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Greening the shipping industry: perspectives and challenges of the main environmental-friendly practices taking over the maritime industry

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❖ A few data on maritime transport

- **90% of overall world trade** volumes are traded by sea (Nunes *et al.* 2017)

SOME DATA ON THE ENVIRONMENTAL IMPACT OF THE SHIPPING INDUSTRY:

- It is responsible for about **5% of global oil demand** (International Energy Agency, 2018)
- It accounts for around **2.2% of global annual CO_2 emissions** (IMO, 2018)
- Its emissions are **expected to increase by 150-250% by 2050**, assuming a business-as-usual scenario with a tripling of world trade (Bouman *et al.* 2017)
- Predictions for **2050**: **15% of total CO_2** emissions will be attributable to maritime transport (IMO, 2018)

❖ Literature in the field

A **growing attention** of policymakers, stakeholders and researchers towards measures, policies, and initiatives aimed at reducing the carbon footprint of transport activities:

- 190 papers published only in 2011 **(Lee et al., 2016)**

- Several literature reviews available:

Davarzani et al. 2016 - Systematic review examining more and less recent research on green ports and maritime logistics **(338 journal articles published between 1975 and 2014)**

Christiansen et al., 2013 - Review on the specific problem of bunker consumption optimization methods

Lindstad et al., 2015; Faber et al., 2011; CNSS, 2011; Winnes et al. 2015 - Comprehensive overview of emissions reduction measures published in literature

Bouman et al., 2017 - Comprehensive overview of the measures with high CO_2 reduction potential **(around 150 studies published after 2009)**

❖ Definition of the research questions

1. **Which are the main drivers of the green revolution taking place in the maritime industry?**
2. **How is the maritime industry trying to comply with the new environmental requirements?**
3. **What are the main challenges and barriers to implementation?**

❖ Methodology

Critical state-of-the-art review performed by consulting relevant work published on the topic, including:

- industrial reports
- academic papers
- technical reports
- updated bulletins of trusted sector experts

RQ 1

Which are the main drivers of the green revolution taking place in the maritime industry?

❖ Identified drivers

1. Regulatory and Institutional pressures

- IMO regulations

2. Market conditions and financial issues

- The constant fluctuation of fuel prices has always led to explore alternative energy options.
- Energy costs = 50% and 70% of operating costs. This percentage is set to further increase, making attractive the adoption of alternative fuel options **(Rehmatulla and Smith, 2015)**
- Information concerning the location and amount of global fuel reserves often difficult to obtain or controversial

3. Social pressures

(Linder, 2018; O'Rourke, 2003)

- Companies need customers' and investors' approval to stay in business
- Citizens, NGOs and other organizations can influence this change by means of local activism and lawsuits
- By disregarding from what is socially accepted, a company risks losing customers, and therefore profits.

4. Ecological awareness and responsiveness

- Be green and perform green

❖ Identified drivers: IMO regulations

IMO – International Maritime Organization

- UN specialised agency for the prevention of marine pollution by ships and for the safety and security of shipping
- From 1997: body responsible for regulating maritime emissions (designated by the UNFCCC)
- Main measure: *MARPOL Convention* (1983)

  Scope: preventing and minimizing ships pollution for both operational and accidental reasons.

  Structure: six technical Annexes, Annexe VI regulates air pollution generated by ships.

The shipping industry, will have to deal with:

- Upcoming **global 0.5 sulphur cap** on fuel content (the present limit is 3.5%): from 1 January 2020
- Existing **0.1% sulphur cap** in designated Emission Control Areas (**ECAs**). EU has also established the same sulphur limit for ships at berth in **several EU ports**.
- Progressively restrictive policies regarding **NO_x** (applicable to ships built after January 2016)
- In April 2018, the IMO agreed on a strategy to reduce GHG emissions in the shipping sector to meet the Paris Agreement goals. The strategy includes a target to "**reduce the total annual GHG emissions by at least 50 percent by 2050 from 2008 levels whilst pursuing efforts towards phasing them out**". A final plan is not expected until 2023!

RQ 2

How is the maritime industry trying to comply with the new requirements?

