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Emissions Reduction in Shipping Beyond Slow Steaming

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ABSTRACT:
Slow steaming has recently been adopted into normal practice by many maritime shipping companies for the fuel and monetary savings it offers. The practice also offers savings in Greenhouse Gas (GHG) emissions. With regulations coming into play such as the 2020 sulfur cap, slow steaming may be the least costly option for some maritime companies to adjust their operations. While some have accepted the new practice, there are still companies and vessels that see this exercise as a loss of revenue due to the extra time it takes to deliver goods to their destination. This paper reviews how rating ships by their GHG emissions per nautical mile can be directly related to factors other than slow steaming such as age, deadweight tonnage and cargo type. We propose that ships with poor ratings (E, F, G) should rely on slow steaming but may also improve their CO_2 output addressing the other factors. Those with superior ratings (A, B, C, D) may also benefit from the implementation of slow steaming, but may also gain from practices addressing age, tonnage and cargo type. Further we will also examine how lowering emissions can benefit maritime businesses both economically and environmentally. Finally this paper reviews possible chain reactions that may occur if these eco-friendly shipping practices are observed.
KEYWORDS: slow steaming, greenhouse gases, vessels, ecological transport

Redução de emissões no transporte além do vapor lento

RESUMO:
O vapor lento foi recentemente adotado na prática normal por muitas companhias marítimas para a economia de combustível e monetária que oferece. A prática também oferece economias em emissões de gases de efeito estufa (GEE). Com os regulamentos que entram em jogo, como o limite de enxofre de 2020, o vapor lento pode ser a opção menos dispendiosa para algumas empresas marítimas ajustar suas operações. Enquanto alguns aceitaram a nova prática, ainda existem empresas e embarcações que vêem esse exercício como uma perda de receita devido ao tempo extra que leva para entregar bens ao seu destino. Este artigo analisa como a classificação dos navios por suas emissões de GEE por milha náutica pode ser diretamente relacionada a fatores como idade, tonelagem de peso morto e carga. Nós propomos que os navios com classificações ruins (E, F, G) encontrem regulamentos obrigatórios para diminuir o vapor ou melhorar sua produção de CO2 de alguma forma. Aqueles com classificações superiores (A, B, C, D) se beneficiariam de pacotes de incentivos ligados à sua implementação de vapor lento ou outras práticas. Também examinará como a redução das emissões pode beneficiar as empresas marítimas de forma econômica e ambiental. Finalmente, este artigo analisa possíveis reações em cadeia que podem ocorrer se essas práticas de transporte ecológico forem observadas.
PALAVRAS-CHAVE: vapor lento, gases de efeito estufa, embarcações, transporte ecológico

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1. Introduction

Mitigating Greenhouse Gas emissions has been a hot topic for the shipping industry in recent years. Without out a true way to measure emissions globally for shipping, the regulators such as the IMO preform estimations from previous years. In the Third IMO Study, it was concluded that "International shipping emissions for 2012 are estimated to be 796 million tonnes CO_2 and 816 million tonnes CO_2e for GHGs combining CO_2, CH_4 and N_2O. International shipping accounts for approximately 2.2% and 2.1% of global CO_2 and GHG emissions on a CO_2 equivalent (CO_2e) basis, respectively" (IMO, 2014). The question then becomes, how can the shipping industry further reduce its impact on the environment while still maintaining a profitable business? One operational option is slow steaming. Through the implementation of slow steaming, many benefits have been observed. By utilizing this practice, a ship will experience less wear and tear on the engine of the vessel due to lower speeds. This leads to less maintenance thus monetary savings can be seen. Fuel savings will also result from this operational adjustment. Reducing fuel usage will not only be monetarily beneficial but also environmentally as well. Burning less fuel contributes directly to GHG mitigation.

Ports could also see benefits from slow steaming. The idea of scheduling a berth time after participating in slow steaming would be an incentive which could lead to mitigating congestion thus further alleviating emissions. This practice would mean less idling time outside of the port for the vessel participating in slow steaming. Some vessels idle for days waiting to get into port, constantly burning fuel. This idling contributes to higher operating costs, it also lends to further GHG emissions. By reducing congestion outside of ports by this berth scheduling incentive, multifaceted savings would be seen.

