Scheduling and fleet management in shipping applications

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Outline of presentation

• Case studies
  – Supply vessel fleet sizing for Statoil
  – TurboRouter, a Decision Support System for vessel fleet scheduling

• Directions for future research
  – Rich models
  – Fleet scheduling as a part of the supply chain
Case study 1: Supply vessel fleet sizing

Kjetil Fagerholt and Håkon Lindstad
MARINTEK

Cooperation between Statoil and MARINTEK

Published in:
Description of supply service

- Coast center base in Kristiansund
- 7 offshore installations on Haltenbanken in the Norwegian Sea
- 6 cargo categories (deck cargoes, dry bulk, mud, brine, diesel and water)
- Deck cargoes binding constraint
- Statoil hired supply vessels from a pool
- TC-rate: $10,000 /day
Supply pattern at the time of the study

- 3.8 vessels in use on average
- Offshore installations were serviced 3.4 times per week on average
- Draugen og Heidrun closed for service during the night
  - Savings in personnel costs: USD 2.5 mill.
  - How was the whole supply operation influenced?
Two main questions of the study

• Could the supply operation be performed more efficiently than today with a less number of supply vessels?

• What was the cost effect of abolishing the night shifts for the whole supply chain?
## Scenario definition

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Number of weekly services</th>
<th>Opening hours, installations 1 and 2</th>
<th>Opening hours, installations 3 - 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.4</td>
<td>7 - 19</td>
<td>0 - 24</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
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<tr>
<td>4</td>
<td>3</td>
<td>7 - 19</td>
<td>0 - 24</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>7 - 19</td>
<td>7 - 19</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>0 - 24</td>
<td>0 - 24</td>
</tr>
</tbody>
</table>

- 150% of average cargo amount
- Aim: Determine optimal fleet and corresponding weekly fleet schedule for each scenario
Solution method

\[
\begin{align*}
\min & \quad M \sum_{k \in K} C^k \delta^k + m \sum_{k \in K} \sum_{r \in R_k} D^k_r x^k_r, \\
\sum & \quad \sum_{k \in K} A^k_r x^k_r \geq S_i, \\
\sum & \quad T^k_r x^k_r \leq 168, \\
\sum & \quad x^k_r - M \delta^k \leq 0, \\
x^k_r & \text{ integer,} \\
\delta^k & \in \{0,1\},
\end{align*}
\]

- Three-step approach
- Step 1: Calculate all feasible routes for each each vessel in the pool
- Step 2: Solving an IP-model to choose fleet vessels and schedule such that costs are minimised and service requirements are satisfied
- Step 3: Adjustment of solutions to ensure sufficient slack/robustness
### Economic figures

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cost of supply ships [%]</th>
<th>Savings for closing during night [%]</th>
<th>Total cost [%]</th>
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</thead>
<tbody>
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<td>-10</td>
<td>100</td>
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<tr>
<td>1</td>
<td>76</td>
<td>-10</td>
<td>66</td>
</tr>
<tr>
<td>2</td>
<td>111</td>
<td>-33</td>
<td>77</td>
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<td>57</td>
<td>0</td>
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<td>76</td>
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<td>56</td>
</tr>
<tr>
<td>6</td>
<td>76</td>
<td>0</td>
<td>76</td>
</tr>
</tbody>
</table>

We proposed solution of scenario 3:
- 2 large vessels compared to 4 small for scenario 5, easier to administrate
- More robustness/slack to handle delays
- 4 weekly services compared to 3
## Proposed schedule (scenario 3)

<table>
<thead>
<tr>
<th></th>
<th>Scheduled arrival time</th>
<th>Scheduled departure time</th>
<th>Days</th>
</tr>
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<tr>
<td>Kr. sund (base)</td>
<td></td>
<td>16.00</td>
<td>man, tir, tor, fre</td>
</tr>
<tr>
<td>Kristin/Lavrans</td>
<td>01.00</td>
<td>05.00</td>
<td>tir, ons, fre, lør</td>
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<tr>
<td>Åsgard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tr. Winner</td>
<td>06.00</td>
<td>11.00</td>
<td>tir, ons, fre, lør</td>
</tr>
<tr>
<td>Tr. Searcher</td>
<td>12.00</td>
<td>18.00</td>
<td>tir, ons, fre, lør</td>
</tr>
<tr>
<td>Tr. Arctic</td>
<td>19.00</td>
<td>02.00</td>
<td>tir, ons, fre, lør</td>
</tr>
<tr>
<td>Heidrun</td>
<td>04.00</td>
<td>08.00</td>
<td>ons, tor, lør, søn</td>
</tr>
<tr>
<td>Draugen</td>
<td>13.00</td>
<td>15.00</td>
<td>ons, tor, lør, søn</td>
</tr>
<tr>
<td>Njord</td>
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<td>18.00</td>
<td>ons, tor, lør, søn</td>
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<tr>
<td>Kr. sund (base)</td>
<td>01.00</td>
<td></td>
<td>tor, fre, søn, man</td>
</tr>
</tbody>
</table>
Conclusions