❖ Critical overview of the main green measures

1. **Technology- related**
   - Change the fuel quality by using low sulphur fuel oil
   - Switch to alternative fuel options (one for all, LNG)
   - Invest in alternative green equipments (scrubbers)
   - Ship design (hull optimization, economies of scale, kites)
   - Port initiatives (OPC)
2. **Operations-related**
   - Slow steaming and voyage optimization
3. **Logistics and management**
   - Network design
   - Decision Support Models
4. **Market-related**
   - Tax and incentives
   - Voluntary environmental programs and Green Shipping Practices

❖ Critical overview of the main green measures

1. Technological measures

Change the fuel quality by using low sulphur fuel oil

- Vessels can use low-sulphur fuel oil, such as MGO, instead of HFO
- It is the simplest way to comply with the new IMO requirements ... but:
  - MGO is currently around **60% more expensive** than conventional HFO **(Ship and Bunker, 2019)**
  - Bunker costs represent on average between 50% and 70% of operating costs of a vessel

(Rehmatulla and Smith, 2015)

Significantly higher costs for the shipping industry

Increase in transportation rates estimated at about 10% per TEU for customers (Hapag-Lloyd, 2018)

❖ Critical overview of the main green measures

1. Technological measures

Switch to alternative energy options

- Global consumption of ship fuel today: around **4 M barrels per day** **(Lloyd's List Outlook, 2019)**
- **Diversification of energy alternatives** seems to be the key for the future:
  - **Renewable energy - wind and solar** (1-50%)*: useful to supplement existing power generating systems, not yet considered as a viable alternative for commercial shipping **(IEA, 2014)**
  - **Hydrogen:** its use rises several challenges concerning production, transport, storage and related costs and safety concerns.
  - **Electrification:** Significant growth in hybrid solutions is expected for the years to come. Its potential to reduce GHG emissions depends on the source of electricity.
  - **Biofuels** (25-84%)*: high potential to contribute to reduce GHG emissions and rapidly biodegradable. Main challenge concerning their adoption on a large scale: possibility to secure the necessary production volume.
  - **Methanol, LPG, and others:** Methanol is in an earlier state of market introduction, but some large scale tests have already been implemented (the Swedish shipowner Stena has replaced to methanol engines all conventional engines of its ro-pax ships). Limited availability: it is not expected they will play in the near future a key role as alternative fuels.

*Potential CO_2 reduction

By 2050, DNV GL forecasts that only 47% of energy for shipping will derive from oil-based fuels, gas-fuels will account for 32%, and the remaining part will be provided by alternative energy sources.

❖ Critical overview of the main green measures

1. Technological measures

Switch to alternative energy options: Liquefied Natural Gas (LNG)

- Better environmental performance with respect to conventional fuels:
  - up to 15-20% CO_2 emission reduction (even compared to low-sulphur fuels)
  - almost complete removal of SO_x and PM emissions
  - up to 85% NO_x emission reduction
  - CO_2 -equivalents emissions do not necessarily favour LNG

(Winnes et al., 2015; Brynolf, 2014)

- Commercially attractive and available in quantities able to meet the fuel demand of shipping

- Increasing number of ships using LNG as a fuel:
  - 125 merchant ships in 2018 (DNV GL, 2019), around 1,000 expected in 2020 (DNV GL, 2016)
  - CMA CGM (4th world's biggest container shipping company), has ordered 9 MGVs powered by LNG
  - Hapag-Lloyd (5th biggest container shipping company in the world), already owns 17 LNG-ready vessels

- High investments in place:
  - many ports investing to offer upgraded LNG refuelling facilities for ships (Malta, North Sea, Antwerp region, …)
  - over 500 M US$ invested in EU for marine bunkering LNG projects

(Baresic et al., 2018)

❖ Critical overview of the main green measures

1. Technological measures

Switch to alternative energy options: Liquefied Natural Gas (LNG)

- Adoption of LNG on a large scale will happen as a consequence of:

- increases of price of conventional fuels;
- development of technology and necessary infrastructures at a global level (large-scale bunkering network);
- further tightening of NOx limits from 2020;
- availability of the gas resources in the long-term.

- There are **skeptical opinions** about the actual value of LNG as a replacement of conventional fuels:

- in relation to the CO_2 reduction required by the IMO's 2050 objectives, there does not seem to be significant CO_2 equivalent reduction achievable through the use of LNG **(Rehmatulla, 2016)**
- depending on the fuel's supply chain used, a switch to LNG can even increase GHG emissions **(Baresic et al., 2018)**

LNG appears to be a very good option for complying with the sulphur limits, but as it cannot enable the required GHG reductions, its role as a marine fuel it is likely to be only transitory.

