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# Operational Measures For Energy Efficiency In Shipping

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## HIGHLIGHTS

- Awareness of fuel efficiency is rising within the maritime industry and becoming more and more important.
- Operational efficiency has lots of aspects which can be investigated to reduce fuel consumption.
- Significant reductions in fuel consumption and emissions can be achieved by implementing various operational measures .

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## ABSTRACT

The aim of this study is to identify potential solutions to improve energy efficiency of the existing ships. To have an Ship Energy Efficiency Management Plan (SEEMP) on board has become mandatory for all ships starting from 1 January 2013. Increasing fuel prices and growing environmental concerns are driving the shipping industry to be more efficient. Therefore it is necessary to develop energy efficient operational measures.

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## 1.Introduction

Energy efficiency and environmental performance are mainstream issues for ship operators who are aiming through low carbon shipping and cost reductions. Although reducing fuel consumption seems to have priority, environmental considerations also push the shipping industry to operate in more efficient way. Strict legislations on GHG emissions and increasing fuel prices turn the focus on energy efficiency and fuel consumption measures.

These financial and environmental motives behind energy efficiency resulted in numerous investigations to find technical and operational measures which increase overall fuel efficiency and reduce emissions. It has been suggested that there is high potential of efficiency improvement and reduce emissions rate by 25% to 75% compared to current figures. (IMO, 2009)

Efficient ship operation is essential for cleaner voyages at oceans and ports around the world. This will not only enable ships to be greener but also maintain the whole value of the ship.

## 2. Fuel Efficient Operations

Constant increases of fuel prices and new regulations on environmental impact of ships have made fuel oil consumption management a necessity for ship owners. Awareness of fuel efficiency is rising within the industry and becoming more and more important.

Saving fuel at operational stage may be possible for all ships. However, there are many different variables affecting the energy efficiency as shown in figure below and it is not

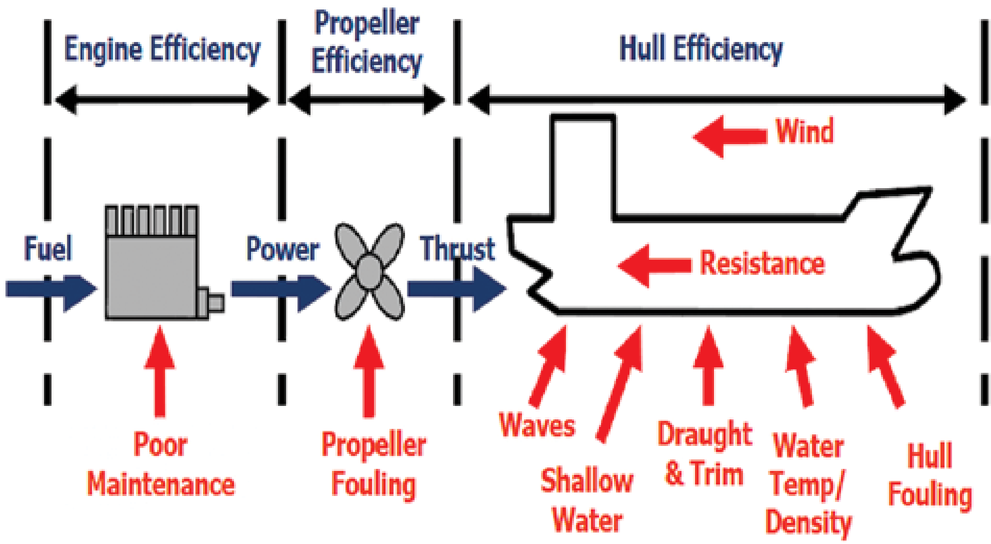


***Figure 1*** *Variables influencing energy efficiency (Pedersen BP, 2009)*

an easy task to define the relationship between fuel efficiency and operational conditions. It can be said that overall efficiency of the vessel may be divided into two parts which are hull efficiency and power and propulsion system efficiency. At operational stage, hull efficiency is affected by wind, resistance, waves, draught, trim, water condition (depth, temperature etc.) and hull fouling. Propeller fouling and engine maintenance performance are other factors which can affect power and propulsion system performance.

