	707.000	10.728	0.200	950.000	14.602	0.050
Container	6000	607.000	9.238	0.300	707.000	10.728	0.200	950.000	14.602	0.050
Bulk	Handymax	670.000	10.132	0.250	707.000	10.728	0.200	950.000	14.602	0.050

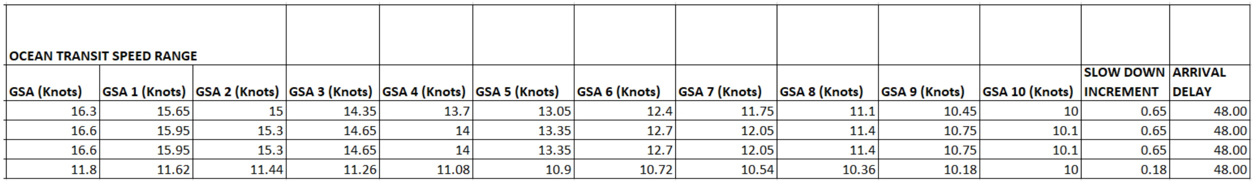
The initial set of inputs are shown in appendix 3.

Appendix 3: Ship Fleet and Distance Inputs.



			SHORTEST	**OCEAN TRANSIT DISTANCE**			**LONGEST**
SHIP TYPE	**SHIP SIZE**	**NO. OF SHIPS**	**DISTANCE 1 (nm)**	**DISTANCE 2 (nm)**	**DISTANCE 3 (nm)**	**DISTANCE 4 (nm)**	**DISTANCE 5 (nm)**
Container	4000	6	300	1800	2200	4400	5000
Container	5000	15	600	2800	6500	10000	13000
Container	6000	10	200	1400	4500	8500	10000
Bulk	Handymax	5	300	1300	3300	7500	9000

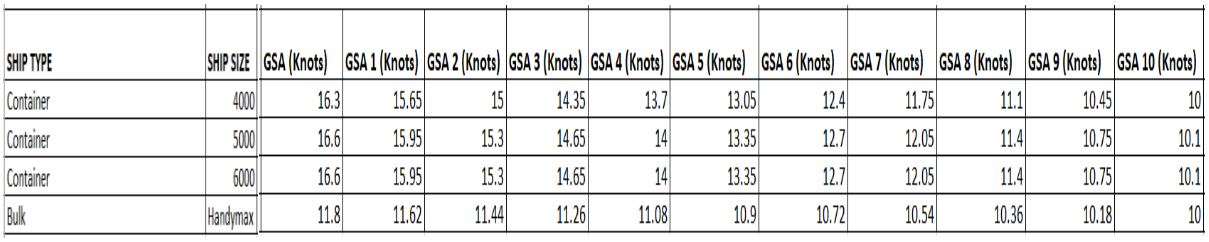
Appendix 4: Baseline Speed and Operational Inputs.



OCEAN TRANSIT SPEED RANGE												
GSA (Knots)	**GSA 1 (Knots)**	**GSA 2 (Knots)**	**GSA 3 (Knots)**	**GSA 4 (Knots)**	**GSA 5 (Knots)**	**GSA 6 (Knots)**	**GSA 7 (Knots)**	**GSA 8 (Knots)**	**GSA 9 (Knots)**	**GSA 10 (Knots)**	**SLOW DOWN INCREMENT**	**ARRIVAL DELAY**
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	10	0.65	48.00
16.6	15.95	15.3	14.65	14	13.35	12.7	12.05	11.4	10.75	10.1	0.65	48.00
16.6	15.95	15.3	14.65	14	13.35	12.7	12.05	11.4	10.75	10.1	0.65	48.00
11.8	11.62	11.44	11.26	11.08	10.9	10.72	10.54	10.36	10.18	10	0.18	48.00

An example of the results obtained from the SSA model for the 2012 Global Speed Average scenario is shown in Appendix 5.

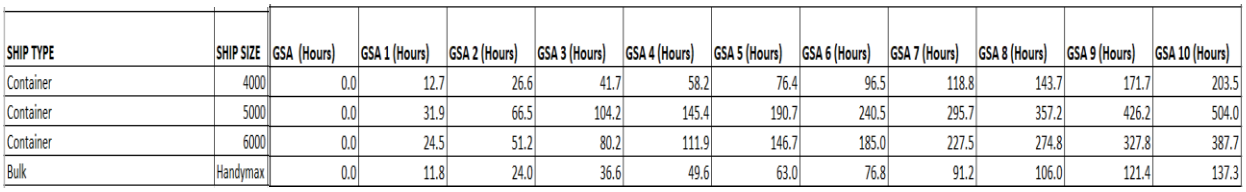
Appendix 5: Matrix 2- Display Results for At-Sea Transit Times (Distance 5).



SHIP TYPE	SHIP SIZE	GSA (Knots)	GSA 1 (Knots)	GSA 2 (Knots)	GSA 3 (Knots)	GSA 4 (Knots)	GSA 5 (Knots)	GSA 6 (Knots)	GSA 7 (Knots)	GSA 8 (Knots)	GSA 9 (Knots)	GSA 10 (Knots)
Container	4000	16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	10
Container	5000	16.6	15.95	15.3	14.65	14	13.35	12.7	12.05	11.4	10.75	10.1
Container	6000	16.6	15.95	15.3	14.65	14	13.35	12.7	12.05	11.4	10.75	10.1
Bulk	Handymax	11.8	11.62	11.44	11.26	11.08	10.9	10.72	10.54	10.36	10.18	10

An example of the results from the SSA model for 2012 Global Speed Average scenario is provided in Appendix 6.