Other factors that could influence vessel emissions are: age of the vessel, weight in deadweight tonnage (DWT), and cargo. Age of vessels while it may seem obvious, contributes to the amount to emissions produced. Deadweight tonnage again appear to have an evident correlation with emissions. Cargo carried has rarely been looked at as a factor but could offer insight to emissions. Emissions data from RightShip addresses these factors. This study could help define more ways for a company to save rather than to just slow down.

Ports could further utilize emissions data from organizations like RightShip, to provide incentives for ships higher rated vessels which could have a snowball effect for other ships to improve their practices and boost their ratings to receive those incentives. Another proposition in utilizing data like this would be for ships rated poorly rated ships, finding more stringent regulation targeted at them to improve their practices and decrease their CO_2 emissions.

2. Literature Review

Literature regarding the benefits of slow steaming for both cost and environmental benefits is becoming increasingly popular. Most of the research on this topic has concentrated on ship speed optimization and the benefits stemming from finding the optimal operating speed of the vessel. Between increased awareness of environmental issues, poor market conditions, and volatile fuel prices, there is more pressure than ever to find the most optimal speed to navigate these circumstances.

Fuel consumption by a vessel can vary based on a few different factors. Whoever is paying for fuel must make the most optimal decision possible. “Contracts many times refer to ‘utmost dispatch’ that encourage carriers to pursue speeds as fast as reasonably possible.” (Alvarez et al, 2010). Hydrodynamic characteristics also play a factor in fuel comsumption. Psaraaftis & Kontovas state, “hull condition can also be an important factor that influences the frictional resistance of a ship, and, as a result, fuel consumption” and continues with“ship resistance and hence fuel consumption at a given speed can be drastically different if the ship is full, empty or at an intermediate leading condition” (Psaraftis & Kontovas, 2014). Along with load of ship, fuel prices themselves are a critical piece to the optimal speed puzzle as well. During the financial crisis of 2009 there was a sharp rise in slow steaming due to the high cost of bunker fuel (Wong et al, 2015).“Fuel prices are a very critical determinant of fuel costs, and, as such, of the speed chosen by the vessel. In fact fuel price is the one of two main factors that play a critical role in the determination of ship speed (the state of the market being the other one)” (Psaraftis & Kontovas, 2014). Freight rates can have an impact on the decision of how fast or slow a ship chooses to go as well. Ultimately the decision of how quickly to arrive in port is associated with net profits. If there is money to be made or saved by arriving to the port as soon as possible shippers and charterers will forgo the environmentally friend options such as slow steaming. However, through further literature review, there are findings which show that there are more reasons than just a depressed market where ships and the environment can benefit from reduced speed.

So far, slow steaming has been “a response to depressed market conditions and/or high fuel prices” (Psaraftis & Kontovas, 2014). However, there is a notable relationship between the environment and speed of a vessel which is gaining some much-deserved attention in literature. As a ship’s speed increases, it will burn more fuel thereby emitting more pollution. With higher demands from consumers, shippers feel the pressure to respond and by supplying goods equal to demand which creates even more congestion in ports. Between the ship’s increased speed to meet demand and the idling in a queue to get into congested ports, unnecessary fuel is being used, therefore producing an even greater amount of emissions. “International shipping accounts for approximately 2% of global carbon emissions” (Mander, 2016). Pierre Cariou’s paper, *Is slow steaming a sustainable means of reducing CO_2 emissions from container shipping?* shows that “Reducing a vessel’s speed by 10% decreases emissions by at least 10-15%” proving that “one positive effect of slow steaming is that it lowers CO_2 emissions that are proportional to the amount of fuel burned” (Cariou, 2011). In another study done by Ching-Chin Chang and Chia-Hong Chang, they used an activity-based method to evaluate fuel consumption against CO_2 emissions and found that “speed reductions of 10%, 20%, and 30% reduced fuel consumption by 27.1%, 48.8%, and 60.3% and CO_2 emissions by 19%, 36%, and 51%, respectively” (Chang & Chang, 2013). An increasing amount of studies are linking speed reduction as a viable way to mitigate carbon emissions and other greenhouse gases.