Therefore, operational efficiency has lots of aspects which can be investigated to reduce fuel consumption. Under these conditions, a large number of different methods have been applied and experienced to reduce the fuel used by vessels over the last couple of years. Some of these measures can be listed as:

*Voyage planning
*Weather routing
*Virtual arriving
*Slow steaming
*Hull and propeller cleaning
*Ballast and trim optimisation

Most of these methods can be implemented with low capital investment cost to increase operational efficiency. It is necessary to discuss these methods in depth to have a better idea of which benefits can be gained through implementation.

### 2.1. Voyage Planning And Virtual Arrival

Careful planning and execution of voyage may provide optimum operational efficiency and thus savings on fuel consumption. Voyage planning for efficient operation may include measures such as virtual arrival, weather routing and just in time operation, within the constraints of scheduling and contractual agreements.

Voyage planning may have significant impact on fuel consumption. Figure 2 above shows an example of variation of total amount of fuel for same voyage and same size of ships. It can be seen that almost 30% difference on fuel consumption can be found between same sized ships on same voyage.

Overall transport efficiency of the ship is affected by time spent in port as well; therefore early communication with next port regarding berth availability is important to reduce waiting times at anchor. Other than that, good communication with tug operators, pilots, bunker suppliers and other service providers may have a role to play in minimizing port time too.

Just-in-time arrival, considering tides, queues, and arrival might be beneficial as

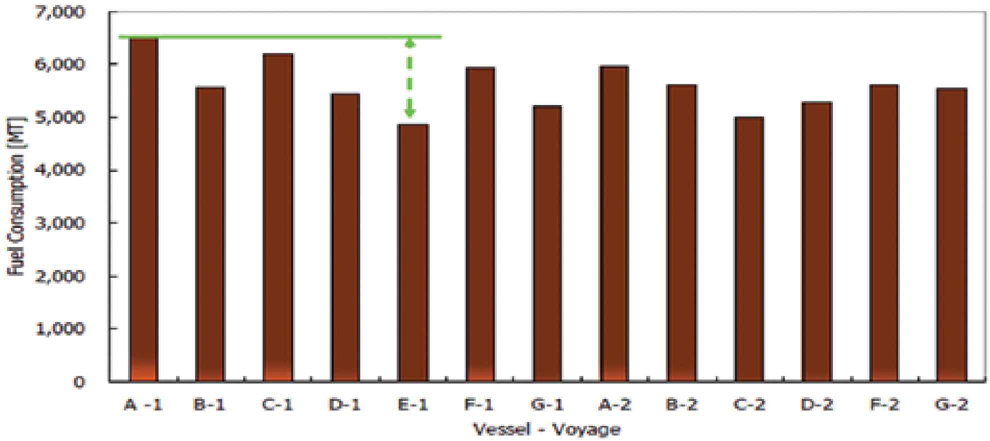


***Figure 2** Fuel consumption – Voyage comparison (Ando, 2011)*

well. Optimising vessels speed due to berth availability rather than sailing at normal speed and waiting at anchor would result in lower fuel consumption and GHG emissions. However, incentives and contractual arrangements are essential for this type of operation and require a change to usual spot charter applications. For instance, severe penalties for late arrival discourage just-in-time operation. On the other hand, it is successfully being pioneered in oil tanker industry with virtual arrival initiative by Intertanko (Fathom Shipping, 2011).

Voyage planning and virtual arrival are very similar measures and it is mostly about managing time and managing speed.

Voyage planning example is illustrated in Figure 3 and it states that insufficient information and lack of communication with next port causes waiting times which increase fuel consumption and costs. If the vessel has the accurate information about available berthing slot time, it can adjust an appropriate lower speed and therefore waiting at anchor can be avoided by slow steaming while reducing fuel consumption.

Virtual arrival is considered as a voyage management optimization tool which aims