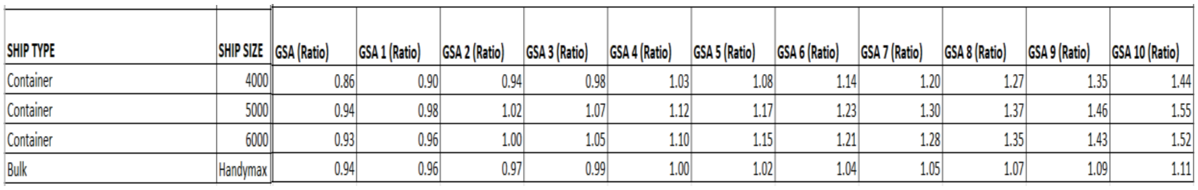
Appendix 6: Matrix 3- Display for Ship Time Delay (Distance 5).



SHIP TYPE	SHIP SIZE	GSA (Hours)	GSA 1 (Hours)	GSA 2 (Hours)	GSA 3 (Hours)	GSA 4 (Hours)	GSA 5 (Hours)	GSA 6 (Hours)	GSA 7 (Hours)	GSA 8 (Hours)	GSA 9 (Hours)	GSA 10 (Hours)
Container	4000	0.0	12.7	26.6	41.7	58.2	76.4	96.5	118.8	143.7	171.7	203.5
Container	5000	0.0	31.9	66.5	104.2	145.4	190.7	240.5	295.7	357.2	426.2	504.0
Container	6000	0.0	24.5	51.2	80.2	111.9	146.7	185.0	227.5	274.8	327.8	387.7
Bulk	Handymax	0.0	11.8	24.0	36.6	49.6	63.0	76.8	91.2	106.0	121.4	137.3

An example of the results from the SSA model for the 2012 Global Average Speed scenario is shown in Appendix 7.

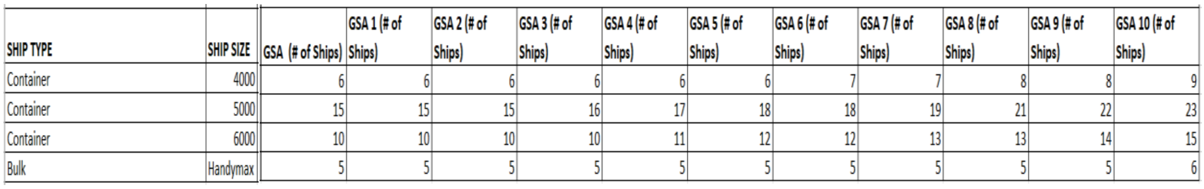
Appendix 7: Matrix 4 – Ship Delay Impact Ratio (Distance 5).



SHIP TYPE	SHIP SIZE	GSA (Ratio)	GSA 1 (Ratio)	GSA 2 (Ratio)	GSA 3 (Ratio)	GSA 4 (Ratio)	GSA 5 (Ratio)	GSA 6 (Ratio)	GSA 7 (Ratio)	GSA 8 (Ratio)	GSA 9 (Ratio)	GSA 10 (Ratio)
Container	4000	0.86	0.90	0.94	0.98	1.03	1.08	1.14	1.20	1.27	1.35	1.44
Container	5000	0.94	0.98	1.02	1.07	1.12	1.17	1.23	1.30	1.37	1.46	1.55
Container	6000	0.93	0.96	1.00	1.05	1.10	1.15	1.21	1.28	1.35	1.43	1.52
Bulk	Handymax	0.94	0.96	0.97	0.99	1.00	1.02	1.04	1.05	1.07	1.09	1.11

An example of the results from the SSA model for the 2012 Global Average Speed scenario is provided in Appendix 8.

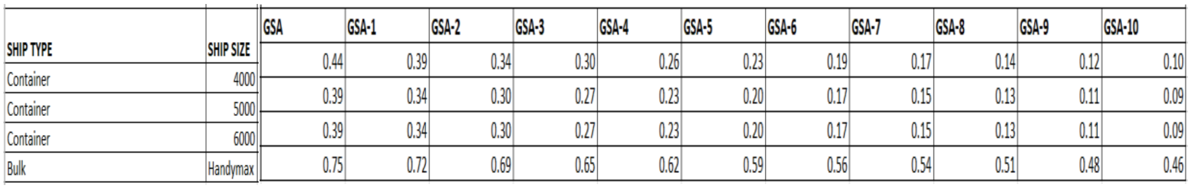
Appendix 8: Matrix 5 – Display for Ship Fleet Impacts (Distance 5).



SHIP TYPE	SHIP SIZE	GSA (# of Ships)	GSA 1 (# of Ships)	GSA 2 (# of Ships)	GSA 3 (# of Ships)	GSA 4 (# of Ships)	GSA 5 (# of Ships)	GSA 6 (# of Ships)	GSA 7 (# of Ships)	GSA 8 (# of Ships)	GSA 9 (# of Ships)	GSA 10 (# of Ships)
Container	4000	6	6	6	6	6	6	7	7	8	8	9
Container	5000	15	15	15	16	17	18	18	19	21	22	23
Container	6000	10	10	10	10	11	12	12	13	13	14	15
Bulk	Handymax	5	5	5	5	5	5	5	5	5	5	6

An example of the results from the SSA model for the 2012 Global Average Speed scenario is displayed in Appendix 9.