It is clear that slow steaming provides benefits in air emissions but there is also a relationship between the speed of a vessel and monetary benefits found from decreasing speed. “Reducing speed could also have important side benefits: cost reduction is one, and helping a depressed market in which shipping overcapacity is the norm these days is another” (Psaraftis & Kontovas, 2012). Market conditions which include factors such as fuel prices and freight rates can also be compared versus a ships speed. In fact, “NYK Group investigated the cost-benefit analysis and emission reduction of slow steaming, indicating a slow steaming of reducing the speed of a vessel with 8,000 Twenty-foot Equivalent Unit (TEU) containers from

24 knots to 20 knots generates an overall 42% reduction of fuel consumption, fuel cost, and CO_2 emission" (Wong, Tai, Lau, & Raman, 2015).

The non-linear relationship between speed and fuel consumption looked at in regards to emissions also applies to operations costs and even the prospect of easing port congestion through slow steaming. "Costs and emissions may actually be even higher if a ship sails to a port at a maximum speed only to wait in line to enter once there" (Psaraftis & Kontovas, 2012). Burning less fuel, mitigating GHG, saving on fuel costs, minimizing engine maintenance, and easing port congestion can all be results of slow steaming as observed through various literature and studies.

While slow steaming has grown in popularity due to higher fuel prices and a higher presence of ecological awareness, it's not the only solution associated with mitigation of carbon emissions. Studies and technologies are improving engines, implementing solar and wind power, and green routing and scheduling. Kontovas emphasizes that the research in the area of "Green Ship Routing and Scheduling" is just beginning to take off. Stating that with existing algorithms, such as the assignment algorithm, a reduction of emissions is possible (Kontovas, 2014). Mander in her work *Slow steaming and a new dawn for wind propulsion: A multi-level analysis of two low carbon shipping transitions* reviews the new technologies becoming available for other low carbon shipping methods such as wind propulsion. Stating that "Wind propulsion is at an earlier stage of innovation… and [can] drive the technology to the point that can challenge the existing regime" (Mander, 2016). With innovation around the corner and everyone joining on the slow steaming bandwagon, companies are looking for other ways to improve their emissions score card. Looking further into age, weight, and cargo carried could find small but effective efficiencies companies are searching for.

3. Methodology

Data Collection

Our data was collected by RightShip. They receive their data directly from the shipowners, managers, yards, classifications societies and charters. As of July 2017, RightShip collects data from eighty-three organizations, 52 of which represent 20% of global trade. Their data is evaluated by third parties to ensure authenticity, such as DNV GL. The sourced data is derived from Classification Societies (e.g. EEDI Technical Files), Ship sourced data (e.g. sea trial and shop tested supplied by the vessel owner/manager), Engine manufacturer's specification (Sourced from ship yards), and IHS Maritime Database (IMO publications). The data that is reviewed in this paper is specifically from Rightship's Vetted fleet of 2015. These are the vessels that turned over their data and have been ensured to be authentic. The data from these ships were then placed into the EEDI or EVDI equations below to provide a rating for GHG emissions.

The GHG emissions rating methodology stems from two sources: EEDI or EVDI. EEDI is the energy efficiency design index and EVDI is the existing vessel design index. EVDI is used when EEDI is added onto existing ships or new ones where EEDI is not available. EEDI is a regulatory requirement for new ships developed by IMO; EVDI was developed by RightShip.

RightShip has provided the finished EVDI and GHG ratings. The EEDI equation below shows the emissions emitted by the engines and energy saving technology per transport work.

Main Engines Engines Energy Saving Technologies (Auxiliary Power) Energy Saving Technologies (Main Power)

$$f_i \cdot Capacity \cdot V_{ref} \cdot f_w$$

Transport Work

in which:

• ME and AE, represent Main Engine(s) and Auxiliary Engine(s);
• P, the power of the engines (kW);
• CF, a conversion factor between fuel consumption and CO_2 based on fuel carbon content;
• SFC, the certified specific fuel consumption of the engines (g/kWh);
• Capacity, the deadweight or gross tonnage (tonnes);
• V_{ref}, the ship speed (nm/h); and
• f_j, a correction factor to account for ship specific design elements (eg. ice-class).

Ultimately, the equation reviews the emission produced (CO_2) per nautical mile travelled. This is similar to how the calculation for EVDI below is found. This equation finds the emissions of an engine per distance traveled as well. This is different for the IMO's EEDI, because it is only applicable new vessels.

$$EVDI = \frac{CO_2}{Transport\ Work}$$

The data was then placed by RightShip onto graphs in house and has been verified by other third parties mentioned above. Below we review the methodology of the calculations made by RightShip. Additionally, we compared the data received from RightShip by placing different parameters around the data.