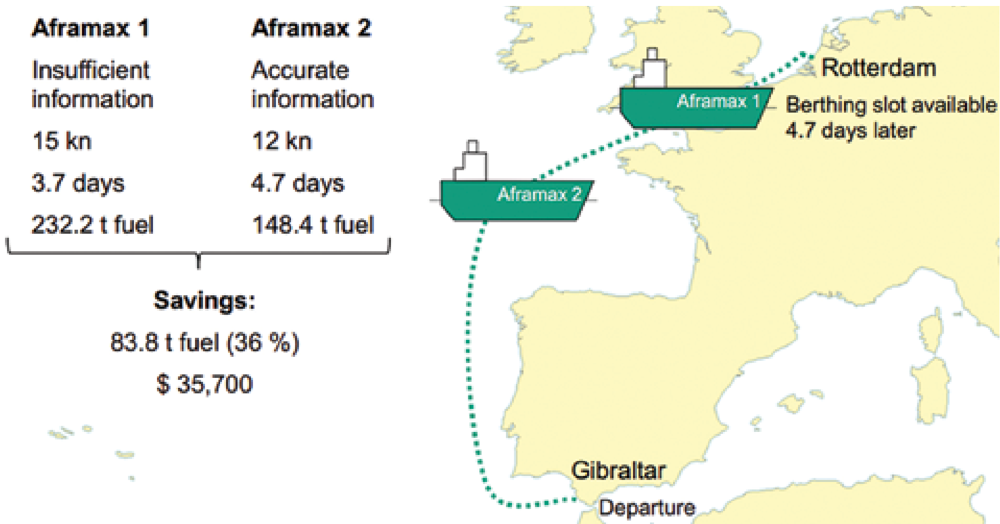


***Figure 3** Voyage planning example (Jahn, 2011)*

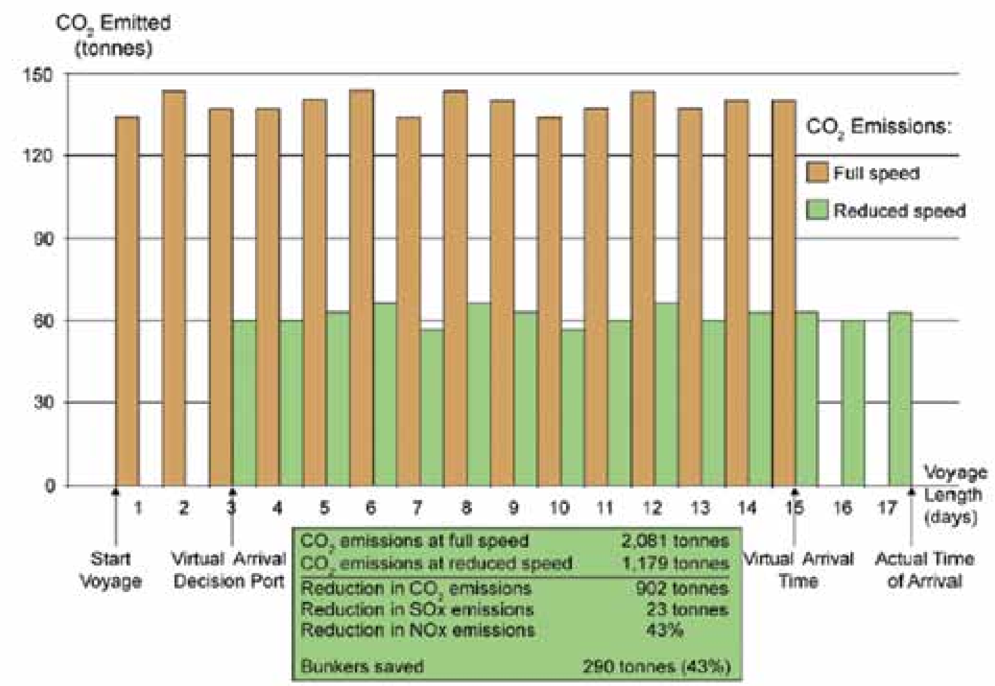


***Figure 4*** *Virtual Arrival impact on reducing emissions and fuel (Intertanko, 2010)*

to improve overall efficiency by identifying delays at discharging ports and then managing the vessel's arrival time at that port/terminal through well managed passage speed. Therefore it aims to reduce emissions and fuel consumption without reducing cargo capacity. Figure below illustrates virtual arrival impact on reducing emissions and bunker consumption.

Virtual arrival aims to provide a win-win situation for all of the parties included. Intertanko explains it as "charterers may be able to offset their demurrage liability, owners may be able to reduce their bunker costs, ports may be able to reduce emissions in their local area, and there are potentially carbon savings through reduced fuel usage." (Intertanko, 2010)

## 2.2. Weather Routing

Weather routing has a long tradition in shipping history. In the past, weather routing has been used mostly to avoid severe weather. The developments in technology revealed more benefits of weather routing such as savings in operating costs, time reductions and increased safety. Weather routing, includes selecting optimal routes based on weather conditions and currents to reduce energy consumption. (Bowditch, 2002) Main principle of weather routing is developing an optimum route based on weather forecasts, sea condition and vessels specific characteristics as well.

