BetterFleet: Data and Method

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This document provides an overview of data and analytical techniques used to calculate BetterFleet information. The techniques described here are based entirely on publicly available data and peer-reviewed analytical techniques to provide universal, robust, and publicly accessible operational efficiency information for the world's shipping fleet.

BetterFleet information is unlikely to match the accuracy of directly measured data and is not intended as a replacement for shipboard data collection and analysis systems. Rather, it provides a universal starting point for understanding the operational efficiency of individual vessels in the context of the larger fleet and where opportunities may be for improvement.

Operational efficiency calculation method

The BetterFleet portal displays several key metrics to indicate and compare the operational efficiency of ships. These are all based fundamentally on the Energy Efficiency Operational Indicator (EEOI). The EEOI measures the efficiency of "transport work" done by a ship by comparing the amount of freight moved to the amount of CO_2 emissions required to move it. The EEOI can be calculated from any timeframe, but is most comparable among ships across multiple voyages. The EEOI, expressed in units as grams of CO_2 per tonne mile ($gCO_2/t.nm$), is calculated by summation over the period of interest according to the following equation:

$$EEOI = \frac{\sum F \cdot C}{\sum m_{cargo} \cdot D}$$

Where:

- F = mass of fuel consumed
- C = fuel mass to CO2 mass conversion factor
- m_{cargo} = mass of cargo carried
- D = distance that the cargo is carried

Estimating the numerator - fuel consumption and CO2 emissions

In the BetterFleet calculations, data for the speed and position of a vessel are taken from the AIS data to calculate fuel consumption and distance travelled. Fuel consumption is estimated from these observations of the speed of the ship and if available, draught. These variables are used as inputs to a model that incorporates both engineering and statistical approaches for representing how

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operational parameters (speed and draught) influence the fuel consumption of the ship. In addition to operational parameters speed and draught, weather, hull and propeller fouling and machinery deterioration can also influence the fuel consumption of a ship. To allow for the effects of weather, an annual aggregate factor, defined in Smith et al. 2014 (method), is used to increment the ship's fuel consumption. Two different factors are derived from literature and deployed depending on whether the ship is operating predominantly in coastal waters or open ocean. For the consequences of hull fouling, an average additional added resistance is applied, along with the assumption that a ship is maintained to achieve this average. This means that if a ship is specifying or maintaining its hull and propeller to above average standards, the BetterFleet calculated fuel consumption will be an overestimate.

The ship's calm water, clean hull resistance and powering requirements are taken from its fleet registry data – including the installed power of the main engine, reference speed, deadweight. Consequently, if there are errors in the values in the fleet registry, or if the ship has been changed (retrofitted) since this data was recorded, then this will also affect the BetterFleet data. There are a number of options of how this can be addressed which are currently being considered.

Detecting based on the sea area in which the ship is operating, the model applies different assumptions about the fuel that is being consumed – when the ship is in an ECA where the sulphur requirements are currently more stringent, then if the ship conventionally consumes HFO, the fuel will be switched to MDO/MGO and the CO_2 emissions factor modified accordingly. If a ship is using an exhaust scrubber to comply with the ECA sulphur regulation, then this will have a slightly different consequence on CO2 emissions that will not be captured. Ships with LNG machinery are assumed to be consuming LNG in both ECAs and open ocean.

BetterFleet includes estimates for fuel consumed in all relevant ship's machinery: main engines, auxiliary machinery and boilers. The main engine fuel consumption is calculated in most detail because it is also, normally, dominant. The auxiliary and boiler fuel consumption are derived from assumptions about the amount of fuel consumed in this equipment at different states (at berth, at anchor, sailing at different speeds), and the amount of time (derived from AIS) the ship spends in those different states. This approach also means that if an individual ship has taken steps to manage its auxiliary and boiler systems more efficiently than the average ship, then BetterFleet will currently overestimate its fuel consumption and CO_2 emissions.

This approach, used in BetterFleet for estimation of fuel consumed, and the corresponding CO_2 emissions, is derived from the approach used in the Third IMO GHG Study and detailed in Smith et al. 2014: Section 1.2 and Annex 1(method).