Parameters selected

Dry bulk carriers have many different characteristics to consider such as size in dead-weight tonnage (DWT), age in years, flag state (where a vessel flags out of), and cargo type. For our paper, we have looked at vessels with ages from 0-35 years old, DWT from 25,000 - 180,000 and cargo types are limited to grain, coal, and iron ore. We looked at the age range of 0-35 years old due to the average age of a dry bulk carrier is 25-27 years old (RightShip, 2015). The DWT was chosen due to the major vessel sizes operating in this sector are the Handy (<60,000), Panamax (60,000-89,000), and Cape size vessels (90,000+). We stopped our parameter of DWT at 180,000 because the average size of a Cape size bulker vessel is 156,000. Cargo types were limited to dry bulk with focus on grain, coal, and iron ore since the other sector was not defined.

EVDI and GHG Emissions Rating Scale

RightShip collects data directly from the ships. They collect the distance traveled, engine capacity, fuel type, speed, carrying capacity and CO_2 emissions. As shown in the equation above, to find EVDI, they took the CO_2 emissions and divided that by the nautical miles traveled. This then gives a ratio of how much CO_2 was produced per nautical mile. From there they are able to assign the GHG Emissions Rating by doing some calculations. First, they find the log values from the EVDI. Next, log values are weighted; then Z score is calculated from the weighted values. Lastly the scores are sized/ranked. These values are attributed to the total engine capacity, fuel type used, speed, and carrying capacity of each specific ship. EVDI are evaluated on a numerical scale where closer to 0 is a better score. The GHG Emissions Ratings are evaluated on an alphabetical scale; A being the best and G being the worst.

Evaluation

When comparing data, we modified the cargo carried and the age of the vessels. This allowed us to see the ages that have the highest GHG Emission ratings and the lowest EVDI. First, we looked at modifying only the cargo types. We were able to compare all dry cargoes, coal, iron ore and grain by the emissions rating and the EVDI. Next, we looked at modifying only age. This showed us what ages have the best EVDI and emissions ratings. The age ranges are 0-5, 6-10, 11-15, 16-20, and 21-355. The last 15 years years are not split into five year segments due to the small amount of data present within our parameters.

5. Results and Analysis

Results

After defining our parameters we looked at the results. We found overall that 22% of ships within our parameters had an E,F, or G rating (Figure 1).

Figure 1

When the vessels were categorized by their sizes, we found Handymax ships in the 60,000 DWT or less category to have the least amount of F and G rated ships, the most E rated ships, and the second most A rated ships. Panamax vessels from 60,000 DWT to 89,999 DWT had the most B and C rated vessels and the least amount of ships rated D through G. Finally the Capesize vessels, 90,000 DWT or greater, were found to have the most A rated vessels as well as the most F and G rated vessels. Overall, this shows that size of vessel does have a minor effect on the GHG emission ratings.

When defining the cargo carried by ships, we found that all types of cargo (coal, iron ore, and grain) all had normally distributed curves. Some major findings were that the grain carrying ships had more A through D rated vessels at all sizes (Figure 2).

Figure 2

Iron ore carrying vessels had the most poorly rated vessels (E through G) at the Handy and Panamax sizes (Figure 3).

