



Emerging Trends in the Shipping Industry – Transitioning Towards Sustainability

Kapil Narula*

Growing concerns about the slow revival of the world economy, volatility in oil prices, overcapacity in shipping and fierce competition is denting profits in the shipping industry. On the other hand, emergence of greenhouse gas emissions and pollution control regimes at sea is forcing ship owners to make expensive technical modifications onboard ships, which are further driving up the costs of operations. In such a rapidly changing scenario, there is a need for a long-term vision for transitioning to an era of sustainability in the international shipping industry. The paper commences with a discussion on the concept of sustainability as applicable to the shipping industry and highlights the recent developments in the maritime domain, which pose significant environmental and economic challenges for the shipping industry. It identifies the emerging trends in the shipping industry and argues that these challenges also present a window of opportunity for the industry, for

*Commander Kapil Narula is a research fellow at the National Maritime Foundation, New Delhi. The views contained in this article are those of the author and bear no relation to the official policy and the views of the Indian Navy and the Foundation. A draft version of this paper was presented at the International Conference and Technology Meet on Military and Marine Applications (IWCEM), Pune on 18–20 May 2013. The paper has been thoroughly revised in the light of the comments received.

undertaking a paradigm shift towards sustainable shipping. It further explores the transition pathways and presents various options that can be implemented in the shipping industry, which will aid its transition towards sustainability. Using a case study, the paper highlights the key characteristics of sustainable shipping and briefly discusses the Indian maritime scene before concluding that the adaptability of the world shipping industry to adopt the practices of sustainability is fundamental to its survivability in forthcoming decades.

Introduction

Shipping is a lifeline for world trade and about 90% of trade (by volume) is carried by sea.¹ World seaborne trade grew by almost 4.3% in 2012, nearly the same rate as in 2011, and more than 4.2 million people are employed as seafarers and in related maritime activities.² Of the 9.2 billion tons³ of goods that were transported by sea in 2012, approximately one third was tanker traffic (oil, gas and petroleum products) and the remaining two-thirds was contributed by ships carrying dry cargo. Hence, global food security and energy security are heavily dependent on international shipping, which is indispensable for the continued growth of the world economy. However, the last few years have been turbulent for international shipping.

Figure 1 shows the developments in international shipping industry from 2008 to 2011. The market for seaborne trade collapsed at the end of 2008 in the aftermath of the widespread economic crisis. Many more ships that were ordered at the end of the high cycle have been entering the market since. This resulted in an increase of 12% in the number of container ships between 2008 and 2011, which led to the situation of oversupply in world's container fleet market. In response to the large supply and low demand of container ships, freight rates dropped sharply (up to 75%) across most segments since their peak in early 2008. Utilization of the container fleet dropped by 9% and 15–20% of the serviceable vessels were at anchorage on any given day in the period 2008–11.

Fuel costs, which dropped abruptly due to the economic downturn in 2008, steadily rose back by 2011, although stopping short of the highs of 2008. In response to the higher cost of operations, increased competition and lower revenue earnings, the shipping industry started employing speed reduction measures in order to reduce the consumption of fuel and to lower the per voyage cost of a ship. The container fleet has reduced speed by about 14% since early 2008, which has resulted in longer

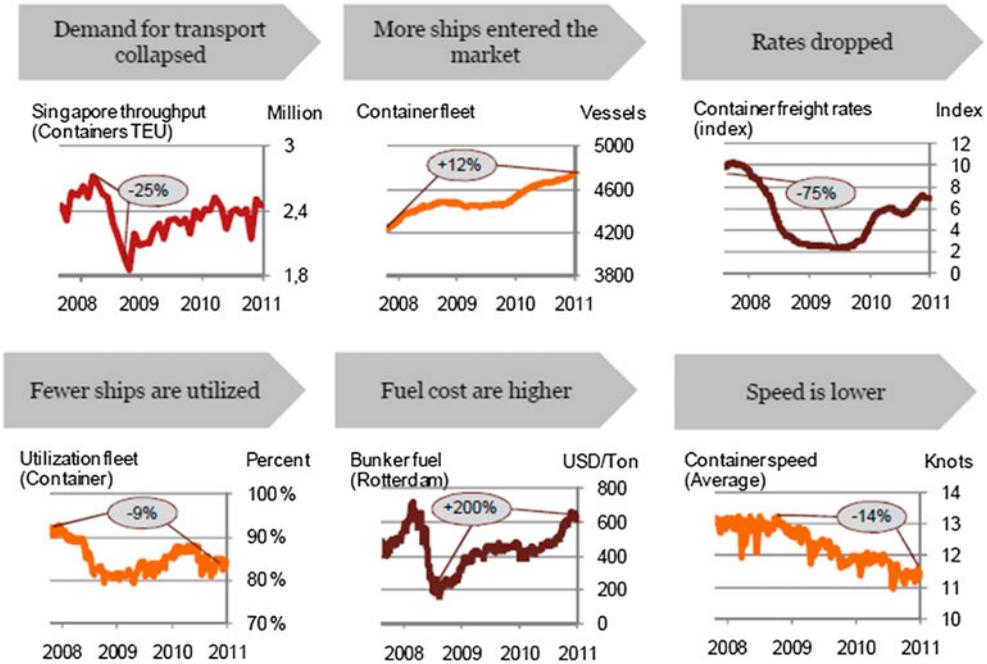


Fig. 1. Developments in international shipping from 2008–11.⁶³

transit time for shipping of commodities and is a sub-optimal way of utilization of maritime assets. These developments are a cause of concern and this period may well go down in the history of the shipping industry as a transition phase, which has the potential to mark the beginning of a new era of sustainable international shipping.

The first aim of this paper is to highlight the concept of sustainability in the shipping industry in the light of the evolving changing maritime scenario. The second objective is to identify the emerging trends and to present various options that can be implemented in the shipping industry, which will aid its transition towards sustainability.

