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# Approaches to a greener DP vessel

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## Abstract

The shipping industry is facing both business and regulatory pressure to improve the environmental performance and reduce the carbon footprint. Despite a drop in oil prices, the fuel still account for the majority of the operating cost and several measures have been proposed and implemented to increase the business margins.

Typically, vessels equipped with a system for dynamic positioning has a different operational pattern than traditional vessels that spend most of the fuel during transit and optimize for minimum amount of time in port. Meanwhile, a DP vessel can spend equal (or less) amounts of time on DP as in transit. In addition, DP vessels have a more complex power system with safety and redundancy concerns.

This paper will outline different methods and applications that, either independently or in combination, save energy and fuel costs during operation of a DP vessel. We will pay particular attention to digital solutions for existing vessels. The paper presents among other things a weather optimal positioning system and data logging opportunities, and describes how a solution may affect the vessel's environmental performance. Finally, the paper addresses the importance of the human factor.

## Introduction

Rules, regulations and business pressures the shipping industry to develop and operate vessels with a smaller environmental footprint. A large effort within maritime research and development is devoted to greener, smarter and safer vessels that perform environmentally better than before. In the context of our paper, a DP vessel is equipped with a dynamic positioning system intended for offshore work.

A green vessel may perform better with respect to lower CO2 or particle emissions. The vessel can operate close to the optimal efficiency level, built to accommodate a longer life span or simplify recycling of components and materials.

This paper primarily considers ways to improve fuel efficiency that also results in better CO2 performance for DP vessels. We will discuss the operational gains from certain equipment, benefits from software systems and operational changes for existing vessels. The paper will not go deep into design changes, fuel quality and vessel lifetime analysis although all those topics have a serious effect on the vessel environmental footprint and should receive proper attention.

We will mention technical upgrades for retrofit and possibilities for new builds but will concentrate on software systems that can significantly reduce the environmental footprint at a relative low cost. We will also argue that the human factor is the most important component and that we can achieve a greener DP vessel without investing in new equipment. Similarly, the full potential of energy savings may be lost if new equipment and systems are installed and not properly operated or planned for. Proper usage comes from motivated personnel, and that relies on a set of incentives.

By constantly motivating different levels in the organization, the right incentives are key to realize the full, long term, energy savings potential. The ship owner adheres to rules and regulations, may save money through lower harbor rates and fuel costs, and may get a better chance at new business opportunities.

## Regulatory Background

The Kyoto Protocol is an international treaty that commits states to reduce greenhouse gases emissions. Within, IMO is mandated to deal with international shipping GHG emissions. The Paris agreement were adopted in December 2015 and will from 2020 aim to reduce greenhouse gases emissions to hold the increase in global average temperature below 2 degrees Celsius.

Shipping is very energy-efficient in terms of g/km (higher oil prices led to slow steaming) but the industry is facing increased scrutiny to lower greenhouse gas (GHG) emissions.

The International Maritime Organization (IMO) published the Third IMO Greenhouse Gas Study in 2014 and estimates that international shipping emitted about 2.2% of total global CO2 emissions in 2012. They forecast that maritime CO2 emissions would increase significantly in the next decades, from 50% to 250% depending on future economic and energy developments. They expect that further developments on emissions and efficiency can mitigate emissions growth but almost all scenarios project higher emissions in the future.

The IMO has several energy efficiency measures to prevent pollution. The energy efficiency design index (EEDI) is a technical measure that requires a minimum energy efficiency per tonmile for different ship type and size segments. It is mandatory and may be an important tool during the design and construction phase. A simplified version is

$$EEDI = \frac{CO2emission}{TransportWork} = \frac{SFC \times C}{Capacity \times Vs} \left[ {}^{g}/_{tonmile} \right]$$

where FOC is the Fuel Oil Consumption, C is a conversion factor between fuel consumption and CO2 emissions, Capacity is usually the deadweight, and Vs is the ship speed. However, this is not applicable to ships with diesel-electric propulsion.

While the EEDI gives a score of the ship hardware performance, the IMO has The Energy Efficiency Operator Index (EEOI) that gives a score for the vessel's actual performance. The EEOI is voluntary and can be used to monitoring CO2 performance improvements of different efforts:

$$EEOI = \frac{FC \times C}{Cargo \times Distance} \left[ {}^{g}/_{tonmile} \right]$$

where FC is the average fuel consumption.

The Ship Energy Efficiency Management Plan (SEEMP) is an operational tool for managing the environmental performance of ships and support operational efficiency improvements. It is mandatory on all ships from January 2013 and expected to be constantly updated It may contain technical vessel-specific measures, company measures, and operator training. The main steps are

- Establish a baseline
- Identify improvement potential
- Implement and monitor
- Evaluate and update

Several studies undertaken at shipping companies and as research projects have identified and qualified savings for different measures. Some are published as guidance for best practice. See for instance the ABS report on Ship Energy Efficiency Measures, and the Fram project, http://www.theframproject.org.

