ECONOMIC FEASIBILITY STUDY OF REFUELING STATIONS FOR VESSELS USING LNG AS FUEL

Leonidas Chrysinas
Strathclyde University
Aim of the Study

➢ Motivations

✓ Environmental Regulations (Existing and Upcoming)

✓ Expectations for increase of HFO and MGO prices the following years

➢ Objective of the Study

✓ Estimation of demand and design an adequate LNG supply network

✓ Evaluation of the costs that will be made in the final part of the supply chain
Key Stages of the Study

- **Research - Statistical Data Collection**
  - Port Authorities
  - Statistical Services

- **Create Database** -(sea-web.com)
  - Initial grouping according to the type of ships
  - Further grouping according to key features of each ship
    - Capacity (i.e. DWT, TEU, ceu, berths)
    - Age
    - Total installed power (kW)
    - Service speed
Key Stages of the Study

- **LNG fuel demand estimation**
  - Assumptions for selecting ships shifted to the use of LNG
    - Selection of ships operating in areas with strict environmental emission limits (π.χ. SECA’s) “Short sea shipping”
    - Selection of younger ships (under 10 or 15 years)
  - Assumptions for the estimated volume of bunkering
    - Bunkering operation after 500 nautical miles for commercial vessels
    - Bunkering operation according to the exact distance that each class of coastal vessels covers
  - Selection of suitable dual fuel engines (MAN, Wärtsilä)
  - Calculations for demand of LNG and for the exact number of bunkering operations for each class of vessels both in annual and daily basis
  - Estimation for the total demand of LNG for each port
Key Stages of the Study

- **Selection of land-based storage tanks of LNG**
  - The basic criterion is the distance between the port and the LNG import terminal (Revithousa)
    - Leasing LNG storage space and providing to facilitate the bunkering operations of the terminal (i.e. Piraeus Port)
    - Land-based storage installation (i.e. Patras Port, Thessalonikis Port)

- **Selection of the appropriate equipment for the bunkering operations of LNG**
  - Criteria
    - Shipping industry overview
    - Estimated demand of LNG for each type of vessel
    - Estimated number of daily bunkering operation
    - Total demand of LNG
Key Stages of the Study

- Investment Proposal
  - Estimation of Investment and Operating Costs

- Selection of Financial Evaluation Criteria
  - Pay Back Period - PBP
  - Net Present Value - NPV
  - Internal Rate of Return - IRR

- Study Results
  - Econometric Results
  - Conclusions
    - Weighted Average Cost of Capital (WACC): 8%
    - The analysis does not include taxis
    - The time horizon of our investment was set to 40 years
Key Stages of the Study

**Technical Part**
- Gather Data
- Categorize according to vessels type
- Re-categorize according to DWT and age
- Using for retrofit vessels under 10 years old
- Choose suitable dual-fuel engine according to total installed power
- Calculate the average fuel consumption for each categories vessels
- Calculate the total fuel consumption of the vessels banker in the port
- Calculate the number and the volume of daily bunkering operations
- Having the annual demand of LNG
- Select suitable equipment for bunkering

**Financial Part**
- Calculate investment cost
- Calculate operational cost
- Calculate the surcharge per tonne LNG for the examined number of depreciation years
- Compare with the fridges of the alternative fuels
- Checking feasibility

Co-funded by the Marco Polo Programme of the European Union
Port of Piraeus

- Market Research - Statistical Data Collection
  - Vehicles Carrier - Car Terminal
    - 716 calls by 202 vessels
  - Container Ship - Container Terminal
    - 2,398 calls by 302 vessels
  - Cruise Ship - Passenger Terminal
    - 770 calls by 110 vessels
  - Ro-Pax Ship - Passenger Terminal
    - 4,293 calls by 31 vessels
Create Database

Vehicles Carrier

- Categorize in two groups according to the capacity
  - Class A (\(\leq 3.999\) ceu)
  - Class B (\(\geq 4.000\) ceu)

- Class A vessels mainly transfer vehicles between key ports and neighboring ports
- Class B vessels mainly transfer vehicles between different continents

*We consider Class A and aged less than 10 years vessels ideal for using LNG as marine fuel*
Create Database

Container Ship

- Categorize in three groups according to the capacity
  - Class A (0-1.999 TEU)
  - Class B (2.000-7.999 TEU)
  - Class C (≥ 8000 TEU)

- Class A vessels mainly operate to TEU transfer between key ports and neighboring ports
- Class B is a group between the other two.
- Class C vessels are used for lines between major continents

We consider that Class A and aged less than 10 years vessels ideal for using LNG as marine fuel
Port of Piraeus