Concept of Sustainability in the Maritime Domain

The essence of the term “sustainable” is “that which can be maintained over time”. Hence any activity that is sustainable should be able to function over a very long period without permanently damaging the interconnected systems and the setting in which they work. This is highly improbable for commercial shipping, as it functions

today. Therefore, sustainable development,⁴ which has economic, environmental and social dimensions, is now emerging as the need of the hour for the shipping industry. The economic dimension of sustainability for shipping implies that shipping continues to contribute to increasing world trade to create wealth for nations and its people. The environmental aspect implies protection of the marine environment, which includes reducing discharges from ships at sea, safeguarding marine biodiversity and limiting airborne emissions. The social dimension implies having a positive impact on livelihood of people, which is achieved by providing employment and promoting corporate social responsibility (CSR) initiatives by shipping companies. Shipping is the most energy efficient and environmentally sustainable form of transportation and due to this inherent advantage, sustainability has itself become a strong driver for growth of the shipping industry. In fact, “what was once an aspiration is now an expectation from the shipping industry”.⁵ The relevance of sustainability⁶ in the maritime industry is evident from the fact that the International Maritime Organization⁷ (IMO), declared, “Sustainable Development: IMO’s contribution beyond Rio +20”, as the theme for World Maritime Day⁸ 2013.⁹

Changing Maritime Scenario and the Need for Sustainability

The scenario for international shipping is transforming at a fast pace and it is forecasted that there will be significant changes in the direction of trade and the type of goods transported in the next few decades due to burgeoning demand from emerging economies.¹⁰ The vulnerability of international seaborne trade to the slow revival of the global economy and the associated financial risk is also becoming a major cause of concern to ship owners. Furthermore, there is significant overcapacity in the shipping industry as the trend of year-on-year increase in the delivery of new ships continued unabated from 2001 to 2011. It was only in 2012 that the fleet of new ships that entered service was smaller than that of the preceding year. However, in spite of the reduction in the number of new ships entering service in 2012, the tonnage of ships entering service continued to grow due to larger ships being delivered. In fact, the dead weight tonnage (DWT) of the world’s shipping fleet has grown to 1.63 billion DWT in January 2013 – doubling in a span of 12 years. This trend is likely to continue at least for the next 5 years as per the Maersk Line, the world’s largest container shipping company.¹¹ This view is supported by Drewry shipping consultants, who point that there has been a revival in new orders for ships

after a dip in 2012. Statistics reveal 750 new dry bulk ships and 205 container ships were ordered in 2013, compared with only 300 dry bulk and 70 container ships ordered in 2012.¹² This will add on to the oversupply burden when these ships are delivered in the next few years. Analysts highlight that the surge in orders is attributable to the stringent environmental norms in the USA and Europe, and the shipping industry is actively responding to these developments as newer ships are more fuel efficient and reduce cost and emissions.¹³

Certain key trends affecting international shipping and seaborne trade as highlighted in the “Review of Maritime Transport – 2013” report include the continued negative effect of the 2008/09 economic crisis on global demand, finance and trade, structural shifts in global production and trade patterns, transport-related technological advances in shipping, the advent of mega container ships, and the increasing relevance of energy costs and environmental sustainability.

Recent Developments in the Regulatory Framework

The IMO is mandated to minimize the adverse environmental impacts from shipping. This is being endeavoured by the implementation arm of the IMO, namely the Marine Environmental Protection Committee (MEPC), which has adopted more than 21 international treaties for control of pollution from ships under the MARPOL (MARine POLLution) convention.¹⁴ Annexure VI of this convention deals with prevention of air pollution from ships and was enforced on 19 May 2005. This annexure covers emissions of ozone-depleting substances (ODS), nitrogen oxides (NO_x), sulphur oxides (SO_x), particulate matter (PM) etc. and specifies the percentage of sulphur permissible to be used as fuel onboard ships.

ECA and Limiting Sulphur Content in Fuel

At present, two sets of fuel quality requirements for bunker fuels are defined, namely global requirements and more stringent requirements, which are applicable to ships in Emission Control Areas (ECA).¹⁵ Figure 2 shows the ECAs.¹⁶ Expanding the ECA to Singapore, Australia and the Mediterranean region is also under active consideration.

Table 1 shows the sulphur content in fuel (by weight) that is permitted outside and inside an ECA.

When a ship is entering an ECA, it mandatorily has to use a fuel with a lower sulphur content. This reduction of sulphur content leads to a limiting of NO_x, SO_x



Fig. 2. Emission Control Areas.

and PM emissions from fuel combustion at sea, thereby contributing to a cleaner marine environment in the ECA. Hence, only ships that have an onboard arrangement to carry out fuel switching or use low sulphur fuel through the entire journey can dock in ports located in the ECA. This restricts the entry of only a select class of ships that adhere to these regulations in the ECA areas and the increasing number of ECA is therefore driving the growth of environmental sustainability in shipping.

Table 1. Allowable Limits of Sulphur Content⁵⁸ In Fuel⁵⁹ (By Weight).

Outside an ECA	Inside an ECA
4.50% m/m prior to 01 January 2012	1.50% m/m prior to 01 July 2010
3.50% m/m on and after 01 January 2012	1.00% m/m on and after 01 July 2010
0.50% m/m on and after 01 January 2020	0.10% m/m on and after 01 January 2015

Limiting Airborne Emissions

The IMO, on 15 July 2011, adopted a new chapter¹⁷ to MARPOL Annex VI which is aimed at improving the energy efficiency and reducing greenhouse gases (GHG) from international shipping. This makes adoption of the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) mandatory for all merchant ships. Both these enforcements have already come into force starting 01 January 2013 and are applicable to the entire shipping industry. Other evolving regulatory mechanisms include taxing of carbon emissions from ships and market mechanisms¹⁸ similar to Emission Trading Schemes (ETS). Going into the COP 17 conference¹⁹ at Durban, there was a proposal²⁰ to tax²¹ carbon emissions emitted from international shipping at a price of \$25/ton CO₂, which was debated. These were discussed in the 63rd session of the MEPC, which was held in London in 2012. However, market-based mechanisms were opposed strongly by major shipping associations such as the Baltic and International Maritime Council and International Chamber of Shipping.²² Although no proposal has been adopted as yet, any ETS or carbon taxes that are levied on the shipping industry in near future will raise the cost of operations for the shipping companies.

Recent developments in the regulatory framework therefore establish beyond doubt the need for immediate action by the shipping industry to adapt to these regulatory changes to make necessary modifications in ship design and ship operations.

Emerging Challenges

Higher fuel costs and volatility²³ in international price of crude oil is now affecting the profitability of shipping companies. Rising fuel prices are also accelerating obsolescence of inefficient vessels and regulatory uncertainty is undermining new investments in shipping. Hence the prime concern of the shipping industry is to reduce its costs of operation and to maximize profits. In order to control the costs, it is important to analyse the share of total running costs of a ship.