While the SEEMP is ship-specific, the ship owner should have a Company Energy Management System (ISO5001) that includes fleet-level energy management. The latter needs to deal with both shore-based and ship-based energy efficiency aspects

Sulphur Emissions Control Areas (SECA) are areas with stricter controls on airborne emissions (SOx, NOx, ODS, VOC). These emissions are determined from emission and fuel quality requirements and typically less affected by vessel operational changes.

## Business background

In addition to the regulatory pressure to reduce emissions and adopt energy-saving measures, there are other incentives to reduce the environmental footprint.

Operational costs such as fuel has traditionally been the charterer's responsibility. In the future, we expect this to change somewhat for the offshore segment, such that charterer may prefer vessels with more efficient fuel consumption or assign a fixed sum for fuel costs.

The NOx tax in Norway is a tax on NOx emissions arising from propulsion machinery, large engines and turbines, and flaring on offshore installations and onshore plants. However, by reporting and paying to the NOx Fund the cost per NOx unit is lower and the companies can apply for financial support from the fund for projects they propose that reduce NOx emissions.

Additionally, there is a large list of different efficiency indicators and incentive providers

- The Environmental Ship Index (ESI) is an initiative by the International Association of Ports and Harbors. Emissions of NOx, SOx and CO2 determine the total score. Several incentive providers, among them many harbors regularly visited by DP vessels. For example, Stavanger Havn (port) offers a discount for vessel with a minimum ESI score.
- The Clean Shipping Index (CSI) is a tool to evaluate the environmental performance of sea transport ships and providers. Five groups of environmental impacts determine the score, CO2, SOx & PM, NOx, Water & Waste, and Chemicals. A network of cargo owners and forwarders manages the index. In March 2016, the Swedish Maritime Authority proposed to differentiate the fairway dues system based on the environmental scores determined with the Clean Shipping Index.
- RightShip have developed the GHG Emission Rating to rank the performance of existing vessels. A few ports use the GHG rating to offer incentives for more efficient ships.

## The DP vessel challenge

An offshore vessel equipped with a dynamic positioning system has a different operational profile than traditional vessels and faces some particular problems that not always addressed in usual energy measures recommendations.

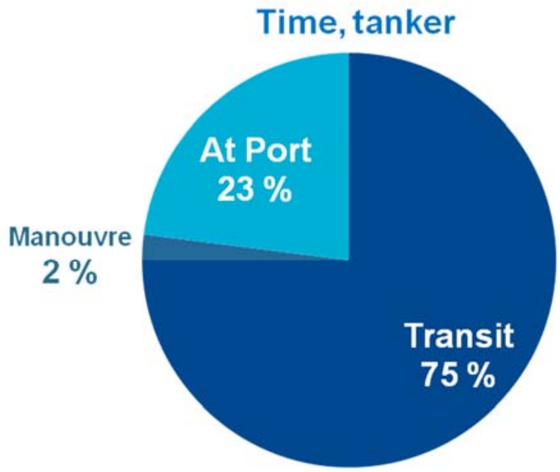
A DP vessel must prioritize safety, but this does not require full capability at all times. Redundancy requirements result in different configurations for different vessels, which makes it harder to compare vessel capability and give unified advice on energy consumption. The EEDI score intends to let customers compare the environmental performance of different vessels, but this is not applicable to DP vessels.

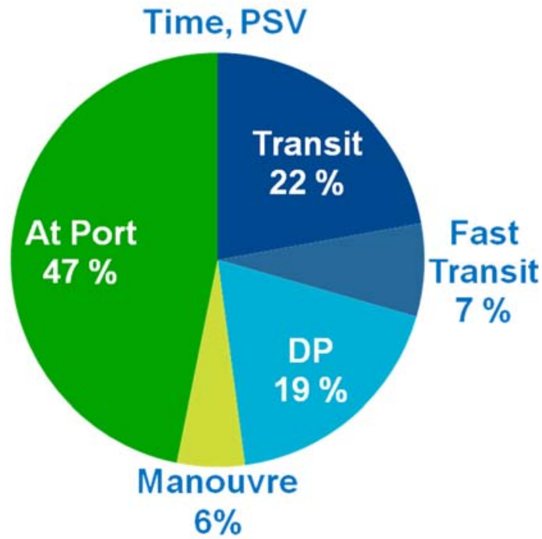
Energy savings measures usually focus on the potential during transit operations as seen in the EEOI score. DP vessels are specialized without a measurable transportation task, so the EEOI score is of limited use. To evaluate the performance of offshore operations we must consider alternate methods.