Estimating the denominator – transport work

Cargo mass can be estimated using the ship's draught value reported by AIS, see Jia et al. 2015. However, often a ship's AIS reported draught data is not reliable and cannot be used for this purpose. Therefore, for the BetterFleet EEOI values, fleet average utilization values (representing loaded/ballast and average payload mass when loaded) are calculated from the subset of ships with AIS reported draughts that are evaluated to be reliable, and applied consistently in the following way:

$$m_{cargo} \cdot D = dwt \cdot D \cdot \eta_p \cdot \eta_a$$

Where:

dwt = ship's deadweight

η_p = payload utilization (average ratio of average cargo payload to dwt)

η_a = allocative utilization (average ratio of loaded distance to total distance travelled)

For the distinction between loaded and ballast voyages, it is assumed that there are two categories of ships:

- ships that operate part of the time loaded and part of the time in ballast (category 1 in Figure 1)
- ships that operate most of the time between part-loaded and fully loaded (category 2 in Figure 1)

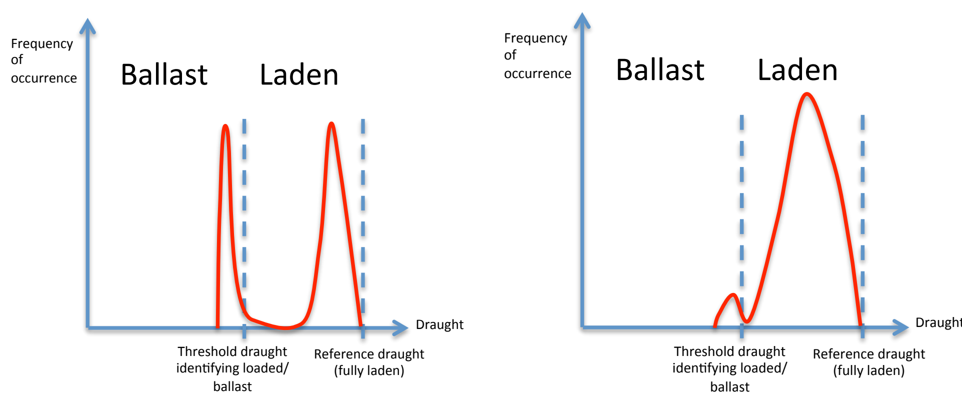

Figure 1: representative draught histograms for category 1 (left) and category 2 (right) ship types

The category 1 ships have a clearly identifiable peak in the frequency of occurrence associated with both their laden draughts and their ballast draughts. The category 2 ships often do not have such a clearly identifiable peak associated with ballast draughts (or in many cases may have no operation with no cargo). This categorization is applied to the BetterFleet ship types, listed in Table 1.

Table 1: Categorisation of ships for loaded/ballast classification

Category 1	Category 2
Bulk carriers	Container ships
Oil tankers	

These data and methods have produced a high-level of agreement with a variety of validation data, including port lineups, fixtures, and a ship's noon report data, for details of estimation validation, see Jia et al. (2015), and Smith et al. (2015).

Data Sources

BetterFleet achieves worldwide, universal coverage of ships by using two primary data sources: Automated Information System (AIS) data and static information on individual ships from a fleet registry.

AIS is a radio-frequency based communication system that broadcasts a range of details about a ship's position and operating details. Mandated by IMO beginning in 2004, AIS was primarily intended to enhance collision avoidance and improved security. AIS systems broadcast more or less continuously and automatically, allowing nearby ships and shore-based receivers to collect position data for the range of vessels in the vicinity. Beginning in 2008, the messages broadcast by AIS began being collected by satellites for government and commercial purposes, eventually leading to worldwide coverage.

BetterFleet uses AIS data collected by exactEarth, a commercial provider with comprehensive data from both satellite and shore-based sources. Raw data from exactEarth is processed with algorithms that screen for major anomalies, outliers, and missing data. This data is matched to individual ship information from VesselTracker's fleet registry database, and fed into models to estimate transport work, fuel consumption, emissions and energy efficiency as described above. The data types used correspond closely to data sources described in Smith et al. 2014, and Smith et al. 2015.