Figure 3 shows the share of total running costs²⁴ (in %) per day for different types of ship. Capital expenditure (CAPEX, cost of investment) comprises capital and repayment costs, tax, depreciation, labour and insurance costs. Operational expenditure (OPEX, running cost) comprises administrative expenses, repairs and maintenance, daily running cost, loading charges, port/canal duties and additional crew expenses. Lastly, fuel expenses include bunker costs and fuelling charges. The cost²⁵

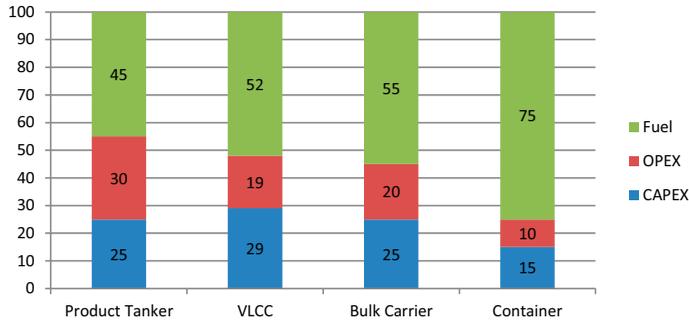


Fig. 3. Share of total running costs (in %) per day.⁶⁴

of fuel is between 45% and 75% of the total costs associated with the operation of the ship while CAPEX and OPEX contribute to a relatively smaller share of the total cost. Due to an estimated increase²⁶ in cost of fuel, the share of fuel costs for a container ship operation is likely to increase to 86% (from 75%) by 2030. Economics necessitates that this impact of increase in the cost of fuel on the bottom line has to be mitigated by lowering the consumption of fuel onboard ships in order to retain the profitability of shipping operators.

Increase in Price Due to Switching from Bunker Fuel to Marine Diesel Oil

As highlighted in Table 1, ship operators have to switch from bunker fuel to low sulphur marine diesel oil (MDO) in a phased manner. The momentum for this shift has been gained from the ECA, which specifies the areas where only low sulphur fuel has to be used. The production of low sulphur fuel requires a higher grade of refining, and there are additional costs that are involved in distilling the crude. It is estimated that reducing sulphur content from 1% to 0.5% would cost an additional €115 per tonne while reducing it further from 0.5% to 0.1% would cost an additional €200 per tonne.²⁷ This in turn increase the total cash outflow for the ship owner.

Figure 4 shows the gradual increase in the price of bunker fuel and MDO²⁸ in the international market. It is estimated that the share of MDO used by merchant shipping in 2010 was only 20% compared with bunker fuel. This is projected to rise to 80% by 2020 and would almost completely displace the use of bunker fuel in the shipping industry by 2030.²⁹ It has been estimated that by 2030 the difference between the cost of distillate and bunker fuel will be about 80%.³⁰ This will imply a significant increase in the total cost of shipping as the cost of MDO per metric ton is

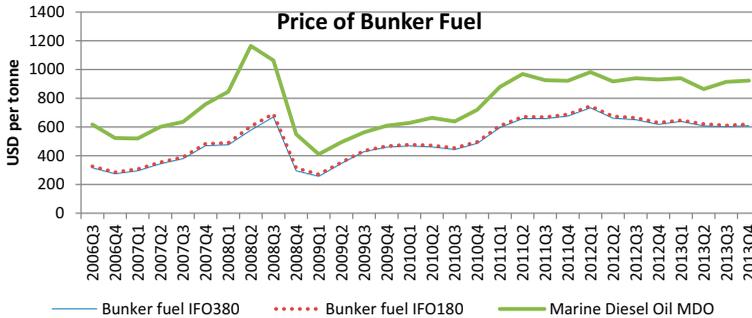


Fig. 4. Spot price of marine bunker fuel (average unit value, FOB Singapore).⁶⁵

already higher³¹ by 53.7% than bunker fuel, and therefore reducing the cost of fuel used onboard ships will be one of the major challenges for the shipping industry.

Stringent Environmental Regulations

Emission intensity of CO₂ from shipping is the lowest and varies from 5 to 55 g CO₂/ton-km for different types of cargo carriers.³² This reduced emission intensity gives shipping the competitive edge over other modes of transport and is a strong driver for growth of the shipping industry. Notwithstanding the lowest emission intensity, global shipping was responsible for 1075 million tons³³ of CO₂ equivalent emissions in 2007. This was approximately 3.3% of world’s entire CO₂ emissions and the global shipping fleet was the sixth largest emitter of carbon dioxide (in 2007). Emission scenarios also predict a doubling to tripling of 2007 emission levels by 2050.³⁴ Hence, pressure is mounting on international shipping industry to limit emissions so as to meet the 450-ppm³⁵ emission scenario by 2030.

In order to maintain the lead of cost-effectiveness and lower emission- intensity over other modes of transport, the shipping industry in a path-breaking move ratified the adoption of GHG emission reduction regime for the entire shipping sector. This is a significant development, as it is the first legally binding climate deal with global coverage since the Kyoto Protocol.³⁶ Furthermore, unlike the Kyoto protocol, which applies to select countries (based on the principle of Common But Differentiated Responsibilities, CBDR), these regulations are equally applicable to all 180 countries who are member states of the IMO. Hence, the reduction of emissions is now legally binding on all merchant shipping irrespective of the flag of the country the ship is flying. It is important to note that, despite these measures, the growth in absolute

CO₂ emissions from shipping will increase due to a projected 140% increase in the total number of ton-miles between 2007 and 2030. But these regulations are expected to slow the overall the rate of growth of total CO₂ emissions from international shipping to 37–44% from 83% under the business-as-usual (BAU) scenario.³⁷

In order to address the emerging challenges, the shipping industry needs to adapt to the regulatory changes and recent developments quickly and should aim to attain the twin objectives of environmental and economic sustainability. This demands innovative solutions from the global shipping industry and hint at a paradigm shift in the philosophy of shipping operations and ship design.

Transition Pathways for Sustainable Shipping

Achieving the Twin Goals of Fuel and Emission Reduction

Figure 5 presents the interaction between the twin goals of reducing fuel consumption and reducing emissions from shipping, which are targeted towards the end goals of achieving higher profits and a better environment, respectively, for the shipping industry.

Any reduction in fuel consumption will automatically contribute to emission reduction and hence the impact of optimization of energy utilization onboard ships is

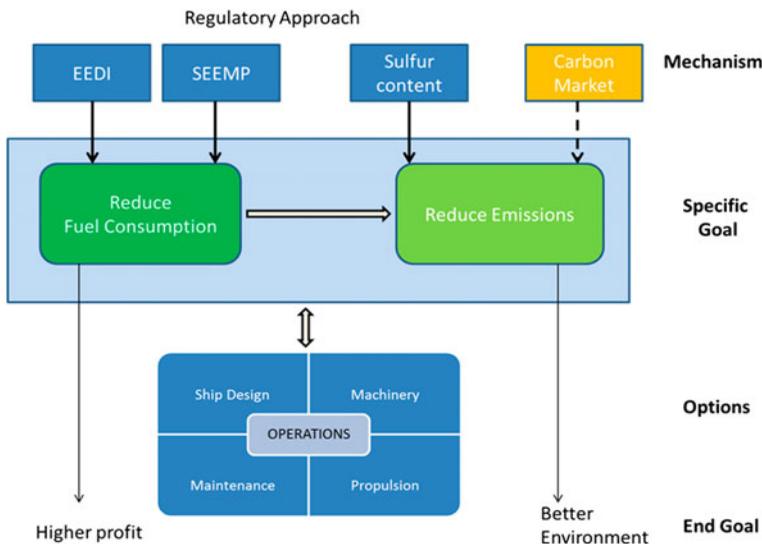


Fig. 5. Mechanisms and options.

