Challenges for innovation in the maritime industry

Perunovic, Zoran; Fürstenberg, Sofia; Christoffersen, Mads

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CHALLENGES
for Innovation in Networks in the Maritime Industry

Zoran Perunovic, Technical University of Denmark
Sofia Furstenberg, AP Moller-Maersk
Mads Christoffersen, Technical University of Denmark
Innovation dynamics in the maritime industry

Perunovic and Vidic-Perunovic (2012)
Research sponsored by the Danish Maritime Fund

Research objectives

- Determine the **key enablers, barriers, and mechanisms** of “innovation in networks” in the maritime industry

- Identify the key **characteristics of collaborative innovation processes** applied in the maritime industry

- Determine **managerial actions** to be undertaken to organize for successful innovation in networks

- **Asses the benefits** of innovation in networks

Research strategy

- Multiple-case research strategy
Explanation of how “innovation in networks” creates value for participants in the maritime industry
Regulatory requirements

Air pollution reduction
SOx, NOx, PM, CO₂

Ballast Water Treatment
Regulatory requirements

**SOx reduction**

<table>
<thead>
<tr>
<th>Outside an ECA established to limit SOx and particulate matter emissions</th>
<th>Inside an ECA established to limit SOx and particulate matter emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.50% m/m prior to 1 January 2012</td>
<td>1.50% m/m prior to 1 July 2010</td>
</tr>
<tr>
<td>3.50% m/m on and after 1 January 2012</td>
<td>1.00% m/m on and after 1 July 2010</td>
</tr>
<tr>
<td>0.50% m/m on and after 1 January 2020*</td>
<td>0.10% m/m on and after 1 January 2015</td>
</tr>
</tbody>
</table>

* May be pushed to 2025. Decision in 2018 or earlier.
**Regulatory requirements**

**NOx reduction**

<table>
<thead>
<tr>
<th>Tier</th>
<th>Ship construction date on or after</th>
<th>Total weighted cycle emission limit (g/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n = engine’s rated speed (rpm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n &lt; 130</td>
</tr>
<tr>
<td>I</td>
<td>1 January 2000</td>
<td>17.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>1 January 2011</td>
<td>14.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>1 January 2016</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Tier III enforcement date (January 2016) is being debated. US and Canada will implement 2016. Other and new ECA still uncertain.**

**Major engine conversion could shift compliance from Tier I to Tier II**

![Graph showing NOx limit vs. rated engine speed](image)
Regulatory requirements

Greenhouse gasses

<table>
<thead>
<tr>
<th>Vessel type</th>
<th>Size</th>
<th>Phase 0 2013 – 2014</th>
<th>Phase 1 2015 - 2019</th>
<th>Phase 2 2020 - 2024</th>
<th>Phase 3 2025 -</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk carriers</td>
<td>&gt;20,000 dwt</td>
<td>0%</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>10-20,000 dwt</td>
<td>n/a</td>
<td>0-10%</td>
<td>0-20%</td>
<td>0-30%</td>
</tr>
<tr>
<td>Gas tankers</td>
<td>&gt;10,000 dwt</td>
<td>0%</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>2-10,000 dwt</td>
<td>n/a</td>
<td>0-10%</td>
<td>0-20%</td>
<td>0-30%</td>
</tr>
<tr>
<td>Tanker and combination carriers</td>
<td>&gt;20,000 dwt</td>
<td>0%</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>4-20,000 dwt</td>
<td>n/a</td>
<td>0-10%</td>
<td>0-20%</td>
<td>0-30%</td>
</tr>
<tr>
<td>Container ships</td>
<td>&gt;15,000 dwt</td>
<td>0%</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>10-15,000 dwt</td>
<td>n/a</td>
<td>0-10%</td>
<td>0-20%</td>
<td>0-30%</td>
</tr>
<tr>
<td>General cargo</td>
<td>&gt;15,000 dwt</td>
<td>0%</td>
<td>10%</td>
<td>15%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>3-15,000 dwt</td>
<td>n/a</td>
<td>0-10%</td>
<td>0-15%</td>
<td>0-30%</td>
</tr>
<tr>
<td>Refrigerated cargo</td>
<td>&gt;5,000 dwt</td>
<td>0%</td>
<td>10%</td>
<td>15%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>3-5,000 dwt</td>
<td>n/a</td>
<td>0-10%</td>
<td>0-15%</td>
<td>0-30%</td>
</tr>
</tbody>
</table>