Modelling and Validation

This section provides greater detail on some of the modelling approaches used, and the validation of these approaches.

Pre-processing of model input data

At the core of the BetterFleet estimation is data that describes a ship's activity and operation over a course of a year. This input data is not perfect and requires processing and interpolation/extrapolation to account for periods when there is missing coverage (e.g. because the ship is not within range of a satellite or shore-station).

To illustrate this, Figure 2 presents a time-series of annual operation data for an example ship for which we also have data available from a shipowner containing onboard measurements collected through a data acquisition system. The graph shows speed in knots on the y-axis, against time on the x-axis. In the top plot, the ship's Speed Over Ground (SOG) measured onboard using a GPS in red, is contrasted against AIS reported, and extrapolated (modelled) estimates of the ship's speed in blue. There are a few periods where the AIS coverage is missing and even in some places for a number of days data is extrapolated so that a continuous hourly time-history of speed can be obtained. The lower plot shows the deviation between this modelled speed time-history and a ship's onboard measured time-history. Whilst there can in any one hour be significant differences, the median deviation is approximately zero, which explains how when the data is aggregated to an annual value (e.g. annual EEOI), as it is in most of the BetterFleet calculations, the quality is appropriate for the tool. Whilst the shape of the hourly energy efficiency histogram should be representative, there will be errors that are present in this diagram and so it should be treated as indicative rather than precise.

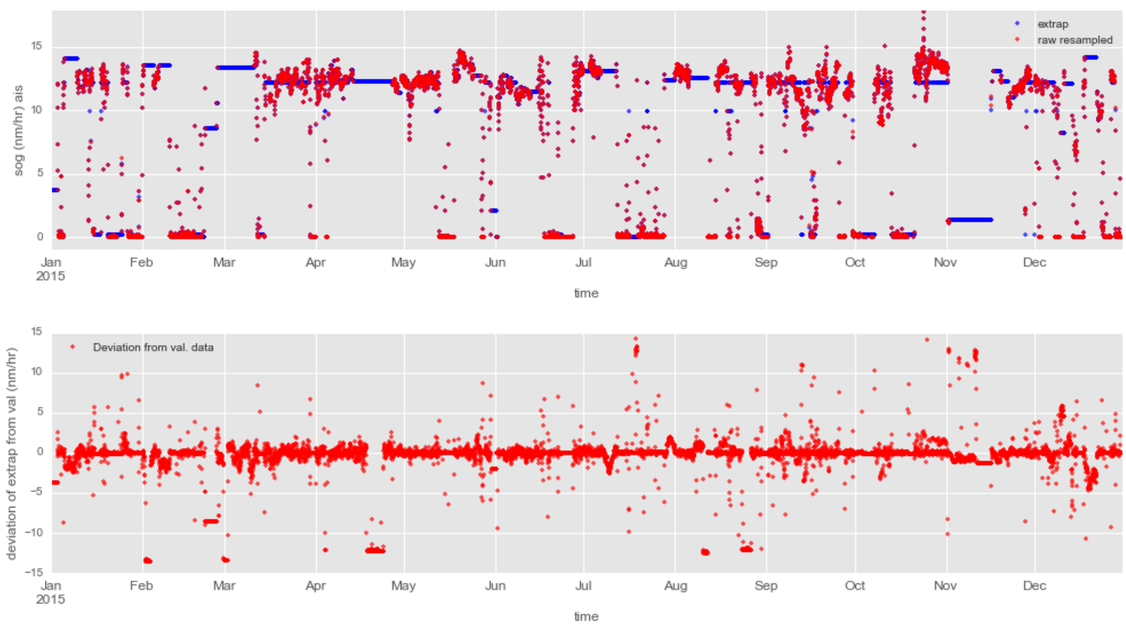

Figure 2: speed time series from AIS and onboard measurement

Where a ship is sailing in currents further discrepancies between SOG and STW (Speed Through Water) occurs, which is important because STW is the parameter that determines a ship's hydrodynamics resistance. Correction to convert SOG to STW is being explored in research versions of the algorithms behind BetterFleet, but is not corrected for in the current release, instead the average impact over the course of the year of currents is assumed to be managed within the annual average weather impacts factor.