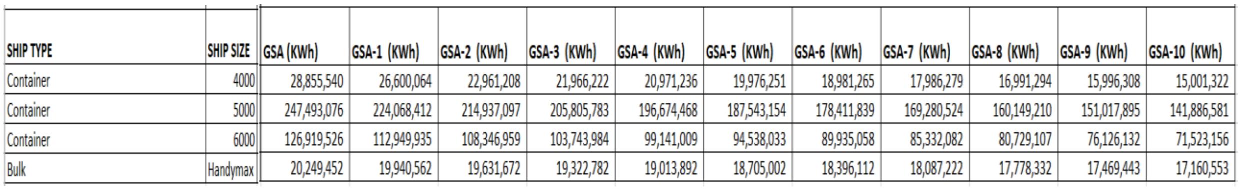
Appendix 9: Matrix 6- Display for Propulsion Engine Load Factors (Distance 5).



SHIP TYPE	SHIP SIZE	GSA	GSA-1	GSA-2	GSA-3	GSA-4	GSA-5	GSA-6	GSA-7	GSA-8	GSA-9	GSA-10
Container	4000	0.44	0.39	0.34	0.30	0.26	0.23	0.19	0.17	0.14	0.12	0.10
Container	5000	0.39	0.34	0.30	0.27	0.23	0.20	0.17	0.15	0.13	0.11	0.09
Container	6000	0.39	0.34	0.30	0.27	0.23	0.20	0.17	0.15	0.13	0.11	0.09
Bulk	Handymax	0.75	0.72	0.69	0.65	0.62	0.59	0.56	0.54	0.51	0.48	0.46

An example of the results from the SSA model for the 2012 Global Average Speed is shown in Appendix 10.

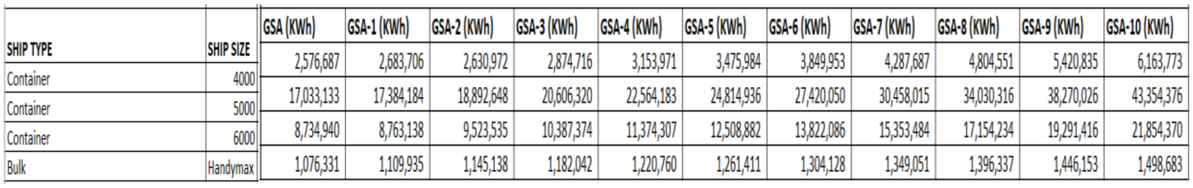
Appendix 10: Matrix 7- Display for Fleet Propulsion Engine Work (Distance 5).



SHIP TYPE	SHIP SIZE	GSA (KWh)	GSA-1 (KWh)	GSA-2 (KWh)	GSA-3 (KWh)	GSA-4 (KWh)	GSA-5 (KWh)	GSA-6 (KWh)	GSA-7 (KWh)	GSA-8 (KWh)	GSA-9 (KWh)	GSA-10 (KWh)
Container	4000	28,855,540	26,600,064	22,961,208	21,966,222	20,971,236	19,976,251	18,981,265	17,986,279	16,991,294	15,996,308	15,001,322
Container	5000	247,493,076	224,068,412	214,937,097	205,805,783	196,674,468	187,543,154	178,411,839	169,280,524	160,149,210	151,017,895	141,886,581
Container	6000	126,919,526	112,949,935	108,346,959	103,743,984	99,141,009	94,538,033	89,935,058	85,332,082	80,729,107	76,126,132	71,523,156
Bulk	Handymax	20,249,452	19,940,562	19,631,672	19,322,782	19,013,892	18,705,002	18,396,112	18,087,222	17,778,332	17,469,443	17,160,553

An example of the results of the SSA model for the 2012 Global Average Speed scenario is displayed in Appendix 11.

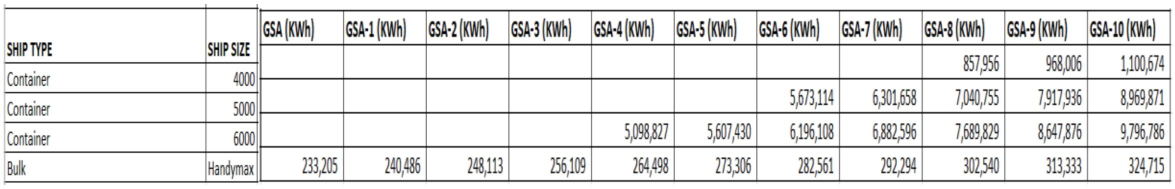
Appendix 11: Matrix 8- Display for the Fleet Auxiliary Engine Work (Distance 5)



SHIP TYPE	SHIP SIZE	GSA (KWh)	GSA-1 (KWh)	GSA-2 (KWh)	GSA-3 (KWh)	GSA-4 (KWh)	GSA-5 (KWh)	GSA-6 (KWh)	GSA-7 (KWh)	GSA-8 (KWh)	GSA-9 (KWh)	GSA-10 (KWh)
Container	4000	2,576,687	2,683,706	2,630,972	2,874,716	3,153,971	3,475,984	3,849,953	4,287,687	4,804,551	5,420,835	6,163,773
Container	5000	17,033,133	17,384,184	18,892,648	20,606,320	22,564,183	24,814,936	27,420,050	30,458,015	34,030,316	38,270,026	43,354,376
Container	6000	8,734,940	8,763,138	9,523,535	10,387,374	11,374,307	12,508,882	13,822,086	15,353,484	17,154,234	19,291,416	21,854,370
Bulk	Handymax	1,076,331	1,109,935	1,145,138	1,182,042	1,220,760	1,261,411	1,304,128	1,349,051	1,396,337	1,446,153	1,498,683

An example of the results of the SSA model for the 2012 Global Average Speed scenario is shown in Appendix 12. The empty cells indicate boilers were not in operations during these speeds.