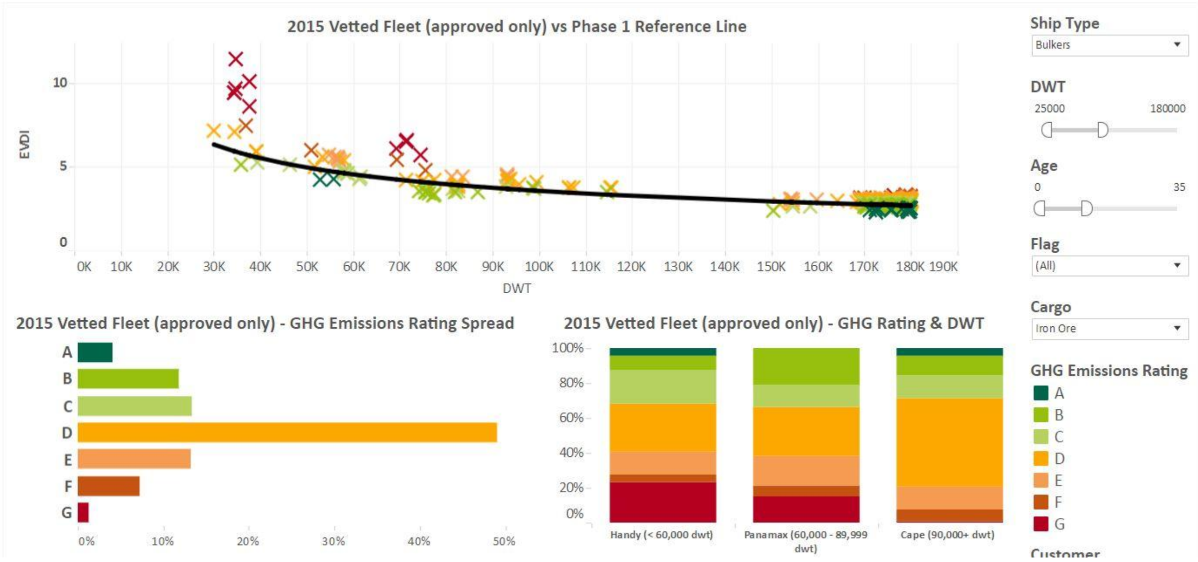

Figure 3

Coal carrying vessels had increasingly more E through G rated vessels as the size increased (Figure 4).

Figure 4

This data shows one is able to conclude that the cargo being carried in coordination with vessel size has an effect on the vessels GHG rating. As vessels increase in size the GHG emissions ratings accoiated with them improve.

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Finally, we looked at the vessel age ranges. We found vessels 0-5 years old had 23% of the vessels rated E-G and 33% of vessels rated A-C (Figure 5).

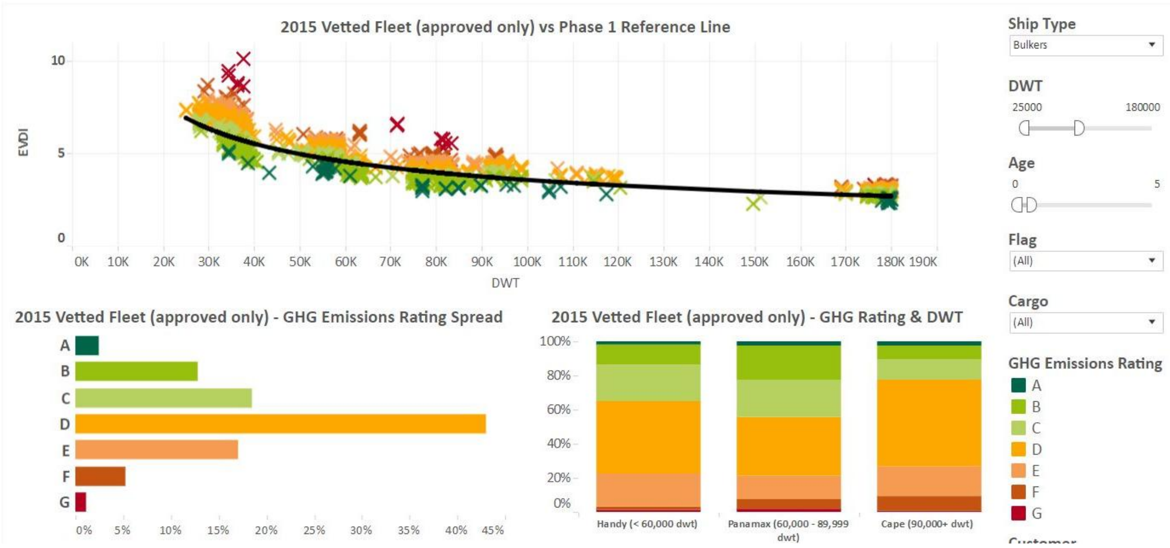

Figure 5

Age range of 6-10 years old showed 23% of vessels rated E and F, none rated G and 29% rated A-C (Figure 6).

