

Green Ship Management: Competence of Research Ships

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ABSTRACT:

The principal focus of this paper is to provide a look at the existing green ship management measures implemented in research ships for an expedition and thereby enhancing the scientific competence as well. Increasing fuel prices, ship emissions [NOX/SOX] and growing environmental concerns are motivating the shipping industry to be more energy efficient. Therefore it is indispensable to develop and implement energy efficient operational measures to make ships greener and cleaner for future generations.

Keywords: Green Ship, Research Ship, Energy Efficiency, Environment.

1. INTRODUCTION

Energy efficiency and environmental performance are typical issues for ship operators who are aiming for low carbon foot print and cost minimization. Although reducing fuel consumption seems to have priority, environmental considerations also thrust the shipping industry to operate in more efficient way. Stringent legislations laid by IMO and MARPOL on Green House Gas emissions and rising fuel prices turn the focus on energy efficiency and fuel consumption measures. These financial and environmental reasons behind energy efficiency resulted in numerous analysis to find technical and operational measures which increase overall fuel efficiency and reduce emissions. It has been recommended that there is high potential of efficiency enhancement and trim down emissions rate by 20% to 70% compared to existing scenario. Proficient ship operation is crucial for cleaner voyages at oceans and ports around the globe. This will not only facilitate ships to be greener but also preserve the entire value of it.

Research is the mode we expand knowledge and perceptive; outputs are the mode we share it. Laboratories and computer-models can generate a bundle of information for a scientist but they don't always provide the form of data required. Satellites utilize microwaves that like most other electro-magnetic waves, including light, can only penetrate the sea surface a few metres.

As a result sound and physical tools remain the only feasible way to reach the depths beyond. Taking into consideration the restrictions of satellites and inventory based simulation models research for innovative methods in order to reduce emissions is an incessant endeavour for the shipping industry. Research Ships and gradually more, unmanned vehicles are used to carry out explorations.

2. SCENARIO OF INDIAN RESEARCH SHIPS

Currently the fleet of India consists of ten Research Vessels viz. ORV Sagar Nidhi, ORV Sagar Manjusha, CRV Sagar Purvi, ORV Sagar Kanya, ORV Sagar Sampada, ORV Sindhu Sankalp, ORV Samudra Ratnakar, ORV Sindhu Sadhana, ORV Sagar Sukhthi and INS Sagardhwani. Of these the first three vessels are operated, maintained and equipped with scientific instruments onboard by the Vessel Management Cell of Earth System Science Organization [ESSO] - National Institute of Ocean Technology [NIOT]. These vessels operate year round, supporting Ministry of Earth Sciences, Govt. of India sponsored projects.

3. GREEN SHIP MANAGEMENT MEASURES FOR AN EXPEDITION PLANNING

Green Ship is a concept to develop and trial environmentally and climate friendly technologies that enhance energy efficiency and trim down operational costs of ships. The overall target of Green Ship Management is to trim down total CO₂ emissions by 20-30 %, total SO_x emissions by 80-90 % and total NO_x emissions by 80-90 %.

It is essential to look for both immediate and long term solutions to reduce fuel consumption. Frequent, onboard fuel composition analysis on existing ships can help to reduce particularly SO_x emissions. At the same time, it is necessary to explore potential alternative fuels. For instance, a research ship [Sagar Nidhi] is using Low Sulphur High Flash High Speed Diesel [LSHFHSD] as fuel. It has been observed that it can cut CO₂ emissions by 25 %, NO_x by 35 % and minimize SO_x emissions widely. When moving from Heavy Fuel Oil [HFO] to Liquid Natural Gas [LNG] the reduction of NO_x emissions can naturally be considerably higher, probably 80-90 %.

A scientific expedition onboard a research ship is commonly known as a cruise, which can give an incorrect intuition. A research cruise is an extremely hectic and intricate exercise, requiring exhaustive planning and homework. For several scientists, the cruise will be the zenith of several years of endeavour and they have elevated expectations. Certainly, the ships work uninterrupted and 'dead' transition time swapping between diverse sampling systems has to be minimized, so the technical manning, working decks and labs all have to be independently organised and optimised for every cruise.

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Moreover, once the ship is on-site, going back to harbour because something has been forgotten isn't really an option when it is several days sailing time away.