twofold. The specific goals of reducing fuel consumption and emissions can be met by adopting a large number of options. It has been estimated that technical measures, which include machinery selection and retro-fitting, use of advanced propulsion technology, improved maintenance and efficient ship design and operational measures to optimize energy usage onboard ships, could increase energy efficiency and reduce the emissions rate by 25–75% below the current levels.³⁸ Furthermore, use of renewable energy onboard ships has the potential to reduce CO₂ emissions from shipping by up to 10% per ton-mile.³⁹

Energy Use and Pattern of Losses Onboard Ships

In order to reduce fuel consumption, it is essential to study the pattern of energy use and energy losses onboard ships, as only a fraction of the energy⁴⁰ generated by the ship’s propulsion engines actually ends up generating propulsion thrust.

This is illustrated in Figure 6,⁴¹ where 100 represents the energy input to the main engine from the bunker fuel. About 57% of the energy is lost in the form of heat and exhaust gasses and only 43% is transferred to the shaft. Eventually only 28% energy is used for propulsion and is utilized to overcome water and air resistance to propel the ship forward. Hence, almost 72% of the energy is actually lost and the nature of losses indicated above also hint at various opportunities to minimize the wastage of energy onboard a ship.

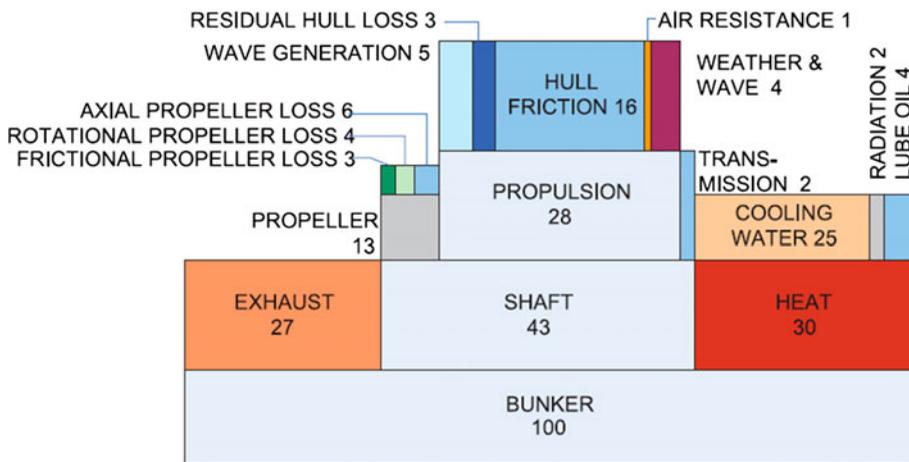


Fig. 6. Energy losses in main engines onboard a ship.

There are various options that are available for shipping operators to optimize energy consumption onboard ships. A 360° approach, which involves regulatory mechanisms, technical measures and operational measures, is recommended to be adopted to achieve synergy in achieving the specific goals of reducing fuel consumption and emissions.

Regulatory Mechanisms

In order to reduce fuel consumption onboard ships, the IMO has mandated the use of EEDI and SEEMP onboard ships.

EEDI

The EEDI is a design index that has been developed by the IMO for use as a tool for monitoring and reducing the carbon emissions from ships by improving their energy efficiency. The EEDI is a performance-based mechanism that specifies the energy-efficiency standards that are to be achieved by ships. The choice of technologies or operational measures in which the ship operators achieve these targets is left to the ship owners. The EEDI regulation⁴² applies to new cargo ships⁴³ greater than 400 gross tons (GT) and varies with ship type, size and function.

The EEDI proposes a minimum energy efficiency level (measured in CO₂ emissions per tonne mile) for different ships as per their size, which is set as a reference baseline. The EEDI standards are expressed as per cent emissions reductions from reference baselines established for each class of ship. A ship's attained EEDI (based on sea trials of new ships) will have to be below the required EEDI (reference baseline value, corrected for emission reductions over time) for that ship type and size, i.e.

$$\text{Attained EEDI} \leq \text{Required EEDI} = (1 - X)/100 \times \text{Reference baseline} \quad (1)$$

where X is the reduction factor.⁴⁴

As long as the required EEDI is attained, the designers would be free to use the most cost-efficient solutions for the ship to comply with the regulations. Table 2 shows the reduction factors that will be implemented in different phases over time for various types of ships. Phase 0, beginning in 2013, calls for new ships to attain the EEDI values at or better than the applicable reference line while phase 1 will require

Table 2. Reduction Factors in Energy Efficiency Design Index (EEDI).

Reduction factors (in percentage) for the EEDI relative to the reference line for each ship type					
	Size	Phase 0 1 Jan 2013– 31 Dec 2014	Phase 1 1 Jan 2015– 31 Dec 2019	Phase 2 1 Jan 2020– 31 Dec 2024	Phase 3 1 Jan 2025 onwards
Bulk Carriers	>20,000 Dwt	0%	10%	20%	30%
	10–20,000 Dwt	n/a	0–10%*	0–20%*	0–30%*
Gas tankers	>10,000 Dwt	0%	10%	20%	30%
	2–10,000 Dwt	n/a	0–10%*	0–20%*	0–30%*
Tankers and combination carriers	>20,000 Dwt	0%	10%	20%	30%
	4–20,000 Dwt	n/a	0–10%*	0–20%*	0–30%*
Container ships	>15,000 Dwt	0%	10%	20%	30%
	10–15,000 Dwt	n/a	0–10%*	0–20%*	0–30%*
General Cargo ships	>15,000 Dwt	0%	10%	15%	30%
	3–15,000 Dwt	n/a	0–10%*	0–15%*	0–30%*
Refrigerated cargo carriers	>5,000 Dwt	0%	10%	15%	30%
	3–5,000 Dwt	n/a	0–10%*	0–15%*	0–30%*

* The reduction factor is to be linearly interpolated between the two values depending on the vessel size. The lower value of the reduction factor is to be applied to the smaller ship size.

ships built between 2015 and 2019 to improve their efficiency by 10%. This will rise to 20% between 2020 and 2024 in phase 2, and 30% for ships delivered after 2024 in phase 3. It is therefore expected that EEDI regulations will continuously improve the energy efficiency of a ship, thereby reducing the fuel consumption and achieving a lower level of CO₂ emissions.⁴⁵