❖ Critical overview of the main green measures

1. Technological measures

Ship design (optimization of hull shape, efficient design, economies of scale, kites)

- **Optimization of hull shape and super-structures** can reduce consumption and CO_2 emissions up to 15% for large ships **(2-30%)*** **(IMO, 2009)**
- According to several estimates, design measures can potentially reduce ships' CO_2 emissions by up to 50% **(IMO, 2009; Winnes *et al.*, 2014)**
- According to an IMO regulation enforced in 2011, all new ships built from 1/01/2013 onwards are obliged to indicate an **Energy Efficiency Design Index (EEDI)**, which must not exceed the reference value.
  The EEDI gives an estimate of CO_2 emissions per dwt*NM.
- **Gigantism trend (4-83%)***: large vessels are more environmentally efficient than smaller ones in terms of consumption per freight unit while their benefits in ports are minor due to the required longer times to perform operations.
- **Kites** to increase propulsion efficiency in navigation: potential for saving fuel with low installation costs

*Potential CO_2 reduction

❖ Critical overview of the main green measures

1. Technological measures

Invest in alternative green equipments (scrubbers, batteries, etc.)

- From 1 January 2020, ships that use fuels with a sulphur content higher than 0.5% (today's limit is 3.5%) will only be allowed to operate if equipped with Exhaust Gas Cleaning Systems (EGCS)

- EGCS: desulphurization equipments that remove the excess pollution from exhaust gas and then flush it into the sea (open-loop mode)

- Shipowners are reluctant to invest in EGCS for several reasons:
  - they are extremely costly (from 1 up to 6 M$ per ship)
  - require up to 20 days for installation (yielding to consequent revenue losses for out-of-service)
  - don't actually reduce sulphur (they mainly transfer it from the atmosphere to the sea)
  - IMO is still implementing regulations

- **May 2018**: only 817 ships (out a global fleet of 60,000) were reported ordered or installed with scrubbers

(DNV GL, 2018)

❖ Critical overview of the main green measures

1. Technological measures

Invest in alternative green equipments (scrubbers, batteries, etc.)

- **There is a lively debate on open-loop scrubbers**:
  - Several port states are reported to have banned the use of open-loop scrubbers within their territorial waters **(Lloyd's List, 2019)**
  - **February 2019:** a study carried out by the MIT was submitted to the IMO stating that scrubbers may not be as efficient in removing small particulate that are harmful to human health.
  - **February 2019:** the EU asked the IMO to review its guidelines on scrubbers and take appropriate measures.
  - **February 2019**: The EU proposal drew the ire of the *Clean Shipping Alliance 2020*, which said the commission was needlessly creating worries by mentioning an alternative Japanese study presented to the IMO only one week before the MIT study, with opposite results.

Research is far from conclusive, more work is needed in order to effectively measure the effects of scrubbers.

THE MATTER IS URGENT AS SHIPPING COMPANIES ARE INVESTING TO INSTALL THEM ON BOARD OF THEIR SHIPS

❖ Critical overview of the main green measures

2. Operational measures

Eco-navigation and speed reduction

- **Eco-navigation/Voyage optimization (1-48%):**

Modern technologies allow predicting the weather and maritime conditions with accuracy in order to select the most energy-efficient navigation routes and bypass "undesirable" routes.

(Styhre and Winnes, 2013)

- **Speed reduction:**

Fuel consumption is proportional to the third power of the sailing speed: a small decrease in speed entails a significant reduction in fuel consumption.
Can be done in two ways:

1. ***Constructing vessels with reduced installed horsepower***

- the first cellular containerships reached up to 33 knots
- Maersk Triple-E fleet (18.000 TEU) have a design speed of 17.8 knots

2. ***Adopting slow steaming*** **(1-60%)**

- Slow steaming spread widely during the 2007 global economic crisis to counteract rising fuel costs.