There are a bundle of intricate elements to a cruise and making sure everything is complete to go onboard ship at the right time is vital. To solve this logistical riddle, the VMC team work jointly to get the ship, equipment, technicians, crew and scientific users ready to navigate along with planning and preparation to guarantee the ship will be set up as required by the cruise's Principal Scientist.

3.1 Laws at sea

The world's oceans are progressively busier operational environment that has to be cautiously regulated in order to maintain the safety of the vessels using it, as well as the security of resources and maintenance of the natural environment. Some of this regulation has a long chronological inheritance, with the speed of change escalating since the 19th Century. Laws and regulations have had to become accustomed to maintain swiftness with developments in ships and technology and how the seas themselves are used by mankind.

Law at sea is divided into two distinct regimes: Maritime law and Laws of the Sea. The President of the 3rd United Nations Conference on the Law of the Sea, Tommy T.B. Koh stated that, 'United Nations Convention on the Law of the Sea (UNCLOS) is 'A Constitution for the Oceans'. UNCLOS is the most comprehensive effort at creating a unified administration for governance of the rights of nations with respect to the world's oceans. The treaty addresses a number of topics including navigational rights, economic rights, pollution of the seas, conservation of marine life, scientific exploration, piracy, and etc. To address a range of claims concerning territorial waters and states control in negotiation, an UNCLOS III has convened. It addressed most important issues like setting limits, navigation, archipelagic status and transit regimes, exclusive economic zones (EEZs), continental shelf jurisdiction, deep seabed mining, the exploitation regime, protection of the marine environment, scientific research, and settlement of disputes. Fig.1 shows the graphical representation of Maritime Zones. UNCLOS III clearly demarcated ocean waters into different zones. Figure 1 shows the 3D-Graphical representation of Maritime Zones

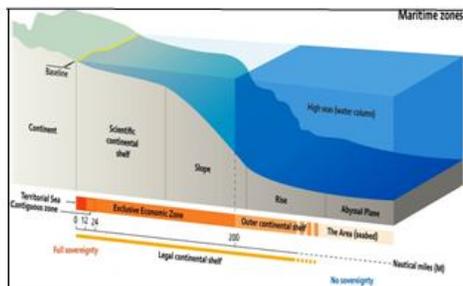


Figure 1 - 3D-Graphical representation of Maritime Zones

To facilitate administration of UNCLOS, the treaty formed four bodies to handle particular issues.

a. *Commission on the Limits of the Continental Shelf* - It deals with a nation to extend sovereignty over a portion of the continental shelf beyond the limits of the EEZ.

b. *International Seabed Authority* - It is the association that is accountable for the governance of the Area.

c. *The Enterprise* - The principle of the Enterprise is to coordinate the exploration and exploitation of resources in the area.

d. *International Tribunal for the Law of the Sea*.

To encourage green shipping, International Maritime Organisation (IMO) was established. The International Maritime Organization is a dedicated agency of the United Nations which is accountable for measures to improve the safety and security of international shipping and to prevent pollution from ships. It is also involved in legal matters, including liability and compensation issues and the facilitation of international maritime traffic. IMO limit pollution from ships through its Marine Environment Protection Committee (MEPC). IMO has adopted measures to reduce air pollution from ships as well as energy efficiency measures including the Energy Efficiency Design Index, which is mandatory for new ships, and the requirement for a Ship Energy Efficiency Management Plan, for all ships.

MARPOL (MARine POLLution) 73/78 is the International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978. MARPOL through its annexes controlling various issues ranging from prevention of pollution by oil, transport of harmful substances to ship emissions.

3.2 Map of action:

The procedure begins with the formulation of a proposal. In a proposal a scientist will give information about their plans, including:

- What they desire to study?
- Why it is significant?
- How much capital it will cost? and
- What will happen to the results?

Some studies will focus on a particular experiment or data to collect. They tend to consist of of a single research expedition or a precise element of one. Other studies need large datasets, such as time-series data and may involve multiple expeditions. This can require leaving instruments in-situ to accumulate data until they are collected, as they are often incapable to transmit their data. In general the tendency is towards a multidisciplinary approach; a variety of disciplines working collectively to exploit the impact of a research expedition.