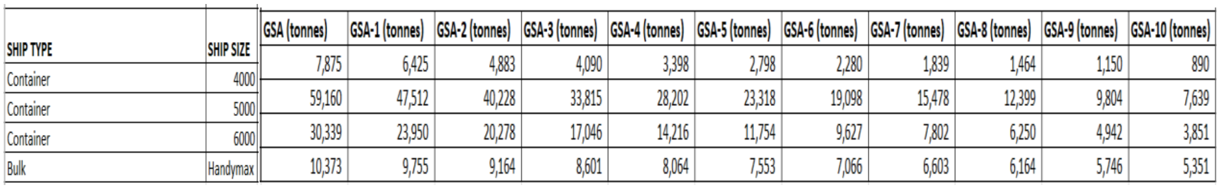
Appendix 12: Matrix 9- Display for the Fleet Boiler Work (Distance 5)



SHIP TYPE	SHIP SIZE	GSA (KWh)	GSA-1 (KWh)	GSA-2 (KWh)	GSA-3 (KWh)	GSA-4 (KWh)	GSA-5 (KWh)	GSA-6 (KWh)	GSA-7 (KWh)	GSA-8 (KWh)	GSA-9 (KWh)	GSA-10 (KWh)
Container	4000									857,956	968,006	1,100,674
Container	5000							5,673,114	6,301,658	7,040,755	7,917,936	8,969,871
Container	6000					5,098,827	5,607,430	6,196,108	6,882,596	7,689,829	8,647,876	9,796,786
Bulk	Handymax	233,205	240,486	248,113	256,109	264,498	273,306	282,561	292,294	302,540	313,333	324,715

An example of the results from the SSA model for the 2012 Global Average Speed scenario is shown in Appendix 13.

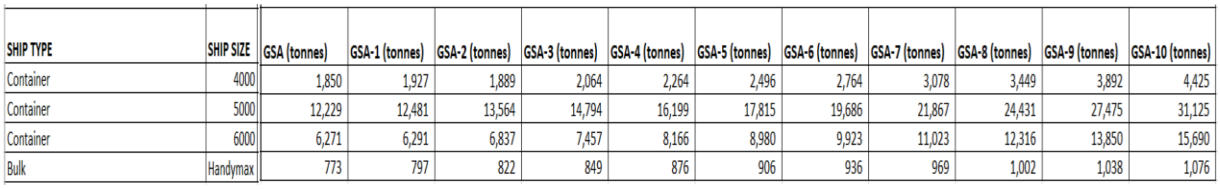
Appendix 13: Matrix 10- Display for the Fleet Propulsion Engine Emissions (Distance 5).



SHIP TYPE	SHIP SIZE	GSA (tonnes)	GSA-1 (tonnes)	GSA-2 (tonnes)	GSA-3 (tonnes)	GSA-4 (tonnes)	GSA-5 (tonnes)	GSA-6 (tonnes)	GSA-7 (tonnes)	GSA-8 (tonnes)	GSA-9 (tonnes)	GSA-10 (tonnes)
Container	4000	7,875	6,425	4,883	4,090	3,398	2,798	2,280	1,839	1,464	1,150	890
Container	5000	59,160	47,512	40,228	33,815	28,202	23,318	19,098	15,478	12,399	9,804	7,639
Container	6000	30,339	23,950	20,278	17,046	14,216	11,754	9,627	7,802	6,250	4,942	3,851
Bulk	Handymax	10,373	9,755	9,164	8,601	8,064	7,553	7,066	6,603	6,164	5,746	5,351

An example of the results from the SSA model for the 2012 Global Average Speed scenario is shown in Appendix 14.

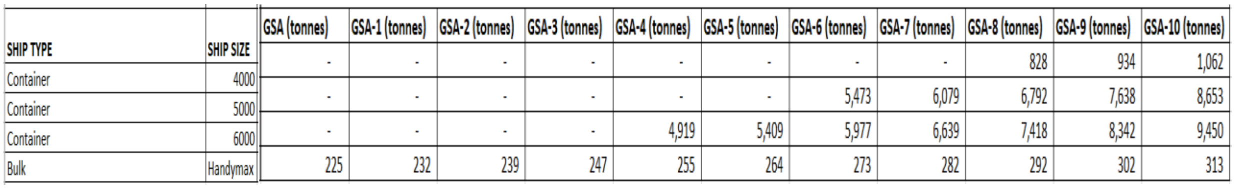
Appendix 14: Matrix 11- Display for the Fleet Auxiliary Engine Emissions (Distance 5).



SHIP TYPE	SHIP SIZE	GSA (tonnes)	GSA-1 (tonnes)	GSA-2 (tonnes)	GSA-3 (tonnes)	GSA-4 (tonnes)	GSA-5 (tonnes)	GSA-6 (tonnes)	GSA-7 (tonnes)	GSA-8 (tonnes)	GSA-9 (tonnes)	GSA-10 (tonnes)
Container	4000	1,850	1,927	1,889	2,064	2,264	2,496	2,764	3,078	3,449	3,892	4,425
Container	5000	12,229	12,481	13,564	14,794	16,199	17,815	19,686	21,867	24,431	27,475	31,125
Container	6000	6,271	6,291	6,837	7,457	8,166	8,980	9,923	11,023	12,316	13,850	15,690
Bulk	Handymax	773	797	822	849	876	906	936	969	1,002	1,038	1,076

An example of the results from the SSA model for the 2012 Global Average Speed scenario is shown in Appendix 15.