Other challenges for DP vessels are

- Different operations with varying power demand
- Spends time at sea in DP and not moving through the waves
- Shorter legs/periods in transit conditions
- Redundant power and thruster capabilities
- A large number of possible power system configurations
- Additional safety and redundancy concerns

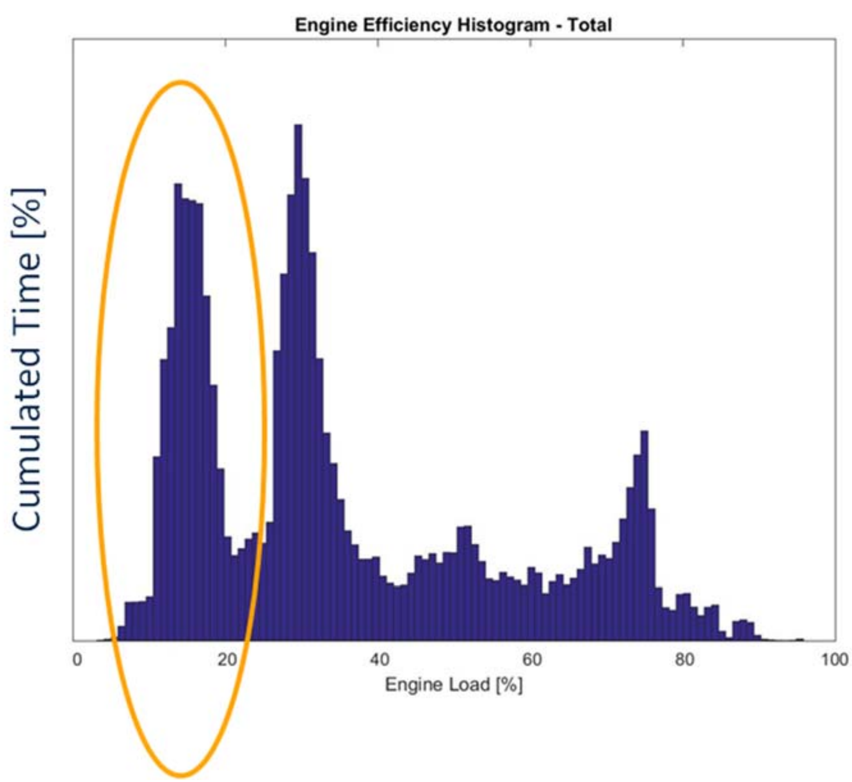
The following figure shows the differences between the operational profile of a tanker (IMO example) and an offshore supply vessel (OSV) of UT design.




The vessels spend time at sea very differently. The tanker moves on longer legs between ports while the OSV spends a significant amount of time in DP mode and moves shorter distances between several installations and ports.

The next figure shows the effect on the engines of running in DP mode. The engines are engaged to satisfy redundancy requirements. The load requirements are small and the engine working point move further away from the design condition.



## How to consume less energy

To achieve the highest potential all parts of the organization must be motivated to reduce energy consumption. The vessel, the ongoing operation and the entire organization should accommodate energy savings. Conditions for maximum savings potential are met when we

- Have equipment/systems that facilitate lower energy consumption
- Configure equipment properly for operation with lower energy consumption, and
- Plan, organize and operate to accommodate energy savings

In the following sections, we will consider the points above. First, the paper considers design and equipment opportunities for new vessels, technology upgrades for retrofit and software systems applicable to existing vessels without major overhauls and modifications to vessel and equipment. Secondly, the paper looks at the role of the shipping company and vessel crew for lowering energy consumption.

## Vessel and equipment

New builds have great possibilities for lower environmental footprint as they can start from scratch. New computational method and advances in ship design improved vessel design. DP vessels have also transitioned from diesel-mechanic to diesel-electric propulsion system with benefits in redundancy and thruster configuration options. New power system solutions are under development and testing. Engines powered by liquid natural gas (LNG) or fuel cells are in operation, but not widely adopted (180 LNG vessels ordered or in operation worldwide).

Energy storage applications on ships have great potential for reduced energy consumption and increased safety. A number of applications are available today and under development from different vendors.

- Reduce load variation and reduce load peaks by reduce starting and stopping of engines
- Ship can operate with a reduced numbers of, or without, generators running. For example, energy storage for port or at shore locations with zero emission tolerance
- Generators can run at constant load with highest efficiency
- Power system can utilize back power from crane and winch operations

The Hybrid Shaft Generator (HSG) upgrade is a modification to the power electronics system that controls the shaft generator to switchboard power flow. This means that the diesel engine and the propeller can operate at variable speeds, whilst keeping the network frequency stable and the voltage fixed. An HSG upgrade can reduce zero-pitch losses by optimizing propeller load to a lower engine rpm.