• Proposed solution is now partially implemented
• 2.4 vessels are being used in average, compared to 3.8 before
• Statoil has experienced annual savings > $7 mill.
• Analysis made the cost effects of abolishing night shifts visible
Case study 2: TurboRouter - Decision Support System for vessel fleet scheduling

- Started as a research project at MARINTEK in 1996
- Funded by The Research Council in Norway and MARINTEK
- First commercial project and installation in 2000
- Now it has become a commercial software, though we are still developing it
- MARINTEK has entered into a sales and marketing agreement with ShipNet
TurboRouter distance calculation

- Electronic sea charts
- Satellite vessel position reports
- Algorithms for port-to-port and ship-to-port distance calculations
- Calculates shortest distance that does not intersect land contours
- Updated ETAs are calculated
- Evaluate when a vessel can arrive a given port in order to load a given cargo
Fleet scheduling with *TurboRouter*

Assigning cargoes to ships:
- A major combinatorial problem with an enormous number of alternatives to evaluate
- 3 vessels and 5 cargoes ⇒ 243 alternatives
- 10 vessels and 20 cargoes ⇒ 100,000,000,000,000,000,000!!!!
- Practical constraints will reduce the number of possible solutions
- Rescheduling often needed

⇒ Need an optimisation routine
Fleet scheduling function

<table>
<thead>
<tr>
<th>Nt</th>
<th>From</th>
<th>To</th>
<th>Quantity</th>
<th>Load Start</th>
<th>Load Stop</th>
<th>Isartern</th>
<th>Iver_Gemini</th>
<th>Iver_Libra</th>
<th>Iver_Exact</th>
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<tbody>
<tr>
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<td>WILMINGTON (USA-NC)</td>
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<tr>
<td>2</td>
<td>JOSE</td>
<td>CARTAGENA (SPA)</td>
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<td>08/03</td>
<td>21/03</td>
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<td></td>
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<tr>
<td>3</td>
<td>EL SEGUNDO</td>
<td>WILMINGTON (USA-NC)</td>
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<td>04/04</td>
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<td>6</td>
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<td>06/04</td>
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<td>09/04</td>
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<tr>
<td>4</td>
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<td>ROTTERDAM</td>
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<td></td>
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<td>WILMINGTON (USA-NC)</td>
<td>14000.0</td>
<td>13/04</td>
<td>28/04</td>
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<tr>
<td>8</td>
<td>CARTAGENA (SPA)</td>
<td>GALVESTON</td>
<td>24000.0</td>
<td>16/04</td>
<td>29/04</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Fleet scheduling with *TurboRouter* (cont.)

Interacting with the market:

- A fleet may interact with the market by taking spot cargoes into its schedule and/or by re-letting cargo commitments in the market
- This market interaction can easily be considered in *TurboRouter*

Knutsen OAS (shuttletank operation) increased their fleet utilisation so that they were able to carry two additional spot cargoes during a few weeks period
Strategic planning with *TurboRouter*

- Evaluate synergies by combining fleets (pooling)
- Analyse whether to charter/contract a new ship or not
- Generate a basis for annual budgets
- Analyse whether to take a new contract or not
Directions for future research

- Much research on routing and scheduling within land and air transportation
- High focus on developing fast algorithms for ‘large problems’
- Little research and commercial tools for routing and scheduling of ships

- Shipping: Several modes of operation and trades (tramp, liner, industrial)
  - Short sea - deep sea
  - Many different vessel types
  => Large variety in problem structures

- Each shipping operation has its own requirements for scheduling algorithms
  => Hard to design tools and algorithms for general shipping applications
  => Rich models are needed
Directions for future research (cont.)

• Planning of fleet schedules is often done in a ‘vacuum’, following instructions from the charterer
  – Tight cargo time windows or laycan
  – Little flexibility in cargo quantities
  – High costs

• Closer co-operation between charterer and shipping company could mean
  – Loosening up of tight cargo time windows
  – More flexibility in cargo quantities, e.g. integrate with inventory management
  – Reduced costs

• Information flow along the supply chain is crucial
• Challenge is to design contracts the stimulate this behaviour and information exchange along the supply chain
Example: Cost of tight cargo time windows

**Scenario 1:**
- Net daily of 21,100
- Uses 4 vessels

**Scenario 2:**
- Loosen up cargo time windows with some days
- Net daily of 25,000
- Increase in profit: 18%
- Uses only 3 vessels, freeing one vessel for alternative tasks