SEEMP

While the EEDI sets the targets that are to be achieved, the SEEMP is a management tool for assisting the crew in managing the energy efficiency of ships. SEEMP will be applicable to all merchant ships, both new and existing, of 400 GT and above. The SEEMP establishes a mechanism for measuring the operational energy efficiency of the ship, setting targets and monitoring the performance against the set targets in four distinct steps, namely planning, implementation, monitoring and self-evaluation. Step 1 involves energy efficiency assessment and planning, where base loads are established, energy saving potential are identified onboard and targets that are to be achieved in terms of energy savings are set. The implementation phase involves establishing a system so that energy efficiency measures can be evaluated. Step 3, which involves monitoring of implemented measures, deals with data collection. The IMO has suggested use of an Energy Efficiency Operational Indicator (EEOI) as a monitoring and/or benchmark tool, which will measure the energy efficiency of each voyage of the ship. The EEOI will be calculated as shown in Equation 2.

$$\text{EEOI} = (\text{Fuel used} \times \text{CO}_2 \text{ conversion factor}) / (\text{cargo quantity} \times \text{distance}) \quad (2)$$

This EEOI from operational data can then be used for subsequent comparison of emissions from each voyage. The last step involves evaluating the effectiveness of the implemented measures and the cycle continues to attain continuous improvements in energy efficiency of the ship.

The SEEMP is a “live” document, containing energy improvement measures identified by the ship owner that will be kept onboard each ship.⁴⁶ The document will be reviewed regularly to establish the relevance and impact of each measure on ship and fleet operations. Each SEEMP will be ship specific but should be linked to a broader corporate energy management policy of the ship owner. Hence the SEEMP

urges the ship owner and operator to consider operational practices and technology upgrades to optimize the energy efficiency performance of a ship and its entire fleet.

Technical and Operational Measures

A large number of potential solutions exist to reduce fuel consumption and minimize emissions onboard ships. These can be broadly classified into aspects related to ship design, use of marine engineering technologies, new propulsion technologies and various operational and maintenance factors. These options along with their approximate power reduction capabilities are briefly listed in Table 3. Suitable measures can be implemented in the design stage for new ships, retro fitment for existing ships and as operational measures for ships at sea.

Case Study: Triple-E ships as Trend Setters in Sustainable Shipping

Newer and more efficient ship designs are redefining the industry standards today. The South Korean firm Daewoo Shipbuilding and Marine Engineering are now building⁴⁷ 20 “Triple-E” ships for Danish shipping firm Maersk at a cost of \$190m each. The name Triple-E stands for Economy of scale, Energy efficiency and Environmentally improved. The Triple-E will be the largest vessel of any type on the water to date. With a length of 400 m, beam width of 59 m and a draught of 14.5 m, the Triple-E ship will have a DWT of 165,000 metric tons and is designed for a top speed of 23 knots. It has a capacity of 18,000 TEU (20-foot container), which is 16% greater (2500 additional containers) than the presently largest container vessels of Maersk’s type “E-class” ships, one of which is named the *Emma Maersk*.

The Triple-E employs various design measures for improving the energy efficiency and reducing onboard emissions. The hull of the Triple-E is more like a U-shape compared with traditional container ships. This allows it to carry 18,000 20-ft containers, despite being only 4 m longer and 3 m wider than *Emma Maersk*. The engines have a lower top speed (23 knots) than the *Emma Maersk*, requiring almost 20% less power and allowing them to run as low as 80 revolutions per minute (rpm). The engine is an ultra-long-stroke engine, with a total power of approximately 30,000 kW per engine. The most fuel-efficient speed is also lower and to retain the efficiency of slower revolutions, Maersk has designed a two-engine, two-propeller “twin-skeg” system. The Triple-E’s two propellers are 9.8 m in diameter with four blades each. The combined diameter of the propellers provides greater pushing power in the water

Table 3. Technical and Operational Measures for Ships.^{60,61}

Ship design	
Efficiency of scale	A 10% larger ship will give about 4–5% higher transport efficiency
Reduce ballast	Removing 3000 tons of permanent ballast and increasing the beam by 0.25 m to achieve the same stability will reduce the propulsion power demand by 8.5%
Lightweight construction	A 20% reduction in steel weight will give a reduction of ~9% in propulsion power requirements
Optimization of dimensions	Adding 10–15% extra length to a typical product tanker can reduce the power demand by more than 10%
Interceptor trim plates	1–5% lower propulsion power demand in total energy demand
Ducktail waterline extension	4–10% lower propulsion power demand
Shaft line arrangement	Up to 3% difference in power demand between poor and good design
Skeg shape	Improvement of up to 2% in total energy consumption for a container vessel
Minimizing resistance of hull openings	Improvement of up to 5% in total energy consumption compared with poor design
Air lubrication to ship's hull	Saving in fuel consumption up to: tanker: ~15%; container: ~7.5%; PCTC: ~8.5%; ferry: ~3.5%
Marine engineering technologies	
Wing thrusters	Better ship performance in the range of 8% to 10%
Contra rotating propellers propulsion	The power reduction for a single screw vessel is 10–15%
Optimization of propeller and hull interaction	Redesigning the hull, appendages and propeller together will improve performance by up to 4%
Propeller rudder combinations	Improved fuel efficiency of 2–6%
Advanced propeller blade sections	Improved propeller efficiency of up to 2%
Propeller wing triplets	Up to 5% power savings compared with a vessel with an open propeller
Variable speed operation for CPP	Saves up to 5% fuel, depending on actual operating conditions

Table 3 (Continued)

Wind power: towed kite	Fuel consumption savings: tanker: ~21%; PCTC: ~20%; ferry: ~8.5%
Solar power	Reductions in total fuel consumption: tanker: ~3.5%; PCTC: ~2.5%; ferry: ~1%
Pulling thruster	Propulsion power demand at the propellers can be reduced by up to 15% with pulling thrusters in advanced setups
Propeller efficiency measurement	Accurate measurement of propeller data will enable fuel savings by as much as 4% in operation
Propulsion technology	
Hybrid technology	Hybrid measures of auxiliary power generation which combine fuel cell, batteries and diesel engine sets using an intelligent control system reduce the total energy consumption by 2% along with reduction of NO _x by 78%, CO ₂ by 30% and PM by 83%
Combined diesel–electric and diesel–mechanical machinery	Total energy consumption is reduced by 4% compared with fully diesel and diesel–electric machinery.
Low loss concept of electric network	Transmission losses reduced by 15–20% and bulky transformers can be removed
Variable speed electric power generation	Fuel saving of 5–10% while also reducing the number of generating sets by 25%
LNG as fuel	Saving in total energy 3–4% for a typical ferry
Waste heat recovery	Exhaust waste heat recovery can provide up to 15–20% of the engine power
Delta tuning	Lower specific fuel consumption at part loads compared with standard tuning
Common rail	Smokeless operation at all loads
Energy saving lighting	Fuel consumption saving in ferry ~1%
Power management	Running extensively at low load can easily increase the SFOC by 5–10%
Advanced power management	Reduces operational fuel costs by 5% and minimizes maintenance
Speed control of cooling water pumps	Pump energy saving (LT only) for cruise ships 20–84%; Ferry 20–30%; AHTS 8–95%