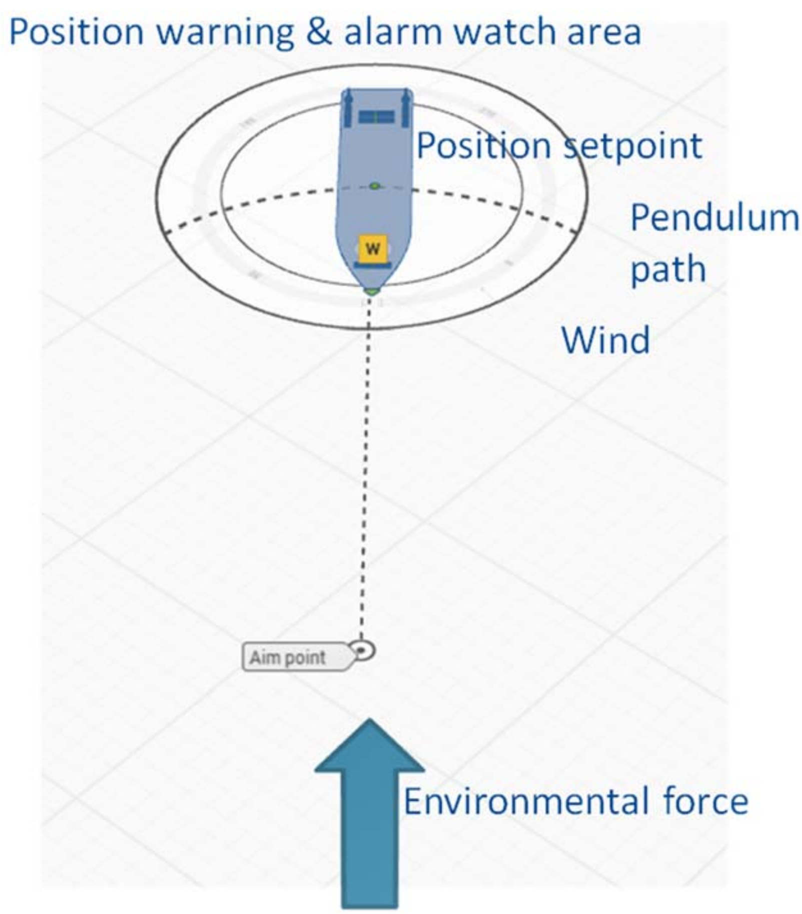
A ship owner who wants to improve the efficiency of the existing fleet has a number of technical upgrade options. Fundamentally, good maintenance is fundamental for energy efficient operation of machineries and systems. Retrofitting new equipment, thrusters and power system may improve the numbers significantly, but there also several budget-friendly possibilities that can bring down emissions.

The following will consider possible onboard software solutions where installation updates fits easily into a vessel schedule. With the ongoing digitalization of vessels, software systems may improve operational efficiency directly or provide information such that operators or vessel owner can act upon it and improve procedures.

## Weather-optimal positioning

A DP operated vessel with weather vaning capabilities can minimize the external forces acting on the vessel by changing the heading and position such that the bow faces the dominant environmental forces. This control strategy, combined with a reduced thruster, reduces the fuel consumption and emissions.