Data from the same example ship that is used in Figure 2 is plotted in Figure 3 to provide another evaluation of the effects of the AIS coverage issues on the model's performance. The AIS derived data is shown in red and the ship's onboard measured data is shown in blue. The chart shows that whilst the AIS dataset has observations available for fewer than 50% of the hours (a_observed), the modelled speed and activity data still provides a good representation of time at sea (t_time_sea), and the main engine's HFO consumption – with the method behind BetterFleet estimating less than 10% discrepancy than the onboard measured values.

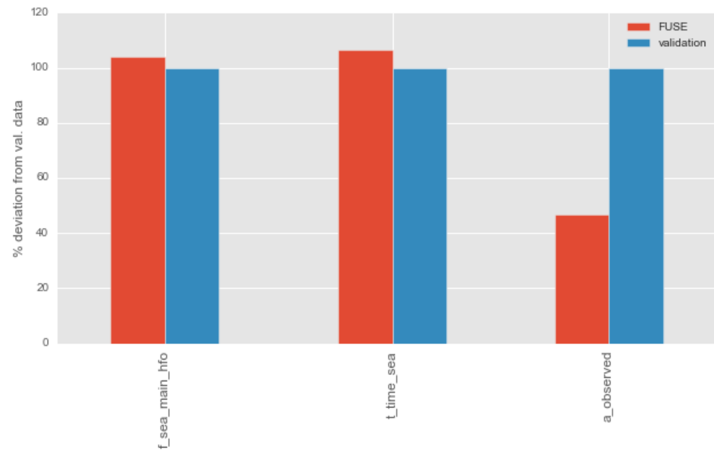

Figure 3: Comparison of fuel consumed, time at sea and AIS coverage

A sample of one ship's results does not prove accuracy fleet wide, and for all the reasons described in the methods section, any individual ship could be misrepresented in the BetterFleet data. Figure 4 displays the comparison for approximately 150 ships of different ship type, between onboard measurements of fuel consumption (x axis) and estimates produced from similar algorithms to those used to populate BetterFleet (y axis). Both over each of the four quarters of the year 2012. The graph is taken from the Third IMO GHG Study, which compiled significant operator data for the year 2012 to enable this validation exercise. The results confirm the expectation based on the method, that there are some ships which have modelled results that are significantly different from the data measured onboard. However, that the majority of ships have a good agreement.