By and large the key elements that need to be planned are:

- Ships – Every ship's capabilities are diverse; safe working loads, deck layouts and supporting systems are some of variables that are taken into account;

- Logistics – What needs to go, how it will get there and back, and how long will it take? and

- Scientific equipment – What specific equipment is necessary, is it existing, does it contain hazardous material or have a risk assessment?
- Technical support – Space is limited on a research ship, knowing the total number of technicians required and the necessary skills is very much essential.

3.2.1 Intention of an expedition

An expedition is an intricate and expensive exercise so it is not one that is undertaken unconsciously. Scientists have to undergo a meticulous process to validate the need for their research and why it needs the use of a particular research vessel and/or other specialised equipment. A scientist's ability to generate peer-reviewed outputs, from their time spent onboard a research ship, defines the quality of their effort. Whereas increasingly it is the societal and environmental impacts of this job which eventually defines how successful it has been. As shown in Figure 2 the 'life-cycle' of an expedition is one that covers several years; from the conception of an idea right through to the final reporting of scientific results.

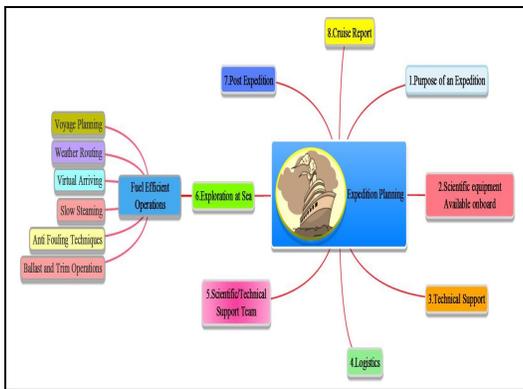


Figure 2 - Schematic Flow Chart for Energy Efficient Expedition Planning & Execution

3.2.2 Scientific Equipment

Generally, Scientists anticipate the ship to work incessantly so prior thought on what equipment is required and where it should be fixed is essential. Some systems are so vital that back-ups are required. All equipment embarked has to be in date for tests and calibrations, as well as supplied with a full set of spares and other consumables such as oil, grease and etc.

For instance, Indian research ships come with a range of in-built equipment that the scientists will use during the expedition viz., CTD Rosette (CTD with water Sampler 12 Bottles upto 6000m depth), Auto analyzer, Chlorophyll Analyzer, Laminar Flow, Auto salinometer, Spectrophotometer, Thermosalinograph, Electronic Balance, Magnetic stirrer, Millipore water purification plant, vacuum pump with filter manifold, Hot plate, Automatic weather station, Gravity Corer (1.5m & 6m length), Weiner Grab, Zoo plankton net and so on to name a few. These systems are essential to enable measurements to be taken and samples to be collected, and

without them conducting research would be a lot more complicated.



Figure 3- Control system for Drop Keel & Drop Keel arrangement

A widespread feature of a modern research vessel is a drop keel. These are large fins that can be lowered so that the bottom face is several metres below the keel of the ship as shown in Figure 3. This has numerous advantages over acoustic instrumentation conventionally fitted to the bottom of the hull itself:

- Instrumentation fixed on the bottom face of the drop keel are clear of any bubble streams which may brush off across the face of the hull (commonly known as bubble sweep-down) when the ship is experiencing considerable ship motion, and
- The drop keel can be raised up inside of the ship and transducers replaced or maintained without having to either dry-dock the ship or utilize divers.

The drop keel arrangement in Sagar Nidhi is as shown in the above figure.

In essence, a calibration is just an assessment between an instrument and a known standard. A fully calibrated instrument will give a user assurance that the measurements they are taking

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are true and accurate. Calibrations are performed on the instrumentation used in research ships to ensure the maximum possible data quality for end users.

3.2.3 Scientific & Technical support team

The Scientific & Technical support team is accountable for the management, preparation and operation of a diverse range of equipment within the fleet's scientific equipment pool. The expert scientific equipment provided requires trained technicians and engineers to operate and maintain it while at sea. All the members working of this team have a core set of skills in which they focus but the need for multidisciplinary skills is indispensable.