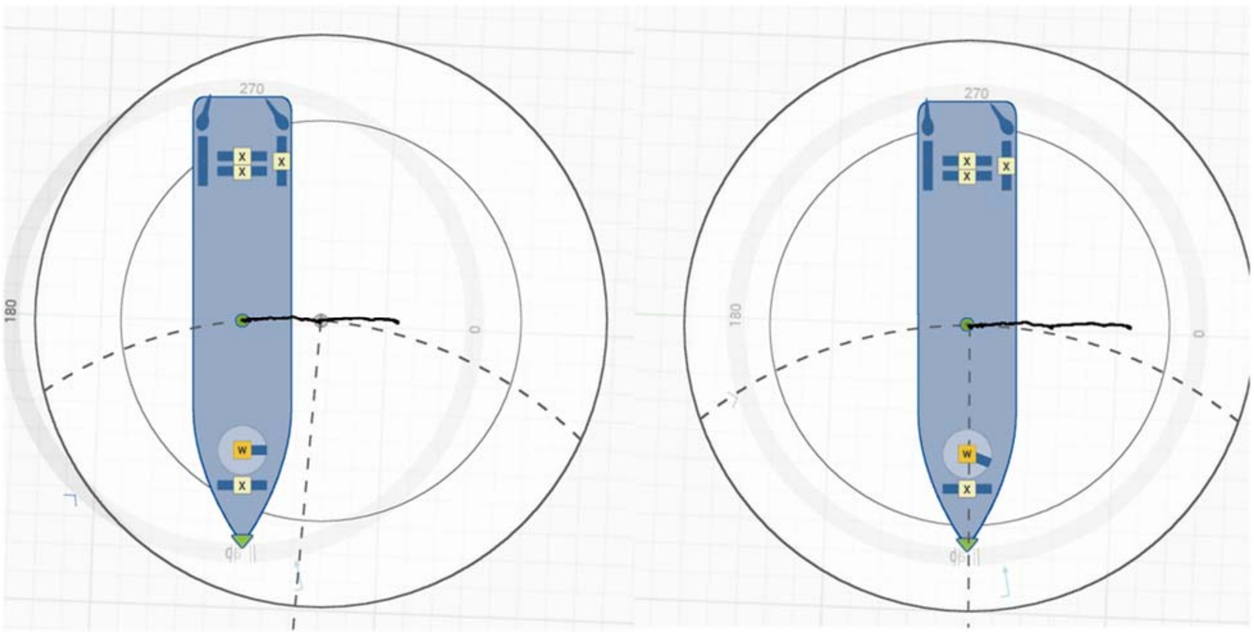
The weather optimal positioning (WOP) function uses the governing weather forces actively in the search for an optimal vessel heading. Instead of counteracting all vessel motion induced by waves, wind, and current, surge and yaw thrust is used exclusively to continuously direct the vessel heading towards a fixed aim-point while keeping the vessel position on a circular pendulum path originating at the position setpoint. The uncounteracted weather forces in sway move the vessel along the pendulum path until the vessel heading coincides with the governing weather direction.




The system maintains a heading and position precision within a prescribed area during operation but there are limitations on absolute position certainty. Given safety restrictions, we see that such a system is most suitable for standby operations for longer periods.

Upon initialization, the WOP system searches for the dominant weather direction and positions the vessel on the pendulum path with an aim angle towards the weather. The vessel remains at the position setpoint for constant weather forces. Variations in weather forces moves the vessel on the pendulum path with a heading towards the dominating weather forces. The warning and alarm watch zones are used for positioning monitoring.

If the average weather direction changes the vessel moves accordingly. The operator determines if the system can automatically update the aim angle and position setpoint at certain intervals. This enables the vessel to remain in WOP with low energy consumption for a long time. In the following figure, the dominant weather forces are not along the aim angle. The operator can update the WOP system setpoint to obtain new watch zones.




Weather-optimal positioning finds the vessel heading and position that requires the least amount of energy to stay on spot and provides a great potential for improved fuel efficiency. However, it will be more energy-efficient when combined with other measures. With WOP, the vessel is able to keep the position in the watch circle with a limited thruster configuration. The reduced demand for energy lets the operator use thrusters such that the minimum amount of power generators need to be running.

## Data collection and analysis

Vessel and voyage information has been logged and stored throughout the history of shipping. Benjamin Franklin could use speed and position data from log books to charter the Gulf Stream and promoted it to speed up delivery of mail from America to Europe, and to improve other commercial shipping. For deep-sea shipping, noon reports with vessel performance data have been prepared onboard and communicated daily to the main office through various channels.

Today, systems records different kinds of data from onboard sensors. Data can be processed to information locally or may be communicated to a central processing location onshore. Communication can be instantaneously or divided into packages.

Collecting readings from engines, power system equipment, position reference systems and sensors generate gigabytes of data. Planning and decision support systems use the available data to, for example,

- establish a vessel's operational pattern,
- identify voyage performance profile,
- find performance baseline for energy measures,
- identity trends in vessel or equipment performance, and
- detect errors and irregularities .

The operator monitors the onboard equipment using the recorded data. The unique conditions and situation of the specific vessel determine decisions on operations and maintenance. The goal is to improve availability, minimize unexpected downtime and extend maintenance intervals to fit vessel operations and equipment demand.

## Planning & decision support systems

The number of available planning and decision support systems for on- and offshore has increased over the last years. Used correctly such systems contribute to increased efficiency by distributing and optimize workload for different parts of a vessel or organization.