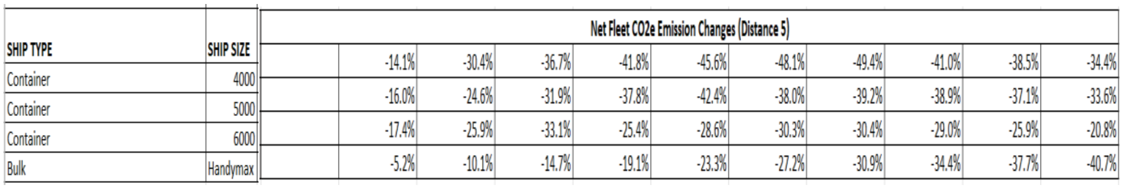
Appendix 15: Matrix 12- Display for the Fleet Boiler CO_2e Emissions (Distance 5).



SHIP TYPE	SHIP SIZE	GSA (tonnes)	GSA-1 (tonnes)	GSA-2 (tonnes)	GSA-3 (tonnes)	GSA-4 (tonnes)	GSA-5 (tonnes)	GSA-6 (tonnes)	GSA-7 (tonnes)	GSA-8 (tonnes)	GSA-9 (tonnes)	GSA-10 (tonnes)
Container	4000	-	-	-	-	-	-	-	-	828	934	1,062
Container	5000	-	-	-	-	-	-	5,473	6,079	6,792	7,638	8,653
Container	6000	-	-	-	-	4,919	5,409	5,977	6,639	7,418	8,342	9,450
Bulk	Handymax	225	232	239	247	255	264	273	282	292	302	313

An example of the results for the SSA model for the 2012 GAS scenario is shown in matrix 16.

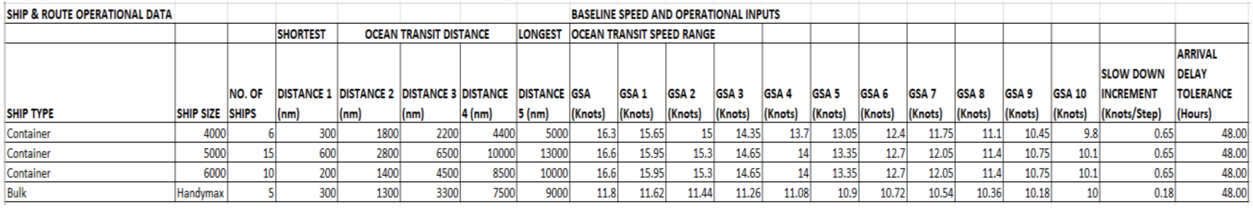
Appendix 16: Matrix 13- Display for the Net Fleet Emissions Changes (Distance 5).



SHIP TYPE	SHIP SIZE	Net Fleet CO2e Emission Changes (Distance 5)										
Container	4000		-14.1%	-30.4%	-36.7%	-41.8%	-45.6%	-48.1%	-49.4%	-41.0%	-38.5%	-34.4%
Container	5000		-16.0%	-24.6%	-31.9%	-37.8%	-42.4%	-38.0%	-39.2%	-38.9%	-37.1%	-33.6%
Container	6000		-17.4%	-25.9%	-33.1%	-25.4%	-28.6%	-30.3%	-30.4%	-29.0%	-25.9%	-20.8%
Bulk	Handymax		-5.2%	-10.1%	-14.7%	-19.1%	-23.3%	-27.2%	-30.9%	-34.4%	-37.7%	-40.7%

Appendix 17 shows the environmental input required for the economic impact module, module 2.

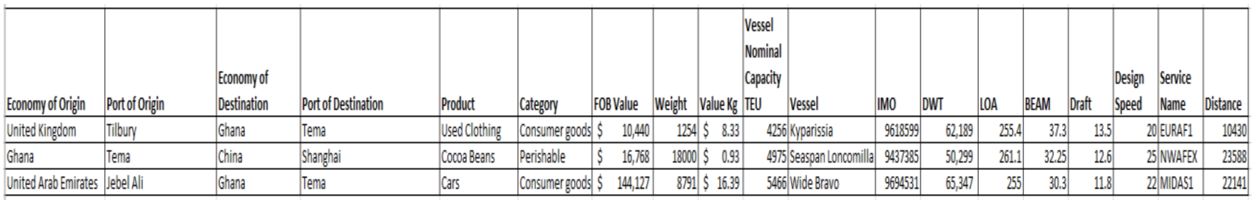
Appendix 17: Environmental Model Inputs.