Table 3 (Continued)

Automation	Engine optimization control, power generation & distribution optimization, thrust control and ballast optimization give 5–10% savings in fuel consumption
Operational and maintenance factors	
Turnaround time in port	Faster turnaround allows for lower port charges and lesser number of days at sea for a journey
Propeller polishing	Up to 10% improvement in a serviced propeller efficiency compared with a fouled propeller
Hull coating	Saving in fuel consumption after 48 months compared with a conventional hull coating: tanker: ~9%; container: ~9%; PCTC: ~5%; ferry: ~3%
Part load operation optimization	New matching (i.e. different TC tuning, fuel injection advance, cam profiles, etc.) that takes into account real operation profiles can significantly improve overall operational efficiency
Ship speed reduction ⁶²	Reduction in ship speed vs. saving in total energy consumption (savings varies as cube of speed): 0.5 kn ~7%; 1.0 kn ~11%; 2.0 kn ~17%; 3.0 kn ~23% lower energy
Voyage planning	Shorter passages, less fuel
Vessel trim	Optimal vessel trim reduces the required power
Autopilot adjustment	Finding the correct parameters or preventing unnecessary use of the rudder gives an anticipated benefit of 1–5%
Energy saving operations awareness	Incentives to crew can reduce energy usage by up to 10%
CBM (cubic metres)	Correctly timed service will ensure optimum engine performance and improve consumption by up to 5%
Hull cleaning	Reduced fuel consumption: tanker: ~3%; container: ~2%, PCTC: ~2%; ferry: ~2%; OSV: ~0.6%

PCTC, pure car/truck carrier; SFOC, specific fuel oil consumption; LT, low tension; AHTS, anchor handling tug supply; TC, temperature combustion; OSV, offshore support vessel.

and fewer blades creates less resistance, while consuming 4% less energy than *Emma Maersk's* single-engine/propeller system.

Triple-E ships have a 75-tonne waste heat recovery system, which will make use of the 25% of energy usually lost through hot exhaust gases to reduce fuel consumption and CO₂ emissions by around 9%. As a result, the ship will emit 20% less CO₂ per container moved than E-class vessels and 50% less than the industry average for craft operating between Asia and Europe. In addition, it will consume approximately 35% less fuel per container than the other vessels. Triple-E ships would also employ EEOI systems and SEEMP measures while steaming and are expected significantly to reduce emissions and the cost of shipping compared with other ships, while they are employed in service.

The advent of these supersized, energy-efficient and environmentally improved ships prove that sustainability in shipping is a win-win situation for all stakeholders and would eventually lead to attaining the end goal of higher profits as well as better environment.

Implications for Indian Shipping

India, with a coastline of 7517 km, has 13 major ports and 187 notified minor/intermediate ports and has historically been a maritime nation. India's maritime sector, which consists of ports, shipping (international and coastal), ship building and the ship repair industry, inland water transport, floating crafts and fishing has been identified as a critical infrastructure for the Indian economy, as it influences the pace, structure and pattern of development of a country.⁴⁸ As on 01 December 2013, India had a fleet strength of 1194 vessels with 10.38 million gross registered tonnage (GRT).⁴⁹ Of this fleet, 830 vessels (1.13 million GRT) were operated in coastal waters and 364 vessels (9.24 million GRT) were employed in overseas trade.⁵⁰ Only 22.4% of the Indian coastal fleet is less than 5 years old and the corresponding figure for the Indian overseas fleet is 32.8%. On the other hand, more than 42% of the coastal shipping fleet owned by India has a life of more than 20 years, while about 30% of the overseas fleet have this age profile. The remaining coastal and overseas fleet composition, with an age profile of 6–20 years is 36% and 38%, respectively.⁵¹ Total cargo traffic (both from overseas and coastal cargo) being handled at Indian ports has grown at a rate of more than 10% annually from 2006–07 to 2009–10⁵² and the total overseas cargo handled at India ports, was 754.87⁵³ million tons⁵⁴ in

2011–12.⁵⁵ Despite the seemingly high growth, Indian shipping accounted for only 1.45% of the share of total world trade generated in terms of value, compared with the USA (10.68%) and China (7.91%), in 2008.⁵⁶ In fact, the number of ships plying on overseas routes under the Indian flag has decreased from 372 to 350 ships with a subsequent decrease in GRT from 10,013 thousand tons (as on 31 December 2011) to 9331 thousand tons (as on 31 December 2012).

The above statistics reveal that India's maritime sector is struggling to keep pace with the growing needs of emerging India. India's "Maritime agenda: 2010 – 2020"⁵⁷ also comments that "the pace of growth (of the shipping sector) has to be increased, that the whole efficiency of the delivery system has to be substantially improved and that the concern for the environment has to be stronger". Although the above statistics paint a dismal picture, this also presents a large scope for the growth of the maritime infrastructure and there is a clear window of opportunity for transitioning towards sustainability in the maritime sector for India.

Adoption of a 360° approach, which is driven by international regulatory amendments, integrates fuel and emission reduction technologies in ship design and implements energy saving measures in shipping operations, is proposed to achieve the transition to sustainable shipping in India. While international bodies such as the IMO provide an institutional framework for regulation, governments of its member states must implement suitable legislation for enforcement of directives that have been ratified. Furthermore, other stakeholders in the maritime sector, which include ship owners, operators, designers, builders, port operators and the local community, also need to synergize their actions to adopt a sustainable approach to shipping.

Conclusion

It is evident that sustainability in the shipping industry is now a necessity that is driven by increased competition, growing concern for marine environment, the need to increase profitability and to ensure all-round development of the maritime sector. The changing international scenario is driving the current developments in the maritime arena and is defining future trends in shipbuilding and shipping operations. International regulations now demand that suitable measures have to be incorporated in new construction ships to make them MARPOL compliant. It is therefore imperative that these regulatory developments should be noted and immediate steps should be taken for implementing technical and operational measures to benchmark

and improve energy efficiency of ships. Therefore, improved hull design, new technologies, retrofitting and better operational practices, which optimize fuel consumption, and stringently following international regulations is the need of the hour. Such a transition would enable the shipping industry to become more energy efficient and environmentally responsible in the forthcoming decades. A sustainable shipping industry will be more resilient, and will further boost the economic and social development while protecting the marine environment. An integrated approach, which synergizes these efforts, will mutually reinforce the gains for all stakeholders and has the potential to transform the shipping industry to a profitable and environmentally responsible industry in the coming decades.