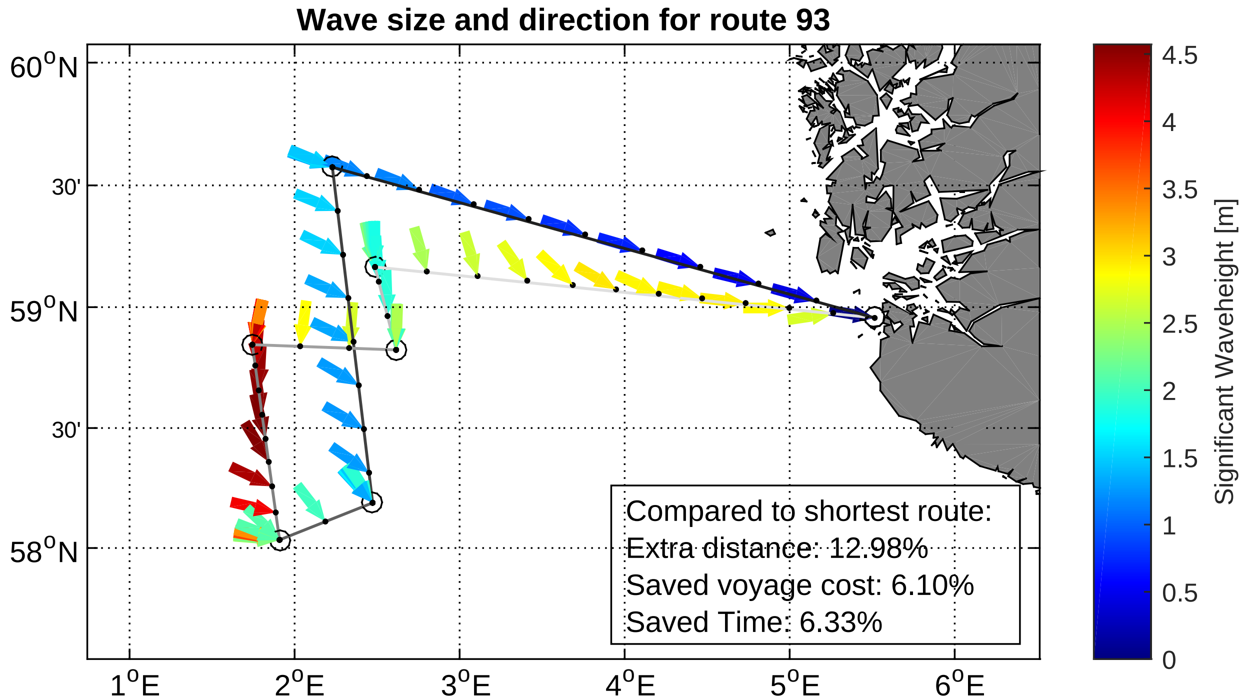
A fleet management tool gives an overview of the state of your vessels with position, speed, weather reports, cargo information, destination and route information. It may also report various performance indicators for the vessel owner to maximize the fleet profitability by coordinating work assignments and optimize vessel efficiency and utilization.

A traditional route planner for a deep-sea voyage considers distances between two ports, often on different continents and with a significant time in transit conditions. On long routes, vessels can change the course significantly which gives the operators a larger possibilities to avoid bad weather and find beneficial conditions (tide, tail wind, etc.).

Larger DP vessels, such as construction vessels, can also benefit from weather routing when travelling between assignments, but that represents only a minor part of their total energy consumption. Platform supply vessels often follow a weekly schedule to supply the installations. Due to relatively small distances between port and installation the energy savings potential for weather routing are small. However, a recent MSc thesis suggests that weather routing is feasible for PSVs by changing the order of installations visited (Kjølleberg, 2015). The figure shows an example from the thesis where the algorithm has found a longer route that is faster and has a lower cost.

Additional implementable options for short sea weather routing:

- Find optimal speed between installations to ensure arrival just-in-time
- Account for nightly close-downs
- Include wave forecast to avoid delays caused by wave height limitations for crane operations
- Extend to fleet planning to maximize coverage of supplies