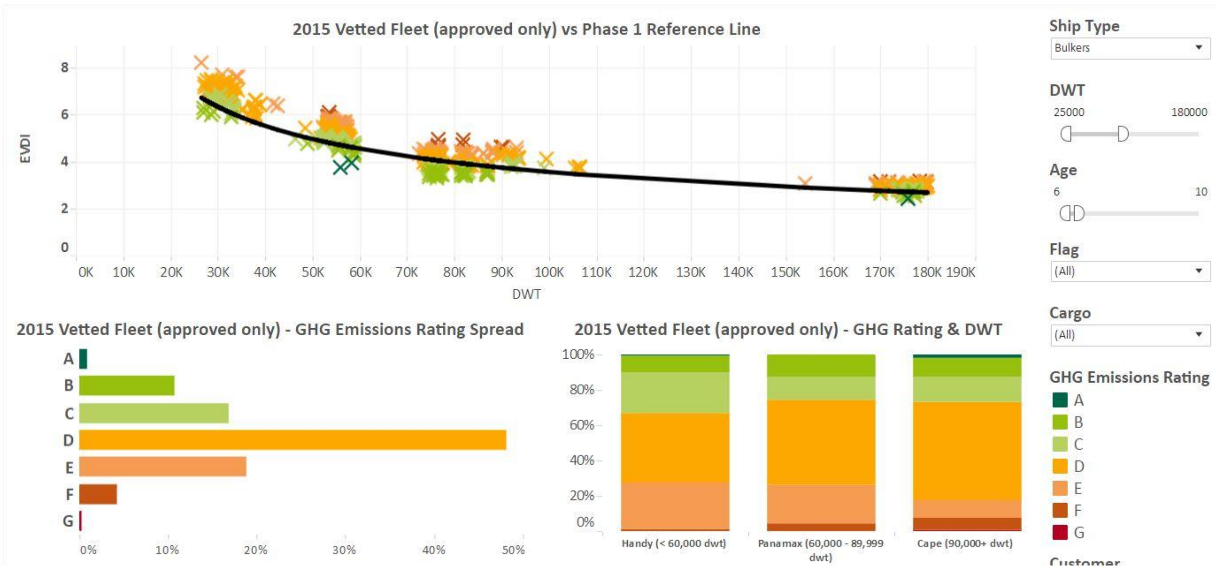

Figure 6

Vessels 11-15 years old started to show a large gap in the sizes of vessels where no ships were recorded in the 100,000 DWT to 160,000 DWT range. The 11-15 year old vessels have no G rated vessels and 35% of vessels are A-C rated (Figure 7).

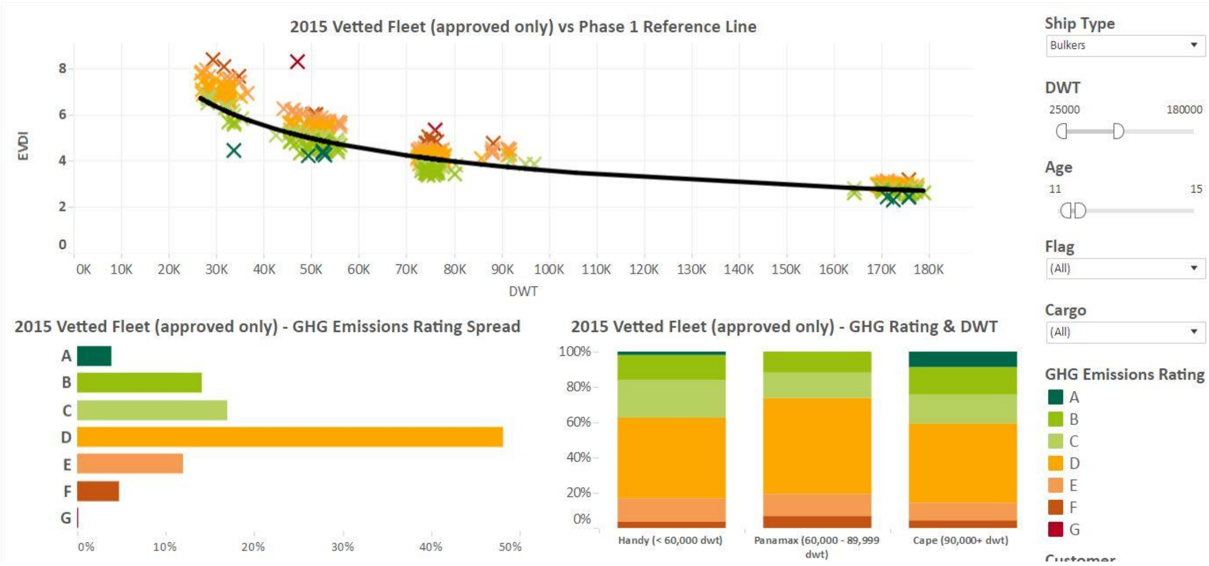

Figure 7

16-20 years old vessels had 29% of A-C ratings, 26% of vessels rated E and F and no G rated vessels (Figure 8).