Market-based, operational, and technical measures proposed

Energy Efficiency Design Index (EEDI)

\[
EEDI = \frac{CO_2 \text{ emission}}{\text{transport work}}
\]

Ship Energy Efficiency Management Plan (SEEMP)

Energy Efficiency Operational Indicator (EEOI)

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# Regulatory requirements

## Ballast water treatment

<table>
<thead>
<tr>
<th>Year constructed</th>
<th>BW Capacity (m³)</th>
<th>Applicability of standards</th>
<th>New schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 2009</td>
<td>1,500 - 5,000</td>
<td>D-1 or D-2 before end of 2014. D-2 from 2015</td>
<td>1st renewal survey after entry into force of the Convention</td>
</tr>
<tr>
<td>Before 2009</td>
<td>Less than 1,500 or greater than 5,000</td>
<td>D-1 and D-2 before end of 2016. D-2 from 2017</td>
<td>1st renewal survey after the anniversary date of delivery of ship in 2016</td>
</tr>
<tr>
<td>In 2009 or after</td>
<td>Less than 5,000</td>
<td>D-2</td>
<td>1st renewal survey after entry into force of the Convention</td>
</tr>
<tr>
<td>Between 2009 and 2012</td>
<td>5,000 or more</td>
<td>D-1 and D-2 before end of 2016. D-2 from 2017</td>
<td>1st renewal survey after the anniversary date of delivery of ship in 2016</td>
</tr>
<tr>
<td>In 2012 or after</td>
<td>5,000 or more</td>
<td>D-2</td>
<td>1st renewal survey after entry into force of the Convention</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vessel type</th>
<th>BW capacity</th>
<th>Date constructed</th>
<th>Vessel’s compliance date</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>All</td>
<td>On or after 1 December 2013</td>
<td>On delivery</td>
</tr>
<tr>
<td>Existing</td>
<td>Less than 1500 m³</td>
<td>Before 1 December 2013</td>
<td>First scheduled drydocking after 1 January 2016</td>
</tr>
<tr>
<td>Existing</td>
<td>1500 - 5000 m³</td>
<td>Before 1 December 2013</td>
<td>First scheduled drydocking after 1 January 2014</td>
</tr>
<tr>
<td>Existing</td>
<td>Greater than 5000 m³</td>
<td>Before 1 December 2013</td>
<td>First scheduled drydocking after 1 January 2016</td>
</tr>
</tbody>
</table>

**IMO postponed - US will start Different requirements for approval of systems 50+ different systems**
Technologies

SOx reduction

SOx reduction measures and technologies

Low sulfur fuels

- Liquefied Natural Gas
- Distillate fuel
  - Marine Diesel Oil
  - Marine Gas Oil
- Biofuels
- Fuel blends

Scrubber

- Wet
  - Open loop
  - Closed loop
- Dry
  - Hybrid

Engine modifications required

Lengthy installation process

LNG not effective for retrofitting

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Technologies
NOx reduction

Tier II
Primary control (at engine)
- Engine design and operational adjustment of parameters and components
  - Fuel injection
  - Valve timing
  - Charge air
  - Compression ratio
- Reduction of temperature and oxygen content
  - Water-in-fuel
  - Fuel water emulsion
  - Direct water injection
  - Humid air motor
  - Scavenging air moistening