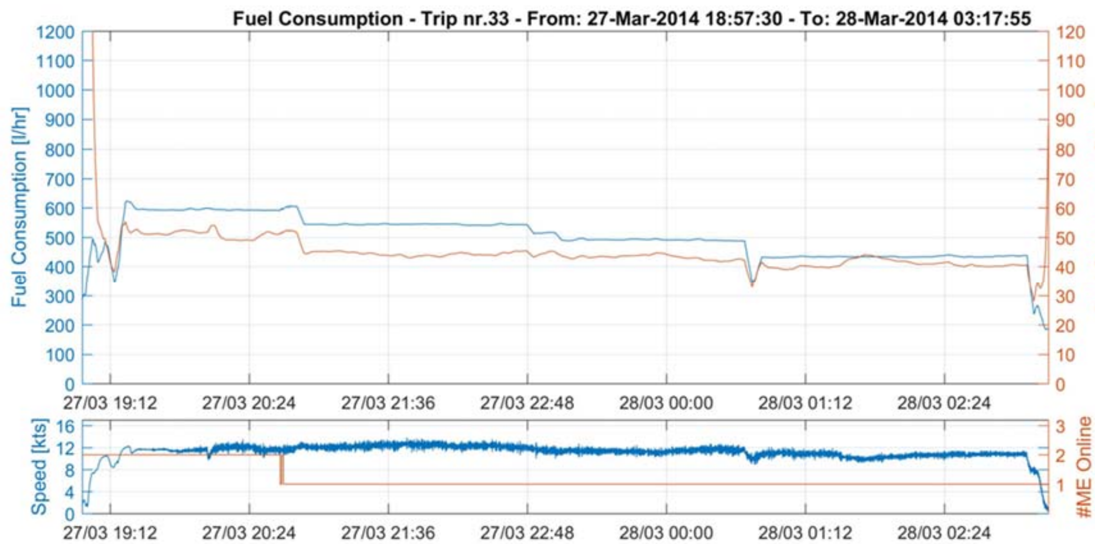


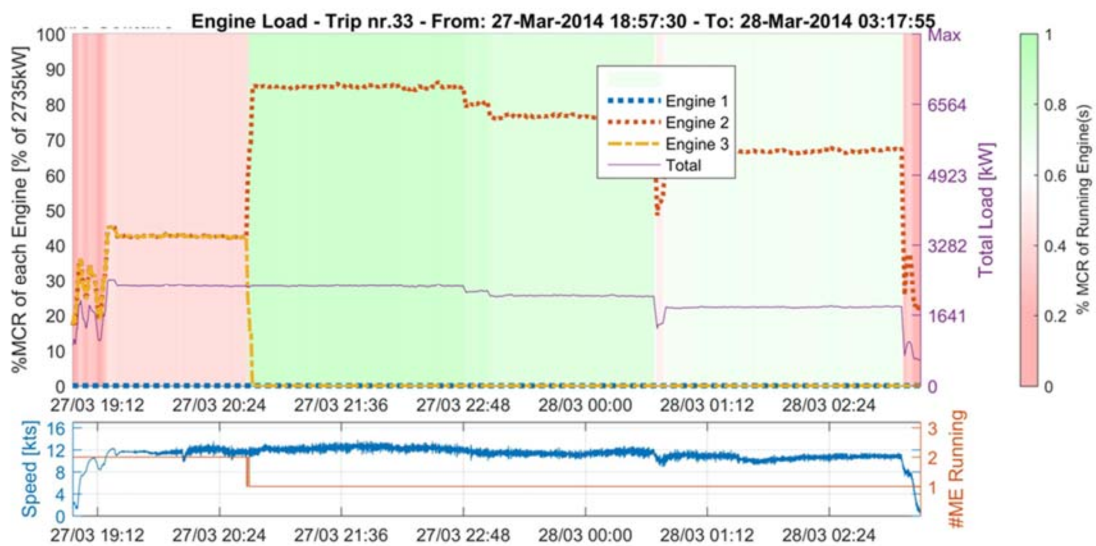

A DP vessel has a redundant thruster configuration such that in case of a failure there is still enough thrust capacity to control vessel heading and position. Operations that does not require full redundancy, such as transit operations on autopilot, should have the thruster setup with the best compromise between fuel efficiency and steering response. Incorporating speed profile and thruster setup in the route planner may yield additional environmental benefits. Numerical simulations can analyze different thruster setups for different transit modes and weather conditions.

Different vessel designs and energy usage profiles may give different results for the same routing problem such that the logistics chain will have to consider the operations and different vessel operational profile in more detail.

This example shows that the energy savings potential can be much higher by including a larger part of the organization. Instead of only considering the voyage from port to installation for a single voyage, the vessel owner can optimize the vessel utilization. For a reduced cost supplies are provided at varying intervals, but this uncertainty in delivery times have to be managed between customer and supplier.

Software systems and data logging can be valuable tools for decision support and provide background data to the decision making process. Ship owners has expressed great interest in knowing how crew operate their vessel. Engine efficiency in transit has been a recurring topic in discussion with shipping companies. The following is an example from the automated logs that illustrates the link between number of main engines running, fuel consumption and engine load. By running on a single engine, and maintaining the required transit speed, the vessel consumes 13% less fuel. With the recorded data, it is a relatively small effort to perform similar analyses to a single vessel and an entire fleet. The knowledge can be used to fill knowledge gaps and increase overall operational performance.