Notes

1. Vincent Valentine, eds., *Review of Maritime Transport 2008* (New York and Geneva: United Nations Conference on Trade and Development, United Nation, 2008). http://unctad.org/en/docs/rmt2008_en.pdf (accessed February 1, 2014).
2. World Shipping Council. <http://www.worldshipping.org/about-the-industry/global-trade/trade-statistics> (accessed February 5, 2014).
3. Expected to be 9.55 billion tons in 2013 as per preliminary estimates.
4. “Sustainable Development” is defined by Brundtland Report, United Nations World Commission on Environment and Development, 1987 as “development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs”.
5. Koji Sekimizu, Secretary-General, IMO, “Vision of Sustainable Maritime Development” (paper presented at side event of Rio +20, Rio de Janeiro, Brazil, June 20, 2012). <http://www.imo.org/mediacentre/secretarygeneral/speechesbythesecretarygeneral/pages/rioplus20sideevent.aspx> (accessed February 10, 2014).
6. IMO has identified seven key areas of work to promote sustainable maritime development, namely global standards for shipping, energy efficiency, new technology and innovation, maritime education and training, maritime security, maritime traffic management and the development of maritime infrastructure in the Rio +20 UN Conference for Sustainable Development.

Anon, *IMO and the Environment* (London: International Maritime Organization, 2011).

<http://www.imo.org/OurWork/Environment/Documents/IMO%20and%20the%20Environment%202011.pdf> (accessed April 10, 2013).

7. The IMO is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships.
8. World Maritime Day focuses on the importance of shipping safety, maritime security and the marine environment and to emphasize a particular aspect of IMO's work. The theme for World Maritime Day theme for 2014 is "IMO Conventions: Effective Implementation".
9. IMO Council: 108th session – 11 to 14 June 2012, Briefing: 23, June 18, 2012. <http://www.imo.org> (accessed on January 21, 2013).
10. Sam Kimmins, Rupert Fausset and Stephanie Draper, *Sustainable Shipping Initiative – The Case for Action* (London: Forum for the Future, 2011). http://ssi2040.org/wp-content/uploads/2012/11/SSI_fullreport.pdf (accessed March 10, 2013).
11. Megha Mandavia, "Shipping industry may confront another deluge of overcapacity," *Economic Times*, April 2, 2014, New Delhi edition.
12. 625 dry bulk and 192 container ships were ordered in 2011. Ibid.
13. Ibid.
14. These include air emissions, ballast water discharges, oil spillages, ship recycling, garbage disposal at sea, ship bio-fouling and emission of volatile organic compounds (VOCs).
15. ECAs are specially protected areas that are sensitive to marine pollution and have high density of shipping. An EAC can be designated for SO_x and PM, or NO_x, or all three types of emissions from ships, subject to a proposal from a Party to Annex VI.
16. Existing EACs include: the Baltic Sea (SO_x, adopted: 1997/entered into force: 2005), the North Sea (SO_x, 2005/2006), the North American ECA, including most of US and Canadian coast (NO_x & SO_x, 2010/2012) and the US Caribbean ECA, including Puerto Rico and the US Virgin Islands (NO_x & SO_x, 2011/2014).
17. Chapter 4, "Regulations on energy efficiency of ships".
18. Market-based mechanisms include emissions trading, emission-related charges and taxes, and emissions offsetting.
19. Seventeenth session of the Conference of the Parties (COP 17), took place from 28 November to 09 December 2011 in Durban, South Africa.
20. Proposed jointly by International Chamber of Shipping (ICS), Oxfam and the World Wildlife Fund (WWF).
21. This tax would raise \$26 billion a year, which would contribute to the UNFCCC "Green Climate Fund".

22. Anon, Comment on “EU shipping carbon tax faces widespread opposition” posted from *People’s Daily* March 7, 2012. <http://www.safety4sea.com/eu-shipping-carbon-tax-faces-wide-spread-opposition-10015> (accessed April 3, 2014).
23. The weekly weighted average bunker fuel prices (in US\$ per metric ton) on the west coast of US changed from 274\$ in the week ending 05 June 2009, peaked to 749 \$ in April 2012 and was 668\$ in the third week of August 2012. It is currently 589 USD/ton for bunker fuel. http://www.tsacarriers.org/calc_bunker.html (accessed April 9, 2014).
24. The cost of bunker fuel was assumed to be 400\$/ton in the study.
25. As per 2010 cost data.
26. The cost of distillate fuel onboard ships in 2030 is forecasted to increase to 1300\$/tonne, as per the projections of Annual Energy Outlook, 2011 (Department of Energy, US), due to the mandatory shift in fuel mix towards low sulphur fuels.
27. Clean North Sea Shipping. “Clean Shipping Technology.” <http://cleantech.cnss.no/air-pollutant-tech/sox/low-sulphur-fuel/> (accessed February 3, 2014).
28. Residual oil is the heaviest fraction of the distillation of crude oil, with high viscosity and high concentration of pollutants (e.g. sulphur). It is the cheapest liquid fuel on the market. IFO stands for intermediate fuel oil. IFO 180 has a viscosity of 180 centistokes at 50°C while IFO 380 has a viscosity of 380 centistokes. While IFO 380 has a mix of 88% residual oil and 12% distillate oil, IFO 180 has 98% residual oil and 2% distillate oil. Due to the higher content in distillate oil, IFO 180 is more expensive than IFO 380. Although the ISO specification for sulphur content (by weight) in both IFO 380 and IFO 180 is 5%, the same has been revised to 4.5% by the IMO. MDO mainly consists of distillate oil (with traces of residual oil) and has a 2% sulphur content (by weight). MGO is a pure distillate oil, has a 1.5% sulphur content (by weight) and is used in boats. Ministry of Transport, Government of New Zealand. “Series data TI 008 Bunker Fuel Prices” Transport-Related Price Indices: Prices. <http://www.transport.govt.nz/ourwork/tmif/transportpriceindices/ti008/> (accessed February 9, 2014). Aviation and the Belgian Climate Policy: Integration Options and Impacts. “Glossary – Marine Fuels”. ABC Impacts. http://dev.ulb.ac.be/ceese/ABC_Impacts/glossary/marinefuels.php (accessed February 9, 2014).
29. Ivar Strand, *A Game Changer for the Shipping Industry* (Oslo: Pricewaterhouse Coopers AS (PwC), June 2011).
30. Ibid.
31. The current cost of MDO and IFO 380 per tonne at Singapore is US\$895 and US\$582. Bunker World. “Bunker Prices.” <http://www.bunkerworld.com/prices/> (accessed on April 9, 2014).