SHIP & ROUTE OPERATIONAL DATA								BASELINE SPEED AND OPERATIONAL INPUTS												
			SHORTEST	OCEAN TRANSIT DISTANCE			LONGEST	OCEAN TRANSIT SPEED RANGE												
SHIP TYPE	SHIP SIZE	NO. OF SHIPS	DISTANCE 1 (nm)	DISTANCE 2 (nm)	DISTANCE 3 (nm)	DISTANCE 4 (nm)	DISTANCE 5 (nm)	GSA (Knots)	GSA 1 (Knots)	GSA 2 (Knots)	GSA 3 (Knots)	GSA 4 (Knots)	GSA 5 (Knots)	GSA 6 (Knots)	GSA 7 (Knots)	GSA 8 (Knots)	GSA 9 (Knots)	GSA 10 (Knots)	SLOW DOWN INCREMENT (Knots/Step)	ARRIVAL DELAY TOLERANCE (Hours)
Container	4000	6	300	1800	2200	4400	5000	16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	0.65	48.00
Container	5000	15	600	2800	6500	10000	13000	16.6	15.95	15.3	14.65	14	13.35	12.7	12.05	11.4	10.75	10.1	0.65	48.00
Container	6000	10	200	1400	4500	8500	10000	16.6	15.95	15.3	14.65	14	13.35	12.7	12.05	11.4	10.75	10.1	0.65	48.00
Bulk	Handymax	5	300	1300	3300	7500	9000	11.8	11.62	11.44	11.26	11.08	10.9	10.72	10.54	10.36	10.18	10	0.18	48.00

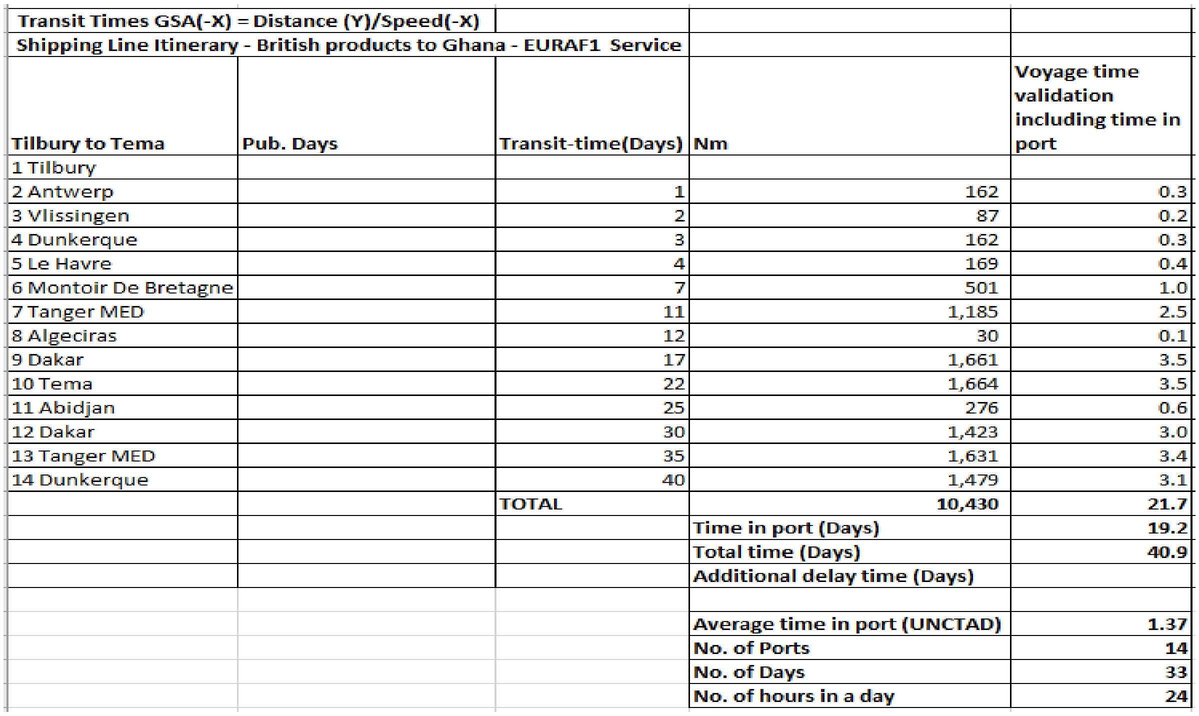
Selected Routes Liners Worksheet.

Appendix 18: Container Ship Selected Service Routes, vessel, cargo and distance.



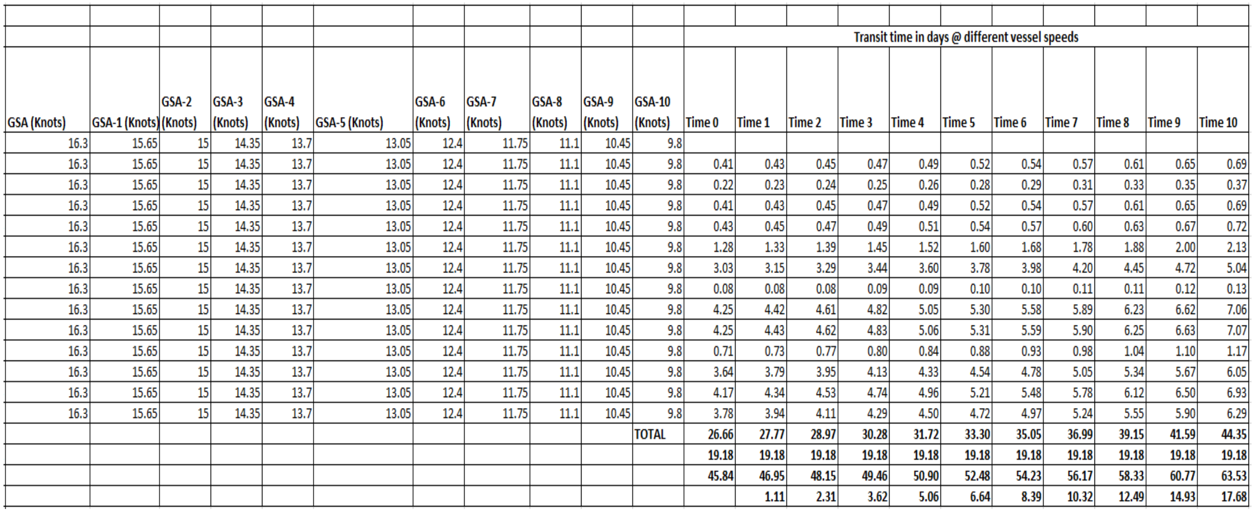
Economy of Origin	Port of Origin	Economy of Destination	Port of Destination	Product	Category	FOB Value	Weight	Value Kg	Vessel Nominal Capacity TEU	Vessel	IMO	DWT	LOA	BEAM	Draft	Design Speed	Service Name	Distance
United Kingdom	Tilbury	Ghana	Tema	Used Clothing	Consumer goods	$ 10,440	1254	$ 8.33	4256	Kyparissia	9618599	62,189	255.4	37.3	13.5	20	EURAF1	10430
Ghana	Tema	China	Shanghai	Cocoa Beans	Perishable	$ 16,768	18000	$ 0.93	4975	Seaspan Loncomilla	9437385	50,299	261.1	32.25	12.6	25	NWAFEX	23588
United Arab Emirates	Jebel Ali	Ghana	Tema	Cars	Consumer goods	$ 144,127	8791	$ 16.39	5466	Wide Bravo	9694531	65,347	255	30.3	11.8	22	MIDAS1	22141

