A Decision Support System for Coordinating Vessel Routing, Inventories and Trade in the LNG Supply Chain

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The project

- Goal: Develop a decision support tool for tactical planning for the LNG value chain
- How: Close cooperation
  - Industrial partners knows the business needs and possibilities
  - SINTEF knows the methodology
- Main result: The software “LNGScheduler”
The LNG Business - geography

- Main regional markets
  - North America
  - Europe
  - Asia
- Accounts for 28% of the natural gas trade between countries
- Heading against natural gas as a global commodity

Source: bp.com
The LNG Business - growth

- Fast growing business
  - Around 8% annual growth expected
- 224 LNG tankers operating in March 2007, 145 new tankers ordered
- Increasing use of short term contracts (spot)

Three LNG Growth Scenarios:

Source: Jensen Associates
Tactical value chain planning

- Main decisions: Production rate, regasification rate, routing and scheduling of vessels, loading/unloading volume, spot vs contract sales
- Traditionally
  - Manual planning in spread sheets and the like
  - Split planning in sub tasks
    - Terminal management, fleet management, contract management
    - Regional planning

Source: Suez Energy International, Michalek 2006
Consequences for tactical planning

• Increasing number of vessels and terminals
  – => combinatorics make problem intractable for manual planning

• Increasing flexibility and dynamics in the value chain
  – => making rules of thumb for planning harder
  – => the risk of sub optimization because of split planning increases
  – => increased need for frequent replanning
Methodology

• Mathematical programming / Operations research / Optimization
• Makes the analytical core of a optimization based decision support software

Properties of an optimization model

• Gives solutions (plans) based on the problem description
  – Not an evaluation of suggested solutions or policies
  – Treats the whole picture simultaneously
The model

• Extended inventory routing problem
  – Routing of vessels
  – Inventory management
  – Extension: contract management and NG markets

• Maximize profit
  – LNG/NG purchase and sales
  – Operation costs
    • Fuel costs, port costs, channel costs, charter cost

• Contains linear and discrete elements => mixed integer linear problem (MILP)
The LNG Value Chain – as we model it
Contract structures

• Given, but time varying price
• Upper and lower limit on purchase and sales within day or period
• Destination clauses
  – Limited possibility to deliver gas outside the contracted destinations
• Destination dependent pricing
  – Net back pricing
  – Profit sharing
• Limits on number of visits and frequency of visits in a port
• Etc…
Computational challenges

• Vessel routing is a classical optimization problem known to be computationally hard
• Our model extends the routing with terminals, contracts and markets

• We try different solution strategies using commercial optimization software and tailor-made solvers

• State-of-the art algorithmic work:
  – Solution times very case dependent
  – 0.5-1 year horizon cases solved to near optimal solutions within 10 hours, first solution typically within an hour
  – More research needed
Some results

Normal Plot of the Standardized Effects
(response is ObjVal, Alpha = 0.05)

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Standardized Effect
Percent

NTNU
Including spot markets

- Example: geographical swap

Production port

Consumption port 1
- Obligation: 130,000 m³
- Contract price: 70 $/m³
- Spot price: 72 $/m³

Consumption port 2
- Spot price: 85 $/m³

Profit: 9.1 mill $  
Profit: 10.79 mill $  
Increase: 1.69 mill $
Partial loading/unloading

![Graph showing inventory over 30 days with peaks at days 1, 4, 7, 10, 13, 16, 19, 22, 25, 28, and 31.]
Partial loading/unloading

Possible loading days

- Falling prices
- Spot opportunity
- Transportation capacity window
Areas of use

- Develop yearly main plan
- Terminal meetings with negotiations for slots
- Respond on spot opportunities
- Fleet evaluation

- The tool is currently being tested on real planning situations by our industrial partners
Summary

• Development in the LNG/NG business gives new possibilities but makes planning more challenging
• An extended inventory routing problem seems like a good way of modeling the LNG value chain
• Business partners are doing initial tests in real decision processes
• Small real life cases can be solved with existing algorithms, but more research is needed to treat larger problems
The end…

Thank you