Tier III
Post-combustion abatement
- Selective catalytic reduction
- Exhaust gas recirculation
  - Four-stroke medium speed engine
  - Two-stroke low speed engine

Negative correlation between fuel combustion efficiency and NOx emission
Technologies

Energy efficiency and CO2 reduction

Operational measures
- Improved voyage planning
- Propeller cleaning
- Slow steaming

Market based measures
- Contribution schemes for CO2 emissions from international shipping
- Emission trading systems
- Schemes based on actual efficiency

Technical measures
- Reduction in ship resistance
  - Optimized hull design
  - Advanced hull coatings
  - Lightweight materials
  - Speed reduction
- Improved efficiency of main and auxiliary engines
  - De-rated engines
  - Efficient engines
  - Contra-rotating propulsion
  - Improved auxiliary machinery
  - Different devices for improving propulsion efficiency
  - Low carbon fuels (LNG and biodiesel)
- Improved power management (Increase in power production efficiency and reduction in auxiliary power consumption)
  - Waste heat recovery system
  - Shaft propulsion generators
  - Electrical energy efficient technologies
  - Improved transmission systems
  - Wind, solar, and nuclear energy
  - Hybrid power systems

Retrofit vs Newbuild
Technologies

Ballast water treatment

Ballast Water Management (BWM)

Recording procedures
- BW Management Plan
- BW Record Book

BWM Methods
- BW Exchange
  - Sequential
  - Flow through
  - Dilution
- BW Treatment
  - Mechanical
  - Physical
  - Chemical
    - Filtration
    - Magnetic separation
    - Hydrocyclone
    - Thermal (heat)
    - Ultraviolet irradiation
    - Ultrasound
    - Cavitation
    - Inert Gas Deoxygenation
- Sediment management
- BW Isolation
  - Reception facilities
  - Return to origin

Training and education

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Market challenges

• Fleet over-capacity creates low freight rates and aggressive competition
• Price development of HFO vs. other fuel options such as LNG, is very difficult to predict, and the outcome will have tremendous effect on the business case for the different options
• Market is growing North-South rather than East-West, with different trade of goods, and thus different types of ships. Hence, obsolete vessels on e.g. Asia-Europe trade cannot easily be transferred to Europe-South America
• Ships being built today have an expected life-time of 25 years. Regulatory landscape will look different by then, but many solutions are irreversible – hence placing the bet on LNG is not something you can go and change
Stakeholders
In general

Stakeholders are not used to innovation dynamics created by deployment of goal-based policies

Reactive behavior on innovation

Innovation paradigms

Conflicting interest of different stakeholders

Enforcement dates
Lack of compliance control
Variation in different regions and countries

Oversaturated market
Fuel cost and availability
Route dependency

Low technology readiness
Myriad of unproven technologies and suppliers
Retrofit or new build

REGULATION
MARKET
TECHNOLOGY
Innovation networks

- Owner driven
- Vertical engine maker-driven
- Horizontal engine maker-driven
- Participant driven informal
- Open networks (government driven)
- Classification society driven decentralized networks
Formation

INNOVATION NETWORK FORMATION

Engine maker vertical

Discontinuous Innovation
High tech industries

UNCERTAINTY
Firm-specific

PARTNER SELECTION
New partners
Non-redundant relationships

STRUCTURAL HOLES
Untapped knowledge between unconnected partners

Class driven

PARTNER SELECTION
Existing pool of partners
Redundant relationships

Owner driven

Uncertainty Market

Engine maker horizontal

PARTNER SELECTION
New partners
Non-redundant relationships

Participant driven informal

INNOVATION NETWORK FORMATION

SOCIAL CAPITAL
Experience, reputation, position, trust, norms of behavior

Incremental innovation

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Key enablers

Good network management
Absorptive capacity

Key barriers

Social capital mind set
Lack of innovation stimulating organizational culture
Use of innovative products and solutions in operations

Opportunity

Structural holes between technology suppliers
Horizontal networks among owners and technology suppliers