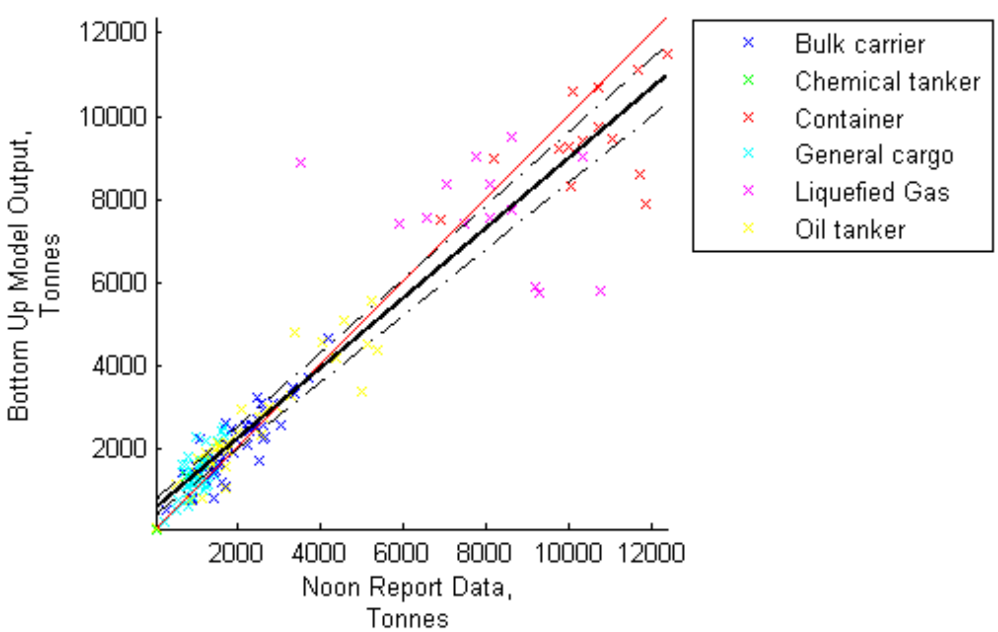

Figure 4: total noon-reported quarterly fuel consumption of the main engine, compared with the bottom-up estimate over each quarter of 2012, with a filter to select only days with high reliability observations of the ship

Further insight into accuracy can be obtained from Figure 5, also extracted from the Third IMO GHG Study 2014. In order to try and quantify the magnitude of the uncertainty in the modelled estimation of CO_2 emissions, an estimate of each of the component sources of uncertainty was undertaken (e.g. the estimate of uncertainty caused by the use of SOG instead of STW, the uncertainty created by the use of partial AIS coverage). These component uncertainties were then combined in a Monte Carlo simulation of the CO_2 estimation system. The results for each ship type and size category were calculated, and Figure 5 presents just one indicative example for the panamax bulk carrier. The result suggests that the uncertainty in annual aggregate estimated CO2 emissions (the numerator of the EEOI equation), for the average ship, should be approximately 10% (to a 95% confidence interval).

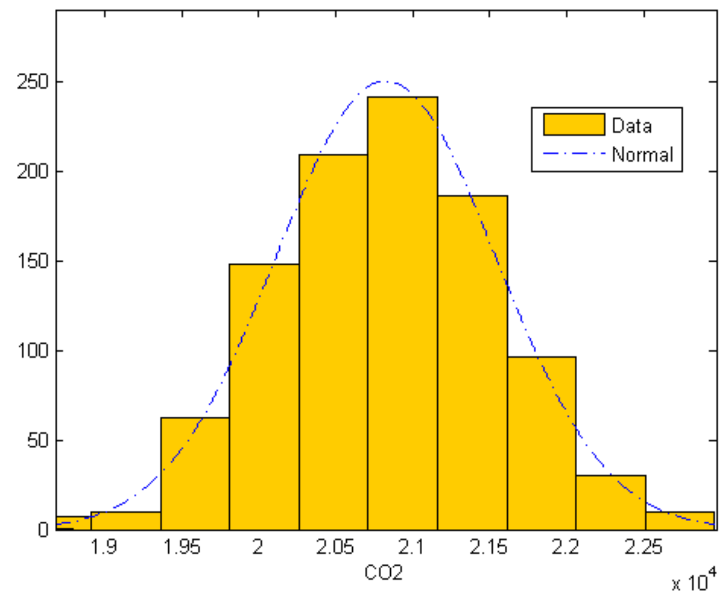

Figure 5: Uncertainty distribution in annual CO2 emissions, y axis is frequency, from a Monte Carlo simulation of an 'average' panamax bulk carrier in 2012

The detailed in Smith et al. 2014: Section 1.4, 1.5 and Annex 3 and 5(quality assurance and uncertainty).

In general, this evidence provides several reasons why it is appropriate to use these estimated fuel consumption and EEOI quantifications to understand the variability of different ship's operational efficiency - because in general the uncertainty is of a smaller magnitude than the variability which is of interest (the variability in energy efficiency of a peer group of ships, or of a ship over the course of a year).

However, the evidence also shows why it is understandable if individual ships are estimated in BetterFleet to be performing significantly better or worse than as measured in practice. For this reason, BetterFleet data should be the start of a conversation, rather than a conclusion or a judgment.

References:

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