Appendix 19: Service rotation, distance and model calibration (validation).



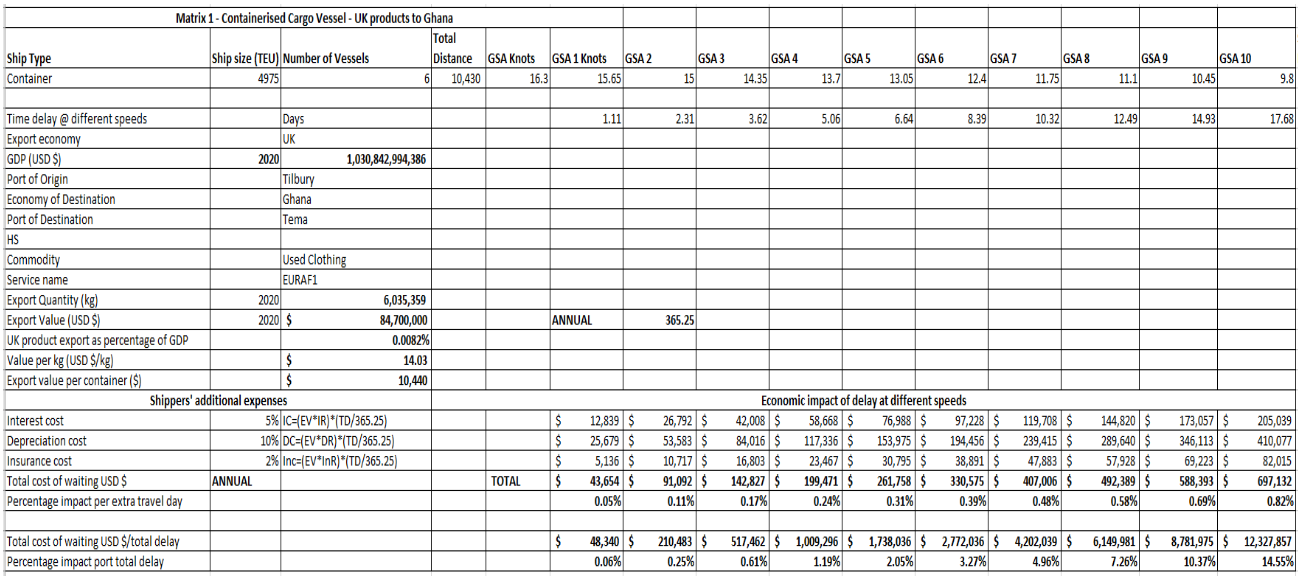
Transit Times GSA(-X) = Distance (Y)/Speed(-X)				
Shipping Line Itinerary - British products to Ghana - EURAF1 Service				
Tilbury to Tema	**Pub. Days**	**Transit-time(Days)**	**Nm**	**Voyage time validation including time in port**
1 Tilbury				
2 Antwerp		1	162	0.3
3 Vlissingen		2	87	0.2
4 Dunkerque		3	162	0.3
5 Le Havre		4	169	0.4
6 Montoir De Bretagne		7	501	1.0
7 Tanger MED		11	1,185	2.5
8 Algeciras		12	30	0.1
9 Dakar		17	1,661	3.5
10 Tema		22	1,664	3.5
11 Abidjan		25	276	0.6
12 Dakar		30	1,423	3.0
13 Tanger MED		35	1,631	3.4
14 Dunkerque		40	1,479	3.1
		TOTAL	**10,430**	**21.7**
			Time in port (Days)	**19.2**
			Total time (Days)	**40.9**
			Additional delay time (Days)	
			Average time in port (UNCTAD)	**1.37**
			No. of Ports	**14**
			No. of Days	**33**
			No. of hours in a day	**24**

Appendix 20: Service time calculation at different speed ranges.