(Cariou and Notteboom 2011; Meyer *et al.* 2012; Notteboom and Vernimmen, 2009)

- Side benefits (in addition to cost reduction): contribute to reduce the shipping overcapacity
- Negative side-effects: shift towards alternative land-based transport alternatives

❖ Critical overview of the main green measures

3. Logistical and management measures

Decision Support Models (DSM)

Simulation and optimization models to improving sustainability in maritime shipping

- Most of the available studies propose mathematical models for optimizing specific maritime operations:
  - fleet deployment
  - berth allocation
  - scheduling optimization
  - fleet routing
  - network design (potential emission reduction: up to 43% **Serra et al., 2018**)
- A common objective of DSM is to make port operations more efficient to reduce turnaround times
- Potential improvements: between 10 and 20% **(Mansouri et al., 2015)**

4. Market measures

- **Green Shipping Practices (GSPs)**

(uncommon) Some shipping firms have begun to respond to environmental concerns by voluntarily embracing GSPs to make their operations greener. Examples include:

- counting the carbon footprint of shipping routes
- using alternative equipment to reduce environmental damage in performing shipping activities

- **Tax, incentives and voluntary programs**

- application of differentiated port fees depending on the environmental footprint of the ship
- provision of incentives for shipping companies to operate with lower emissions
- promotion of effective voluntary programs to improve air quality (an example was implemented in the ports of Los Angeles and Long Beach. Related emissions reductions were estimated at 43% for SO_x, 42% for NO_x and 49% for PM) **(Linder, 2018)**

RQ 3

What are the main challenges and barriers to implementation?

❖ Challenges and implementation barriers…

▪ …of a practical nature

Financial: High investments required and limited access to capital market **(Rehmatulla and Smith, 2015)**

According to estimates, the new IMO regulations will cost the shipping industry 60 billion US$ per annum

Technological: Limited availability of infrastructures (especially for LNG) or not yet mature technology

Time-related: it takes time to convert ships to LNG or to build new LNG-burning vessels. It also takes time to install scrubbers. Shipowners may have their own agenda, and this can be in conflict with IMO ones.

▪ …traditionally inherent in the sector

Inertia: Shipowners and port operators are very conservative and often make resistance to innovation.

(Faber et al., 2011)

Risk appetite: Shipping operators may be skeptical about the implementation of new solutions as a result of the needed large capital investments needed and the risk of being locked-in in unsuccessful technologies.

Three dimensions of risk: external (*uncertainty on future regulatory steps*), business, technical. **(Sorrell et al., 2000)**

❖ Challenges and barriers…

▪ … related to the market

Market barriers: type of charter contracts that hamper an implementation.

Split incentives: this obstacle arises when two parties engaged in a contract have different goals. Typically occur between ship-owners and charterers due to divided responsibility for fuel cost. **(Rehmatulla and Smith, 2015)**

Unclear and unfair regulatory frameworks: If a country adopts unilaterally more strict measures the competition is distorted.

▪ … related to boundary constraints

Measurability: It is probably the mainly undervalued problem when dealing with the reduction of maritime emissions. *Is there a reliable way to measure emissions?* **(Psaraftis, 2016)**
It is necessary to choose a common method and apply it consistently

Informational problems: they mainly concern the lack of reliable and trusted information concerning costs and efficiency of the measures from independent third parties **(Faber et al., 2011)**

❖ Conclusions

- Greening the shipping sector will involve gradually moving away from conventional fuels, as well as combining different operational measures and practices
- Some of the analyzed measures are already technologically advanced while others are not, some are easy to implement in the short-term while others require relevant capital investments and longer timescales
- No single measure is enough to realize the IMO's targets by 2050. A multi-strategy approach is needed
- A green efficiency gap exists between the actual level of implementation and the higher level that would be expected based on technical analysis
- A number of barriers impede a wider diffusion and adoption of green practices in the shipping industry
- Only those innovations that fit the concepts of environmental sustainability with those of economic sustainability and shipping needs will have a chance to succeed

❖ Conclusions: Potential Enablers

International Institutions and Governments:

- Ensure that legislative and regulatory frameworks are agreed and adopted in order not to distort competition in international shipping
- Fill some existing regulatory gaps
- Develop a structured plan to support and foster the adoption of green initiatives, including:
  - Providing financial support for the implementation
  - Investing in complementary infrastructures
  - Investing in research and training

Research:

- Investigate relationship between a proactive environmental strategy and greater profits
- Investigate side-effects of the various green measures
- Develop a reliable estimation method for emissions
- Develop DS tools that can help decision makers to appraise the most effective strategy through evidence-based and transparent cost-benefit assessment

Many thanks for your attention

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