Create Database

- Cruise ship
  - Categorize in two groups according to the capacity
    - Class A ($\leq 999$ berths)
    - Class B ($\geq 1,000$ berths)
  - More calls made by Class B vessels (63% more than Class A vessels)
  - The third quarter of year 2012, both classes present more arrivals with the cruise ships of Class A to have 125 out of 292 total calls while cruise ships from Class B had 183 out of 428 total calls

We consider that both Classes and aged less than 15 years vessels ideal for using LNG as marine fuel
Port of Piraeus

- Create Database
  - Passenger Ro-Ro Ship (Vehicles)
    - The segmentation has been made according to the route for year 2012
      - Cyclades
      - Crete
      - North Aegean
      - Dodecanese
    - The third quarter noted more calls and specifically 1.704 out of 4.293 annual calls.
    - The majority of the departures from port of Piraeus addressed to the Cyclades islands

*We consider aged less than 15 years vessels ideal for using LNG as marine fuel*
## Estimated Demand of LNG

<table>
<thead>
<tr>
<th></th>
<th>Vehicles Carrier (≤3,999 ceu)</th>
<th>Container Ship (0-1.999 TEU)</th>
<th>Cruise Ship (≤999 berths)</th>
<th>Cruise Ship (≥1,000 berths)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required amount of fuel (m³)</td>
<td>80</td>
<td>95</td>
<td>145</td>
<td>450</td>
</tr>
<tr>
<td>Annual number of bunkering operations 2020</td>
<td>83</td>
<td>210</td>
<td>65</td>
<td>169</td>
</tr>
</tbody>
</table>
Port of Piraeus

Expected Annual Demand of LNG (2020)
<table>
<thead>
<tr>
<th>Type of Vessel</th>
<th>Expected Calls (2020)</th>
<th>Average Refuelling volumes (m$^3$)</th>
<th>Percentage of vessels that will use LNG</th>
<th>Percentage of vessels that will make bunkering in Piraeus</th>
<th>Estimated number of bunkering operations</th>
<th>Annual Demand of LNG (m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Container Ship</td>
<td>1355</td>
<td>92,3</td>
<td>26%</td>
<td>60%</td>
<td>210</td>
<td>19.382,9</td>
</tr>
<tr>
<td>Small Passenger Cruise</td>
<td>292</td>
<td>143,5</td>
<td>37%</td>
<td>60%</td>
<td>65</td>
<td>9.384,5</td>
</tr>
<tr>
<td>Large Passenger Cruise</td>
<td>478</td>
<td>450,2</td>
<td>59%</td>
<td>60%</td>
<td>169</td>
<td>75.898,6</td>
</tr>
<tr>
<td>Small Vehicles Carrier</td>
<td>395</td>
<td>77,7</td>
<td>33%</td>
<td>60%</td>
<td>78</td>
<td>6.009,7</td>
</tr>
<tr>
<td>Small Passenger Ro-Ro Ship (Vehicles) Crete</td>
<td>1332</td>
<td>89,6</td>
<td>0%</td>
<td>100%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Large Passenger Ro-Ro Ship (Vehicles) Crete</td>
<td>756</td>
<td>188,8</td>
<td>60%</td>
<td>100%</td>
<td>425</td>
<td>80.195,5</td>
</tr>
<tr>
<td>Small Passenger Ro-Ro Ship (Vehicles) Cyclades</td>
<td>664</td>
<td>43,8</td>
<td>44%</td>
<td>100%</td>
<td>502</td>
<td>21978,0</td>
</tr>
<tr>
<td>Large Passenger Ro-Ro Ship (Vehicles) Cyclades</td>
<td>708</td>
<td>58,7</td>
<td>46%</td>
<td>100%</td>
<td>348</td>
<td>20431,6</td>
</tr>
<tr>
<td>Small Passenger Ro-Ro Ship (Vehicles) North Aegean</td>
<td>116</td>
<td>85,4</td>
<td>0%</td>
<td>100%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Large Passenger Ro-Ro Ship (Vehicles) North Aegean</td>
<td>408</td>
<td>132,5</td>
<td>44%</td>
<td>100%</td>
<td>180</td>
<td>23849,8</td>
</tr>
<tr>
<td>Small Passenger Ro-Ro Ship (Vehicles) Dodecanese</td>
<td>238</td>
<td>78,4</td>
<td>0%</td>
<td>100%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Large Passenger Ro-Ro Ship (Vehicles Dodecanese)</td>
<td>274</td>
<td>241,7</td>
<td>60%</td>
<td>100%</td>
<td>164</td>
<td>39742,5</td>
</tr>
<tr>
<td>Total</td>
<td>2.141</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>296.872,9</td>
</tr>
</tbody>
</table>

Port of Piraeus
Port of Piraeus

- **Selection of Land Storage Tanks of LNG**
  - Use of the LNG Import Terminal (Revithousa)