Weather routing service providers require comprehensive information, including detailed ship performance models to calculate the best route for each weather and vessel type. In addition, the calculations should take into account the individual vessel's RPM, speed and fuel oil consumption, as well as ship motion and performance in severe weather. It would be possible to identify ideal speed of the vessel for different conditions by using that information.

Navigating with traditional routing, for example, is biased towards choosing the shortest route option, except for a few extreme situations. Weather routing; on the other hand, can indicate that in some situations a longer route can actually be covered with a lesser bunker consumption (A. M. S. Delitala, 2010). This method aims to avoid, reduce or benefit from weather and sea conditions by issuing initial route recommendations both before sailing and while on passage if poor weather and sea conditions are expected to be encountered. Those conditions which could not be avoided by diversion but could cause damage, reduction in speed, increase in fuel consumption and time loss. Weather routing would support ship captains virtually all the time about the adverse effect of wind and sea conditions.

Some of the biggest shipping companies such as Maersk and NYK consider the use of weather routing to be highly effective in terms of operational efficiency. In conclusion, weather routing is possible for all types of ships and has the potential to achieve substantial savings and emission reductions as high as 2 to 4 per cent due to reduced fuel consumption (E. H. Green, 2008).

### 2.3. Speed Optimisation

Speed optimisation is an essential part of the fuel efficient operations. IMO describes optimal speed as "the speed at which the fuel used per tonne mile is at a minimum level for that voyage. It does not mean minimum speed; in fact sailing at less than optimum speed will burn more fuel rather than less."

Engine manufacturars state that vessels with only one main engine will probably gain the most from a speed reduction if the engines load program is also modified for the new speed. (Wartsila, 2009)

As part of the speed optimization process, it is necessary to take measures to coordinate arrival times with the availability of loading and discharge facilities and sailing at constant speed until arrival. Maintaining a constant vessel speed would be possible by planning ahead to ensure that loading and discharging schedules are still met with the least amount of fuel consumed. Fuel consumption increases disproportionally at higher speeds therefore it is crucial to avoid unnecessary speeding even for a short time as increased consumption cannot be compensated by slow steaming.

It should be mentioned that most ships are optimised for a certain speed, and steaming at lower speeds which can be called off-design conditions, may have unexpected consequences in terms of engine maintenance, auxiliary machinery and boiler efficiency and thus fuel consumption.

| Ship speed | 24 knot | 20 knot | - 16 % |
|---|---|---|---|
| M/E fuel consumption | 225 ton/day | 130 ton/day | |
| M/E fuel cost (@ 600 USD/MT) | 134,800 USD/day | 78,000 USD/day | - 42 % |
| CO2 emission | 696 ton/day | 403 ton/day | |

***Figure 5*** *Cost benefit and emission reduction by slow steaming for 8000 TEU Containership*

Potential fuel and emission savings of slow steaming are considerably high. A share of these savings has already been achieved, as many shipping companies have announced slow steaming (see e.g. Maersk, 2010 Cosco, 2009). It can be observed from the figure above that 42% reduction in bunker costs and CO2 emissions is possible by reducing vessels speed by 16%. Maersk states that 20% reduction in vessel's speed will lead to 40% less fuel consumption, hence reducing CO2 emissions correspondingly. It continues as "to maintain the same service frequency and compensate for a lower average speed, 1-2 extra vessels are added per route, or string. Despite the extra vessels, slow steaming has over the last 1½ year reduced Maersk Line's CO2 emissions by about 7% per container moved" (Maersk, 2010). It is possible to say that slow steaming has been practised mostly by container shipping companies.

### 2.4. Hull And Propeller Cleaning

Hull and propeller condition have significant impact on fuel consumption. Main reason for that is marine growth on ships hull and propeller. The most visible forms of these fouling are barnacles and shells which reduce vessels efficiency substantially. These marine growths create a rough surface on the hull which increases resistance of the vessel. Therefore extra fuel is being consumed to overcome that resistance and maintain vessels speed. Regular maintenance and cleaning of hull and propeller may help to achieve a cost effective solution for better operational efficiency.

Hull and propeller roughness increases the frictional drag of the vessel, therefore increases fuel consumption. IMO states that hull and propeller cleaning may increase fuel efficiency significantly. Hull cleaning and propeller polishing which reduces fouling and roughness may provide up to 10% savings in fuel consumption. Therefore monitoring performance of the hull and propeller is crucial for operational efficiency.