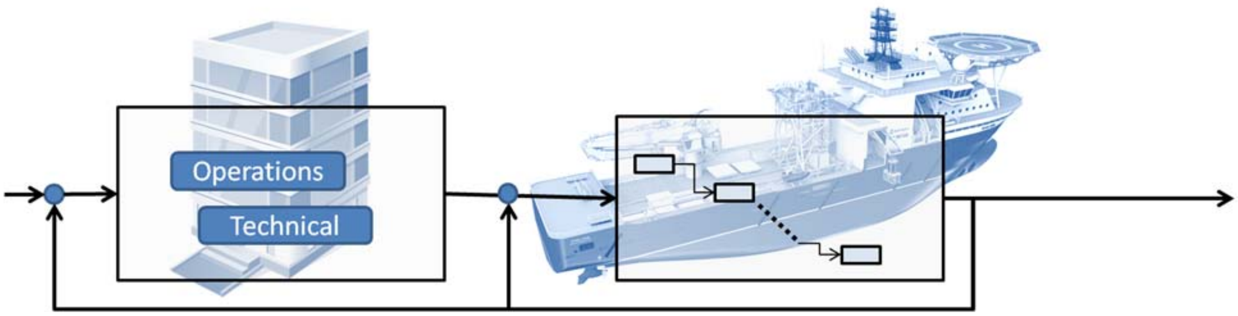



Another ship-owner used the logged data to negotiate a contract with new operational terms with a charterer. The old terms required all engines to be running during operations. The analysis showed the average and maximum load on each engine during normal operational procedures and convinced the charterer to reduce the amount of running engines. The change improved engine load and decreased fuel consumption

## Planning and operation – the human factor

The technical equipment onboard is an important element and enabler for saving energy. However, the human factor is the most important component and must be used together with technical improvements. According to the DNV GL Energy Management Study for 2015, about 50% of achievable savings originate from technical retrofits and upgrades. Operational and managerial measures achieve the other 50%.




The shipping company management have the biggest impact and responsibility for reducing emissions within the fleet. Two departments are particularly important:

- The operations department seeks to maximize the economic deployment by planning and scheduling, and coordination with ships, charterers, ports, agents, etc.
- The technical department's main responsibility is to keep the ships in a seaworthy and good maintenance conditions, and is in charge of new building projects.

According to IMO the main ship-board staff has the following impact on energy saving

- The Master: His/her commitment to shipboard energy efficiency is vital.
- The Chief Officer (2nd in command): Plays significant roles on the cargo and loading/unloading operations, ballast management operations, trim optimization, etc.
- The Chief Engineer: Plays a major role on technical issues including the maintenance, condition and performance, and utilization of engines and various machinery.
- The Second Engineer: By virtue of being the most engaged person in the engine department on day-to-day operation and maintenance of various systems, has the second most important role in engine department.

Even the smarter vessels we expect to see in the future will depend on human effort for efficient operations. Crew engagement may likely provide the biggest energy efficiency increase at a relatively low cost. IMO list the following possibilities to train staff:

- Training or distance learning on ship energy efficiency
- Raise awareness and interest in a safety and efficiency culture with campaigns, company magazines or other documents
- Regular on-board meetings on the subject
- Gather ideas of best practice from the seafarers, documented, highlighted and implemented.
- Motivate with the best incentives. E.g., develop competition for energy efficiency between ships and crews.

Motivating personnel and engaging the crew in the long term is a challenging task. Energy savings can be substantial at an early stage when the concept is novel and a source of entertainment. However, studies have shown that after an introductory period the energy savings diminishes as the novelty wears off. The company must look at available options to lower barriers and provide incentives.

As discussed before, efficiency gains depend on a number of factors and decisions. This is especially true for DP vessels. A well-trained individual can take the right decision at the right time if he/she has the right information and the possibility to exploit it.

A technical solution that could mitigate the issue is a vessel advisory system that offers guidance on power system and thruster configuration, energy consumption and operational parameters. The system should of course take into account safety considerations and class requirements. In addition to being a support tool, the system can raise crew awareness by providing information constantly and discreetly.

## Conclusions

There is an increasing regulatory pressure to lower the emissions from the shipping industry. Ships with a small environmental footprint and emission reducing equipment may benefit from reduced port fees, project financing from the NOx Fund, and access to restricted areas.

Vessels equipped with dynamic positioning systems for offshore work face distinctive challenges and cannot directly use indexes and measures developed for the traditional commercial fleet. All personnel involved in DP vessel operations should be aware of how redundancy requirements affect operational planning, safety, wear and tear etc.

The largest emission reductions can be realized when the vessel and onboard equipment, crew and shipping company accommodates for energy savings. Different technical solutions exist for reducing energy demand or providing information that leads to better decisions on efficient operations, but the biggest responsibilities and possibilities depend on the human factor.

## Acknowledgements

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