- **Selection of Refuelling Equipment for LNG**
  - 1 “bunker vessel” 3,000 m³
  - 4 specially designed trucks 50 m³
Investment Proposal
- Estimation of Investment and Operating Costs
  - Initial Investment Costs 64,5 mil. €
  - Operating Costs 2020 11,00 mil. €
  - Operating Costs 2030 13,50 mil. €

Study Results
- Econometric Results
  - Cost per ton of LNG for 10 years repayment PBP
    - 159,81 €/ton LNG
  - Internal Rate of Return- IRR
    - 17%
  - Net Present Value- NPV
    - 76 mil. €
Port of Piraeus

Study Results

Conclusions

- Costal vessels cover more than 50% of the annual demand of LNG
- Leasing LNG storage space at the import terminal in Revithousa is a feasible solution as it makes the investment proposal financially favourable since it requires the creation of land-based storage facilities, reducing the initial capital investment.
- A bunker vessel (3,000 m³ capacity) costs 24 mil. € (extremely high)
- Fuel prices at the port of Piraeus 573 €/ton LNG, 540 €/ton HFO και 700 €/ton MGO
- There should be grants from financial institutions, the EU
- The EU Member States to create incentives for investments by companies to develop onshore LNG supply infrastructure
Market Research - Statistical Data Collection

- Ro-Pax Ship - Passenger Terminal
  - 2,074 arrivals by 27 vessels
Port of Patras

Create Database

- Ro-Pax Ship

  - The segmentation has been made according to the route for year 2012
    - Ancona
    - Venice
    - Bari
    - Brindisi
    - Ionian Islands

  - The majority of the departures addressed to the port of Ancona

*We consider aged less than 15 years vessels ideal for using LNG as marine fuel*
### Estimated Demand of LNG

<table>
<thead>
<tr>
<th></th>
<th>Ro-Pax Ship Ancona</th>
<th>Ro-Pax Ship Venice</th>
<th>Ro-Pax Ship Bari</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required amount of fuel (m³)</td>
<td>295</td>
<td>195</td>
<td>95</td>
</tr>
<tr>
<td>Annual number of bunkering operations 2020 (2030)</td>
<td>412 (686)</td>
<td>10 (16)</td>
<td>210 (351)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Ro-Pax Ship Brindisi</th>
<th>Ro-Pax Ship Ionian Sea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required amount of fuel (m³)</td>
<td>65</td>
<td>15</td>
</tr>
<tr>
<td>Annual number of bunkering operations 2020 (2030)</td>
<td>121 (202)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>
Port of Patras

- Estimation of Demand of LNG
  - 2020
    - 150,500 m³ LNG
    - 753 Bunkering Operations
  - 2030
    - 251,000 m³ LNG
    - 1,255 Bunkering Operations

- Selection of Land Storage Tanks of LNG
  - Installation of Land-based storage tank with total capacity 10,000 m³

- Selection of Refuelling Equipment for LNG
  - 1 “bunker vessel” 1,000 m³
  - Capability of refuelling by land based storage tank via pipeline
Investment Proposal

- Estimation of Investment and Operating Costs
  - Initial Investment Costs 80,2 mil. €
  - Operating Costs 2020 9,8 mil. €
  - Operating Costs 2030 13,9 mil. €

Study Results

- Econometric Results
  - Cost per ton of LNG for 10 years repayment PBP
    - 319,00 €/ton LNG
  - Internal Rate of Return- IRR
    - 17 %
  - Net Present Value- NPV
    - 112.8 mil. €
Port of Patras

Study Results

- Conclusions
  - The vessels that cover the route Patra-Ancona gather the higher annual demand of LNG (120,000 m³)
  - Installation of a land-based storage tank with 10,000 m³ capacity (High investment cost 23 mil. €)
  - A bunker vessel (1,000 m³ capacity) costs 20 mil. € (extremely high)
  - Fuel prices at the port of Patras 731 €/ton LNG, 595 €/ton HFO και 770 €/ton MGO
  - There should be grants from financial institutions, the EU
  - The EU Member States to create incentives for investments by companies to develop onshore LNG supply infrastructure

Co-funded by the Marco Polo Programme of the European Union
Port of Thessaloniki

- Market Research - Statistical Data Collection

  - Container Ship
    - 499 calls by 56 vessels
  - General Cargo Ship
    - 301 calls by 186 vessels
  - Tanker Ship
    - 336 calls by 121 vessels
  - Bulk Carrier Ship
    - 475 calls by 156 vessels
Create Database

- Container Ship
  - Categorize in two groups according to their capacity
    - Class A (0-1,999 TEU)
    - Class B (2,000-7,999 TEU)

We consider that Class A and aged less than 10 years vessels ideal for using LNG as marine fuel
Create Database

- Tanker Ship

  - Categorize in two groups according to their Deadweight (DWT)
    - Class A (≤24.999 tons)
    - Class B (≥25.000 tons)