Research performed by DNV states that different types of fouling have different impact on fuel consumption as shown in graph below. It can be seen that dense barnacles on hull may increase fuel consumption substantially. Power demand increases of 20% in two years time have been reported due to fouling.

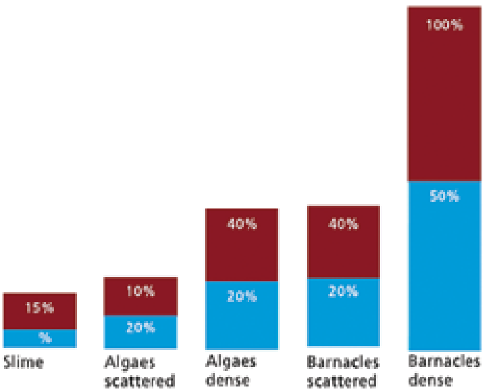


***Figure 6*** *Fouling impact on fuel consumption (CleanHull, 2012)*

Fouling can easily be cleaned at dry-dock or even underwater by divers or ROVs.

### 2.5. Ballast And Trim Optimisation

Ships optimal position in the water considering the operating condition in terms of ballast, cargo and bunker relation has significant impact on the resistance and thus fuel consumption. For any given draft value there is an optimum trim to minimise the resistance. There are different software tools available to install on board to assist the crew to find the optimum trim and reduce consumption and emissions.

## 3. Energy Efficiency Operational Indicator (EEOI)

Energy Efficiency Operational Indicator guidelines have been developed by MEPC as a monitoring tool for measuring each ship's energy efficiency on a specific voyage or over a certain period of time. As mentioned above, SEEMP will be mandatory for all ships starting from 2013 and EEOI may be a useful tool for monitoring operational energy efficiency performance as suggested by IMO.

EEOI principle is based on the ratio of mass of CO2 emitted per unit of transport work. Vessel's specific operational data is necessary to calculate EEOI. The unit of EEOI is determined by carried cargo measures (tonnes) or work done in case of container ships or passenger ships. EEOI formula for a voyage can be expressed as follows:

where:

$$EEOI = \frac{\sum_i FC_i \times C_{carbon}}{\sum_i m_{cargo,i} \times D_i}$$

FCi represents consumed fuel on voyage i;

Ccarbon is the carbon content of the fuel used;

mcargo,i is the mass of cargo transported on voyage i; and

Di is the distance of voyage i.

It is possible to say that smaller EEOI value means a more energy efficient voyage. This formula can be adapted for multiple numbers of voyages and an average EEOI value can be obtained for a period of time.

EEOI itself is not mandatory however monitoring the efficiency of implemented

measures is an important part of SEEMP. Therefore, performing EEOI calculations would enable the operators to measure the fuel efficiency of a ship in operation and to analyse the effect of any changes in operation such as improved voyage planning or hull and propeller cleaning etc. It can be expected to see that more ship owners and operators will start to collect necessary data and experience EEOI calculations with mandatory regulation of SEEMP. Continuous performance monitoring and identifying the positive or negative effects of implementations can be achieved by EEOI application. As a result, the impact of the EEOI would be beneficial to achieve improved operational measures.

## 4. Discussions and Concluding Remarks

This study has focused on operational measures to improve energy efficiency. Fuel efficient operations such as voyage planning and virtual arrival, weather routing, speed optimisation, hull and propeller cleaning were explained and discussed. Examples have been given to provide up to 40% reductions in fuel costs by voyage planning and virtual arrival which are all about managing time and speed. Examples from the industry were given for speed optimisation and hull and propeller cleaning to show how big achievements can be gained.

EEOI was explained as it is suggested by IMO to act as a monitoring tool to measure the fuel efficiency of vessel operation. It can be said that EEOI value is heavily dependant on carried cargo on the voyage. Establishing a dynamic EEOI monitoring system on board based on fuel consumption and loading condition may be beneficial to observe efficiency performance for each ship on each individual voyage.

Shipping industry needs to take serious action as fuel-oil prices are currently at high levels and it is not expected to drop in forthcoming years while higher bunker costs are predicted in the future. Growing environmental concerns and new regulations on shipping to reduce its emissions are other factors which push the industry to be more energy efficient. To cope with high fuel prices and upcoming regulations this study has shown that significant reductions in fuel consumption and emissions can be achieved by operational measures which are broadly applicable and easy to implement.

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