											Transit time in days @ different vessel speeds										
GSA (Knots)	GSA-1 (Knots)	GSA-2 (Knots)	GSA-3 (Knots)	GSA-4 (Knots)	GSA-5 (Knots)	GSA-6 (Knots)	GSA-7 (Knots)	GSA-8 (Knots)	GSA-9 (Knots)	GSA-10 (Knots)	Time 0	Time 1	Time 2	Time 3	Time 4	Time 5	Time 6	Time 7	Time 8	Time 9	Time 10
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8											
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	0.41	0.43	0.45	0.47	0.49	0.52	0.54	0.57	0.61	0.65	0.69
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	0.22	0.23	0.24	0.25	0.26	0.28	0.29	0.31	0.33	0.35	0.37
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	0.41	0.43	0.45	0.47	0.49	0.52	0.54	0.57	0.61	0.65	0.69
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	0.43	0.45	0.47	0.49	0.51	0.54	0.57	0.60	0.63	0.67	0.72
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	1.28	1.33	1.39	1.45	1.52	1.60	1.68	1.78	1.88	2.00	2.13
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	3.03	3.15	3.29	3.44	3.60	3.78	3.98	4.20	4.45	4.72	5.04
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	0.08	0.08	0.08	0.09	0.09	0.10	0.10	0.11	0.11	0.12	0.13
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	4.25	4.42	4.61	4.82	5.05	5.30	5.58	5.89	6.23	6.62	7.06
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	4.25	4.43	4.62	4.83	5.06	5.31	5.59	5.90	6.25	6.63	7.07
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	0.71	0.73	0.77	0.80	0.84	0.88	0.93	0.98	1.04	1.10	1.17
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	3.64	3.79	3.95	4.13	4.33	4.54	4.78	5.05	5.34	5.67	6.05
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	4.17	4.34	4.53	4.74	4.96	5.21	5.48	5.78	6.12	6.50	6.93
16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8	3.78	3.94	4.11	4.29	4.50	4.72	4.97	5.24	5.55	5.90	6.29
										TOTAL	**26.66**	**27.77**	**28.97**	**30.28**	**31.72**	**33.30**	**35.05**	**36.99**	**39.15**	**41.59**	**44.35**
											19.18	**19.18**	**19.18**	**19.18**	**19.18**	**19.18**	**19.18**	**19.18**	**19.18**	**19.18**	**19.18**
											45.84	**46.95**	**48.15**	**49.46**	**50.90**	**52.48**	**54.23**	**56.17**	**58.33**	**60.77**	**63.53**
												1.11	2.31	3.62	5.06	6.64	8.39	10.32	12.49	14.93	17.68

Appendix 21: Economic Impact Module Matrix Inputs and Outputs.



Matrix 1 - Containerised Cargo Vessel - UK products to Ghana														
Ship Type	**Ship size (TEU)**	**Number of Vessels**	**Total Distance**	**GSA Knots**	**GSA 1 Knots**	**GSA 2**	**GSA 3**	**GSA 4**	**GSA 5**	**GSA 6**	**GSA 7**	**GSA 8**	**GSA 9**	**GSA 10**
Container	4975	6	10,430	16.3	15.65	15	14.35	13.7	13.05	12.4	11.75	11.1	10.45	9.8
Time delay @ different speeds		Days			1.11	2.31	3.62	5.06	6.64	8.39	10.32	12.49	14.93	17.68
Export economy		UK												
GDP (USD $)	**2020**	**1,030,842,994,386**												
Port of Origin		Tilbury												
Economy of Destination		Ghana												
Port of Destination		Tema												
HS														
Commodity		Used Clothing												
Service name		EURAF1												
Export Quantity (kg)	2020	**6,035,359**												
Export Value (USD $)	2020	**$ 84,700,000**			**ANNUAL**	**365.25**								
UK product export as percentage of GDP		**0.0082%**												
Value per kg (USD $/kg)		**$ 14.03**												
Export value per container ($)		**$ 10,440**												
Shippers' additional expenses			**Economic impact of delay at different speeds**											
Interest cost	5%	IC=(EV*IR)*(TD/365.25)			$ 12,839	$ 26,792	$ 42,008	$ 58,668	$ 76,988	$ 97,228	$ 119,708	$ 144,820	$ 173,057	$ 205,039
Depreciation cost	10%	DC=(EV*DR)*(TD/365.25)			$ 25,679	$ 53,583	$ 84,016	$ 117,336	$ 153,975	$ 194,456	$ 239,415	$ 289,640	$ 346,113	$ 410,077
Insurance cost	2%	Inc=(EV*InR)*(TD/365.25)			$ 5,136	$ 10,717	$ 16,803	$ 23,467	$ 30,795	$ 38,891	$ 47,883	$ 57,928	$ 69,223	$ 82,015
Total cost of waiting USD $	**ANNUAL**			**TOTAL**	**$ 43,654**	**$ 91,092**	**$ 142,827**	**$ 199,471**	**$ 261,758**	**$ 330,575**	**$ 407,006**	**$ 492,389**	**$ 588,393**	**$ 697,132**
Percentage impact per extra travel day					**0.05%**	**0.11%**	**0.17%**	**0.24%**	**0.31%**	**0.39%**	**0.48%**	**0.58%**	**0.69%**	**0.82%**
Total cost of waiting USD $/total delay					**$ 48,340**	**$ 210,483**	**$ 517,462**	**$ 1,009,296**	**$ 1,738,036**	**$ 2,772,036**	**$ 4,202,039**	**$ 6,149,981**	**$ 8,781,975**	**$ 12,327,857**
Percentage impact port total delay					**0.06%**	**0.25%**	**0.61%**	**1.19%**	**2.05%**	**3.27%**	**4.96%**	**7.26%**	**10.37%**	**14.55%**