We consider that Class A and B and aged less than 10 years vessels ideal for using LNG as marine fuel
Create Database

- General Cargo Ship
  
  - Categorize in two groups according to their Deadweight (DWT)
    - Class A (≤4.999 tons)
    - Class B (≥5.000 tons)

We consider that Class A and B and aged less than 10 years vessels ideal for using LNG as marine fuel.
Create Database

Bulk Carrier Ship

- Categorize in two groups according to their Deadweight (DWT)
  - Class A (≤34.999 tons)
  - Class B (≥35.000 tons)

We consider that Class A and B and aged less than 10 years vessels ideal for using LNG as marine fuel
### Port of Thessaloniki

#### Estimated Demand of LNG

<table>
<thead>
<tr>
<th></th>
<th>Container Ship (0-1.999 TEU)</th>
<th>Tanker Ship (&lt;25.000 dwt)</th>
<th>Tanker Ship (≥25.000 dwt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required amount of fuel (m³)</td>
<td>80</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>Annual number of bunkering operations 2020</td>
<td>31</td>
<td>39</td>
<td>31</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>General Cargo (&lt;5.000 dwt)</th>
<th>General Cargo (≥5.000 dwt)</th>
<th>Bulk Carrier (&lt;35.000 dwt)</th>
<th>Bulk Carrier (≥35.000 dwt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required amount of fuel (m³)</td>
<td>16</td>
<td>40</td>
<td>30</td>
<td>90</td>
</tr>
<tr>
<td>Annual number of bunkering operations 2020</td>
<td>15</td>
<td>11</td>
<td>40</td>
<td>24</td>
</tr>
</tbody>
</table>
Port of Thessaloniki

- Estimation of Demand of LNG
  - 2020
  - 11,350 m³ LNG
  - 191 Bunkering Operations

- Selection of Land Storage Tanks of LNG
  - Installation of Land-based storage tank with total capacity 5,000 m³

- Selection of Refuelling Equipment for LNG
  - 1 specially designed trucks 50 m³
  - Capability of refuelling by land based storage tank via pipeline
Investment Proposal
- Estimation of Investment and Operating Costs
  - Initial Investment Costs 16.7 mil. €
  - Operating Costs 2020 1.5 mil. €

Study Results
- Econometric Results
  - Cost per ton of LNG for 10 years repayment PBP 765.78 €/ton LNG
  - Internal Rate of Return- IRR 14%
  - Net Present Value- NPV 11.8 mil. €
Port of Thessaloniki

- Study Results
  - Conclusions
    - Large tanker ships and container ships gather the highest annual demand of LNG with 3400 m³ and 2500 m³ respectively
    - A bunker vessel (1,000 m³ capacity) costs 20 mil. € (extremely high)
    - Fuel prices at the port of Thessaloniki 1178 €/ton LNG, 595 €/ton HFO και 770 €/ton MGO
    - There should be grants from financial institutions, the EU
    - The EU Member States to create incentives for investments by companies to develop onshore LNG supply infrastructure
Conclusions

- **High and/or Volatile LNG Price**
  - May Lead to Almost Zero Orders for LNG Fuelled Vessels in Future
  - Make Retrofitting of Middle Aged Vessels not Feasible in Financial Terms
  - Turn Existing LNG Fuelled Projects to “Toxic Investments”

- **Sustainability**
  - The Use of LNG as Fuel will Increase Demand and Sooner or Later the Price. Some Say that LNG Production Might not Meet Demand by 2030.
  - Uncertainties on LNG Price and Spread are Present Although Oil Indexed Prices are Less Volatile and do not Exhibit Seasonality
Conclusions

- **Ability to Manage LNG Price and Spread**
  - Political Means to Manage LNG & LSF Spread
  - Use of Risk Management Tools. Risk Management can do very Little to Reduce Variability, but can be very Effective in Reducing Uncertainty for those Involved in Risk-Taking Decisions

- **Sustainable Financing is the Answer:**
  - Know & Avoid Catastrophic Risks
  - Impugn Greed For Profits Or Phobic Attitudes!!
  - Technocratic Criteria In Financing
  - Establish Formal Procedures For Rating Corporate Performance and Investment Evaluation
Conclusions

- Also by 2020 / 2030:
  - Hopefully Economy will Recover Starting a New Shipping / Shipbuilding Cycle
  - Economies of scale and widespread of LNG would reduce Equipment Cost
  - There is Time to Solve all Technical Issues and Train an adequate Number of Skilled Seafarers

- Manage Small Scale LNG Terminals issue:
  - Reveal Demand and Design a Sufficient Bunkering Network.
  - Market LNG Solution to Private Equity Funds or Sovereign Funds.
  - Special Funds and Companies with Excess Liquidity are Seeking for Energy Related Projects.
THANK you!