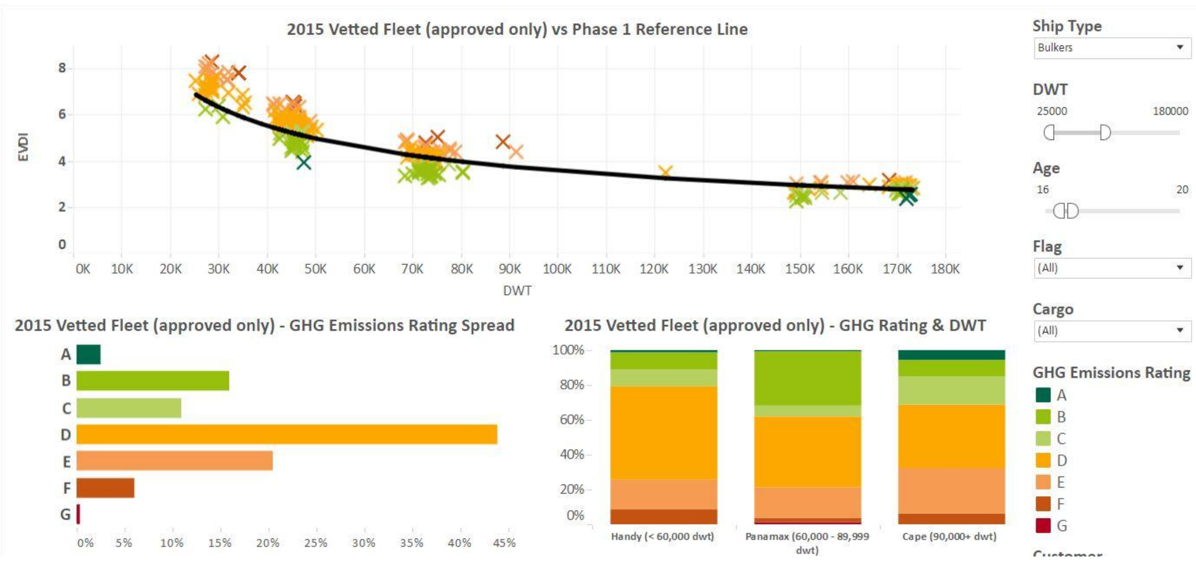

Figure 8

Starting at the age of 21 years old there are few ships represented in the age groups. For vessels 21-35 years old, there were 32% of ships rated A-C, and 25% are rated with F and G EVDI values (Figure 9).