3.2.4 Exploration at ocean

Once at ocean the science work can commence. Different scientists will be involved in different areas of the ocean; geoscientists are normally interested in the ocean floor, biogeochemists may explore the water column and the ecosystems that support marine life, while physicists and climate modellers lean to spotlight on the surface and beyond. No matter the area of study a scientist requires the correct equipment to perform an exploration. Figure 4 represents the ORV Sagar Nidhi in Antarctica waters.



Figure 4- ORV Sagar Nidhi in Antarctic Waters

3.2.5 Fuel Efficient Operations as part of Green Ship Management

Steady increases of fuel prices and latest regulations on environmental impact of ships have made fuel oil consumption management inevitable for ship owners. Awareness of fuel efficiency is growing within the industry and becoming more and more vital. Saving fuel at operational phase may be achievable for all ships. Nevertheless, there are numerous variables affecting the energy efficiency as shown in figure below and it is not an easy task to describe 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 phase, 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 aspects which can affect power and propulsion system performance.

Consequently, operational efficiency has lots of aspects which can be investigated to trim down fuel consumption. Under these conditions, a large number of different methods have been

applied and experienced to trim down the fuel used by vessels over the recent years.

Some of these measures can be listed as:

- a) Voyage Planning and Virtual Arriving
- b) Weather Routing
- c) Slow Steaming
- d) Speed Nozzle
- e) Hull and Propeller Cleaning
- f) Ballast and Trim Optimisation

Most of these methods can be put into practice with low capital investment cost to amplify operational efficiency. It is necessary to discuss these methods in depth to have a better idea of which benefits can be gained through implementation. Figure 5 shows the variables influencing energy efficiency.

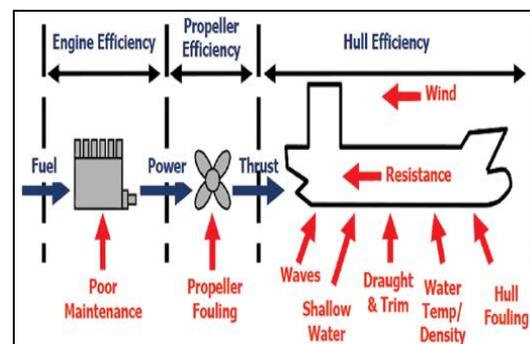


Figure 5- Variables influencing energy efficiency

3.2.5.1 Voyage Planning and Virtual Arrival

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

Voyage planning may have noteworthy impact on fuel consumption. Overall transport efficiency of the ship is affected by time spent in harbour as well; so early communication with next harbour regarding berth availability is essential to reduce waiting times at anchor. Optimising vessels speed due to berth availability rather than sailing at normal speed and waiting at anchor would result in lower fuel consumption and Green House Gas [GHG] emissions. Other than that, good rapport 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 favourable as well.

Voyage planning and virtual arrival are very similar measures and it is predominantly about managing time and managing speed. Inadequate information and lack of communication with next harbour causes waiting times which increase fuel consumption and costs. If the vessel has the precise information

about available berthing slot time, it can adjust an suitable lower speed and therefore waiting at anchor can be avoided by slow steaming while reducing fuel consumption. Figure 6 shows the Integrated Bridge system at Sagar Nidhi.



Figure 6- Integrated Bridge System of Sagar Nidhi

Virtual arrival is considered a voyage management optimization tool which aims to improve overall efficiency by identifying delays at discharging ports and then managing the vessel's arrival time at that harbour through well managed passage speed. Therefore it aims to reduce emissions and fuel consumption devoid of reducing cargo capacity. Virtual arrival aims to provide a win-win situation for all of the parties included.

3.2.5.2 Weather Routing

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

Weather routing service providers require complete information, including detailed ship performance models to compute 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 adverse weather. It would be feasible to identify ideal speed of the vessel for different conditions by using that information. Figure 7 shows the ship maintaining its position at Mid-sea in Antarctic waters using Dynamic Positioning [DP] system.



Figure 7- Sagar Nidhi maintaining position at mid-sea using DP

Navigating with conventional routing, for example, is inclined towards choosing the shortest route option, except for a few extreme situations. Weather routing; on the other hand, can specify that in some situations a longer route can actually be covered with minor bunker consumption. This method aims to shun, 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.