32. In comparison, the same for rail and road is in the range of 15–120 and 80–180 g CO₂/ton-km respectively. Ø. Buhaug et al., *Second IMO GHG Study 2009* (London: International Maritime Organization, 2009).
33. Of this, 870 million tons of CO₂ was emitted from international shipping and the rest was attributed to domestic shipping and fishing. Ibid.
34. Ibid.
35. A modelling scenario in climate change mitigation, which sets out an energy pathway consistent with the goal of limiting the global increase in temperature to 2°C by limiting concentration of greenhouse gases in the atmosphere to around 450 parts per million of CO₂.
36. IMO Council: 108th session – 11 to 14 June 2012, Briefing: 23, June 18, 2012, Available at <http://www.imo.org> (accessed on January 21, 2013).
37. Carbon intensity from shipping is projected to decline from 25.93 grams of CO₂ per ton-mile in 2007 to 17.22 grams per ton-mile in 2030 under the intermediate scenario and to 16.40 grams CO₂ per ton-mile, under the best-case scenario. Buhaug, Ø. et al., *Second IMO GHG Study 2009* (London: International Maritime Organization, 2009).
38. These measures could see carbon dioxide emissions reduced by between 100 and 180 million tonnes a year by 2020. Ibid.
39. Anon, *IMO and the Environment* (London: International Maritime Organization, 2011). <http://www.imo.org/OurWork/Environment/Documents/IMO%20and%20the%20Environment%202011.pdf> (accessed April 10, 2013).
40. Energy for operation of auxiliary engines and power generation is separate and is not shown here.
41. For a small well-maintained cargo ship moving at about at 15 knots in Beaufort 6 head weather condition.
42. Parties to the MARPOL Annex VI have the option to waive the EEDI requirement on their ships for a maximum of 4–6.5 years after the entry into force. However, no country has a yet approached the IMO for this waiver.
43. The categories of ships covered include oil and gas tankers, bulk carriers, general cargo ships, refrigerated cargo carriers and container ships.
44. Zabi Bazari and Tore Longva, *Implementing the EEDI, Guidance for owners, operators, shipyards and tank test organisations*, Version 3.0 (London: Lloyd's Register, 2012).
45. Together, the included ship categories will account for 72% of CO₂ emissions from the newly built fleet.

46. Anon, 2012 Guidelines for the development of a SEEMP, MEPC 63/23, Annex 9, page 1. <http://www.imo.org/KnowledgeCentre/IndexofIMOResolutions/Documents/MEPC%20-%20Marine%20Environment%20Protection/213%2863%29.pdf> (accessed April 10, 2013).
47. Maersk expects delivery between 2013 and 2015. *MV Mærsk Mc-Kinney Møller* is the lead ship of Maersk's Triple-E class of container vessels and was pressed into service in July 2013. It is the largest ship build in the world.
48. Anon, *Annual report 2008–09: Ministry of Shipping* (New Delhi, Government of India, 2009).
49. Ministry of Shipping. "Development of Indian Shipping Tonnage," <http://shipping.nic.in/writereaddata/l892s/tonnage-35709190.pdf> (accessed on April 2, 2014).
50. A large number of coastal vessels were tugs, offshore supply vessels and those belonging to port trust and were not involved in actual cargo movement and hence overseas vessels, which include dry cargo bulk carriers and crude oil carriers contributed to 89% of the GRT, while being lower in number, than coastal vessels.
51. *Indian Shipping Statistics, 2012 Ministry of Road transport and highways, Transport research wing* (New Delhi, Government of India, 2013), p. 9. <http://shipping.nic.in/showfile.php?lid=1205>.
52. Except 2008–09 when it was only 2.5% due to global economic downturn.
53. Ibid.
54. Of this, only 58.23 million tons, which is just 7.95% of India's total overseas cargo, was carried by Indian registered flag vessels in 2010–11. This has increased significantly in one year to 82.09 million tons, which is 10.87% of India's total overseas cargo in 2011–12.
55. Basic port statistics of India 2010–11, Ministry Of Shipping, Transport research wing (New Delhi, Government of India, 2012).
56. Vincent Valentine, ed., *Review of Maritime Transport 2008* (New York and Geneva: United Nations Conference on Trade and Development, United Nation, 2008). http://unctad.org/en/docs/rmt2008_en.pdf (accessed May 12, 2013).
57. Anon, *Maritime agenda: 2010–2020: Ministry of Shipping* (New Delhi, Government of India, 2011) (accessed on May 15, 2013).
58. By comparison, the diesel fuel used for land-based transport contains only 0.0010% sulphur by mass.
59. Theo Notteboom and Eef Delhaye, *Analysis of the Consequences of Low Sulphur Fuel Requirements*, Study commissioned by European Community Shipowners' Associations (ECSA) (Antwerp: University of Antwerp, 2010). <http://www.lemoci.com/media/anvers-enqueteecsapdf> (accessed on May 10, 2013).

60. Zabi Bazari and Tore Longva, *Assessment of IMO Mandated Energy Efficiency Measures for International Shipping* (London: Lloyd's Register and DNV, 2011). <http://www.imo.org/MediaCentre/HotTopics/GHG/Documents/REPORT%20ASSESSMENT%20OF%20IMO%20MANDATED%20ENERGY%20EFFICIENCY%20MEASURES%20FOR%20INTERNATIONAL%20SHIPPING.pdf> (accessed on April 4, 2013).
61. Rob Almeida, How to Design a More Efficient Ship (Part 1–4), gCaptain, Courtesy Wartsila Technologies, posted January 4, 2012. <http://gcaptain.com/part-propel-efficient-ship/> (accessed February 15, 2013).
62. Reducing ship speed by 10% will lead to a 27% reduction of the ship's emissions. Overall, if all ships were to slow steam, the available capacity on the market would be reduced (more ships would be needed to carry the same transport work). If the additional emissions of building and operating these new ships were considered in the equation, then reducing the fleet's speed by 10% would lead to overall CO₂ savings of 19%.
63. Ivar Strand, *A Game Changer for the Shipping Industry* (Oslo: Pricewaterhouse Coopers AS (PwC), June 2011). [http://www.rederi.no/nrweb/mm.nsf/lupgraphics/Shipping%20GHG%20PwC%20Final.pdf/\\$file/Shipping%20GHG%20PwC%20Final.pdf](http://www.rederi.no/nrweb/mm.nsf/lupgraphics/Shipping%20GHG%20PwC%20Final.pdf/$file/Shipping%20GHG%20PwC%20Final.pdf) (accessed May 15, 2013).
64. Ivar Strand, *ibid.* (accessed May 15, 2013).
65. Ministry of Transport, Government of New Zealand. "Series data TI 008 Bunker Fuel Prices" Transport-Related Price Indices: Prices. <http://www.transport.govt.nz/ourwork/tmif/transportpriceindices/ti008/> (accessed February 9, 2014).