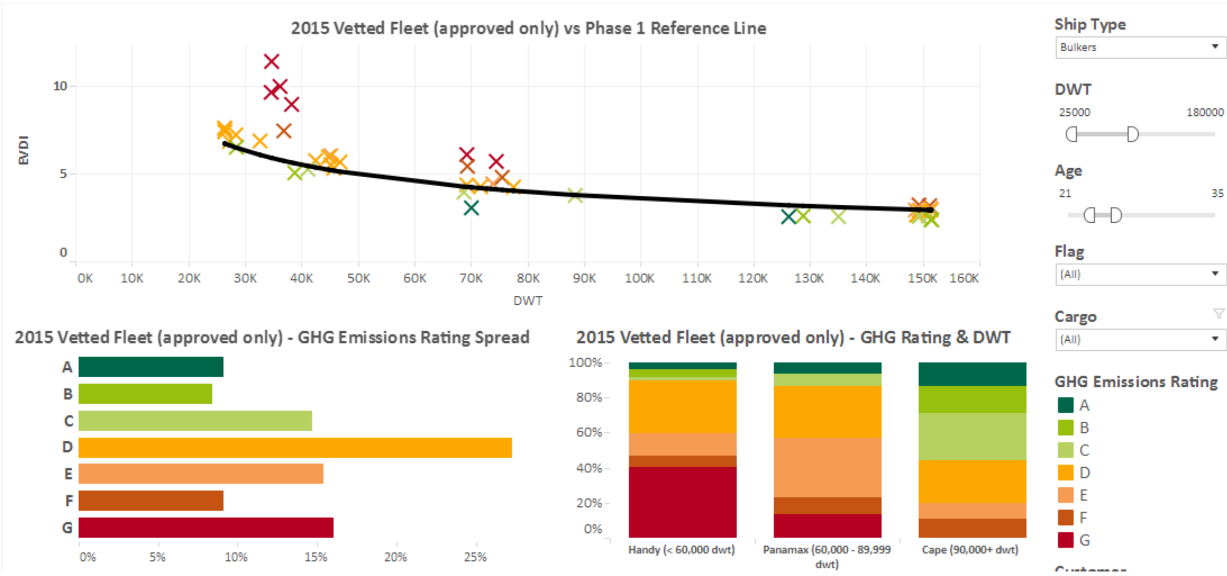

Figure 9

Overall the trend of larger ship sizes correlates with an improved EVDI is shown to be consistent with the cargo carried by the vessel data. Age also shows a strong role in emissions. As ships age the EVDI ratings overall decreased.

<u>Analysis</u>

When analyzing the results, one can conclude that the DWT size class of the vessel does help define the GHG emissions rating. The next conclusion that can be made is that the cargo type does show tendencies that shipments of grain have better rated GHG Emissions. Finally, the age results show that there are larger than expected F and G rated vessels. Dry bulk carriers with age range from 21-35 had 16% of the vessels were G rated. The theory that quantity of E through G rated vessels increase as the age increases was proven. Lastly, the age range of 21-35 with the fewest number of vessels in the sample within the parameters showed only 32% of vessels were rated A through C. This suggests that these a large portion of ships run inefficiently. At this age, most ships are subject to more breakdowns and inefficient engines. These results also show that middle aged ships are the most efficient vessels. This suggests that they are producing less emissions per nautical mile.

6. Conclusion and Remaining Questions

Above you saw that the most efficient vessels are those carrying grain. Additionally the emissions ratings improved as vessel DWT increased. Vessels that from the ages 0-5 and

16-20 had the best EVDI ratings compared to the other age classes. This was defined by the GHG emissions rating defined by EEDI or EVDI. These figures are found by measuring the CO_2 emitted (work of the engine) per nautical mile.

These leads us to look at the age composition of the fleet. Scraping ships at the age of 20 could improve overall fleet ratings. Discontinuing the use of poorly rated ships will improve emissions from the global fleet. Compositions of cargo carried should also be address. If vessels are able to find a mix of cargos that improves the emission ratings this would also improve the global fleet emissions. Weight was the surprising result. As DWT increased the overall emissions ratings increased. These larger vessels are believed to be the longer distance voyagers, thus improving the larger vessel emissions when compared to smaller vessels on shorter voyages.

In our findings, we found overall that 22% of ships within our parameters had an E,F, or G rating. Seeing as RightShip's data-collection covers approximately one-third of the world fleet, this is a large number of bulk carriers which need to improve their practices in order to assist in the goals that IMO would like to meet to reduce GHG emissions. Regulating agencies could also use data similar to this to see the need for more stringent regulations. From these graphs, we can see that even in the past 10 years, companies are still choosing to charter poorly rated (E, F & G) ships which inevitably costs them more money in fuel and external costs to the environment. We observed ships that were less than 10 years old, less than 5 years old, and even less than 3 years old still receiving these poor ratings. If no regulations are put into place and ships are still being built that have high environmental impacts, then we are not working toward reducing GHG emissions but instead just looking to make a quick buck. There could potentially be programs in place- "green practice incentive" programs- in order to reward those who are implementing practices such as slow steaming which are aiding in the reduction of GHG emissions. The ships with ratings A-D could find incentives through ports for their "green ship practices". Not only would A-D rated ships benefit but hopefully this would also incentivize E-G rated ships to improve their practices so that they too can reap the benefits of green practice incentive programs.

While we consider there are other options to how ships can get lower or higher emissions ratings such as route, weather, or time sensitive charters, the dry-bulk carriers are able to improve their GHG ratings by reducing speed and saving emissions and fuel. In future research, it would be helpful to be able to focus on dry-bulk carriers which have specific routes: transAtlantic and transPacific. Future research in this area could potentially lead to solving other issues, such as green ship routing.

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