NIOT considered the use of weather routing to be highly effective in terms of operational efficiency and it's a part of standard practice for the major cruises undertaken. In conclusion, weather routing is possible for all types of ships and has the potential to achieve substantial savings and emission reductions due to reduced fuel consumption. Besides, the valuable ship-time towards scientific operations in sampling stations shall be planned accordingly.

3.2.5.3 Slow Steaming

Speed optimisation is an indispensable 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."

As part of the speed optimization process, it is essential to take measures to organize arrival times with the availability of scientific equipments to be loaded/discharged and sailing at constant speed until arrival. Maintaining a stable vessel speed would be feasible by planning ahead to guarantee that loading and discharging schedules are still met with the least amount of fuel consumed. Fuel consumption increases disproportionately at higher speeds therefore it is essential to avoid pointless 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 unforeseen consequences in terms of engine maintenance,

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auxiliary machinery efficiency and thus fuel consumption as well.

Potential fuel and emission savings of slow steaming are significantly high. A share of these savings has already been achieved, as many shipping companies have announced slow steaming and Research Ships are practicing the same whenever there is a potential to do so.

3.2.5.4 Speed Nozzle

Normally, nozzles are used to enhance the bollard pull on vessels which need high pulling power at low speed. This new kind of nozzle, called a speed nozzle shown in Figure 8, is developed to enhance the propulsion power at service speed. Using the new speed nozzle concept has a fuel saving potential of approximately 3-5%.



Figure 8- Speed Nozzle in Sagar Nidhi

3.2.5.5 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. 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. Fouling can easily be cleaned at dry-dock as shown in Figure 9 or even underwater by divers. This is being strictly adhered in order to achieve efficient management of fuel consumption. The choice of the right hull

paint is essential to keep the resistance at a minimum. Modern anti-fouling hull paint with a low water friction has a fuel saving potential in the region of 3 to 8%. The reduction of emissions is proportional to the fuel savings.



Figure 9- Hull & Propeller cleaning during dry-dock of Sagar Nidhi

3.2.5.6 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 onboard modern research ships like Sagar Nidhi, Samudra Ratnakar and etc., to assist the crew to find the optimum trim and reduce consumption and emissions.

3.2.6 Post Expedition

The research work does not stop after the research cruise has ended. While some scientists can start to construe the data gathered and develop their findings onboard. Others will have to wait for their data to be collected, particularly those working with long term moorings.

3.2.6.1 Samples

Carrying samples back from a cruise not only allows others to study the material, but it also facilitates diverse studies to take place. Several specialist equipment cannot be transported so instead the material is taken to it. This results in a more detailed analysis or enhanced preservation of the sample. These samples include sediment cores, ice cores, marine life collections and etc.

Figure 10 shows the laboratory facilities in Sagar Nidhi for data collection and sample storage.



Fig.10 - Labs in Sagar Nidhi for sample collection and analysis onboard

3.2.6.2 Data

Gathering data and samples on a cruise allows the scientists at ocean to study. By bringing them back to shore this information can be placed in collections and repositories; to be shared and used. On top of saving time and money by preventing duplicate cruises, suitable and accessible storage helps to promote knowledge and advance disciplines.

Data can be used to two major ways:

- To authenticate models or theories, and substantiate understanding, or if it does not;
- Provide better parameterisation so that models and theories can be enhanced.

Research vessels log data from many different instruments, measurements about the air, the sea and the ship's position are all regularly stored.

4. CRUISE REPORT & FEEDBACK REPORT

A cruise report is a document written mainly by the Chief Scientist of the expedition that details what happened on an expedition; the equipment used, the time and date it was deployed and the data it collected. Technicians can provide information about specific pieces of equipment as well. It generally contains the hypothesis, results and conclusions the scientist has drawn, as well as their future plans, if any. Cruise reports are original detailed sources of information, making them very important documents. Similarly, feedback reports serves as a platform for improving the things onboard better.

5. CONCLUSION & FUTURE SCOPE

This paper had focused on the effective green ship management measures implemented in research vessels to

maximize the energy efficiency and thereby improving the scientific competence for an expedition.

Fuel efficient operations were explained and discussed. 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 article has shown that significant reductions in fuel consumption and emissions can be achieved by operational measures which are broadly applicable and easy to implement.

'After decades of slack oversight, it's high time for Ships to get a whole lot greener.'

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