

Optimization of supply base location & hub location supplying oil & gas installations in the Barents Sea

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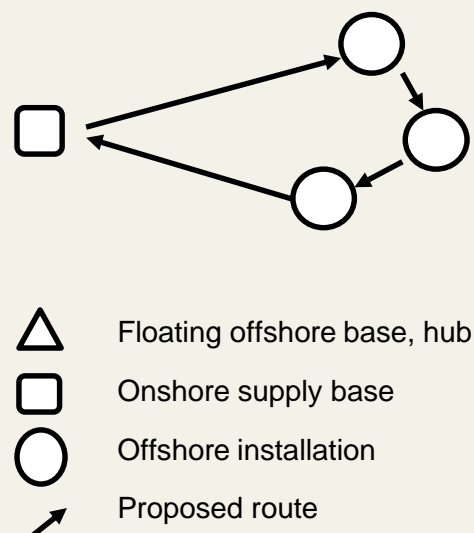
Background

The petroleum industry is the largest industry in Norway. The sector constituted 30 per cent of the state revenues and 23 per cent of the country's total value creation in 2012 (Bertelsen, 2013). Today Statoil is the leading oil and gas company on the Norwegian continental shelf, operating approximately 80 % of the production (ASA, 2013).

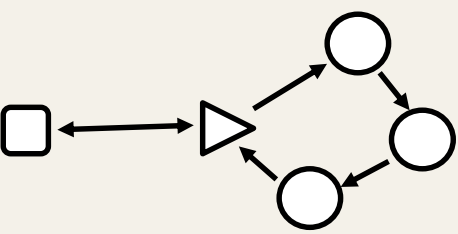
The Arctic continental shelf is anticipated to be the petroleum area with the highest potential of oil and gas (Barlindhaug, 2013). Norwegian governments have been given the rights to distribute areas to stakeholders to search for oil and gas. Statoil is currently exploring for oil and gas in areas in the Barents Sea proposed during the 23. licensing round at the Ministry of Petroleum and Energy at the Norwegian Stortinget (Myhra & Gilje, 2014).

All offshore installations require regular supply of spare parts, equipment, commodities and other cargo. Special supply ships, platform supply vessels (PSVs), are designed to carry out necessary cargo to oil and gas installations and return backload to onshore bases. Adequate routes and a proper fleet is among other things important elements in upstream logistics. In offshore supply logistics, the fleet of supply vessels constitutes the major resources of costs (Statoil, 2013). By reducing the sailing distance as much as possible, transportation costs can be kept at a minimum and furthermore result in increased profit.

Real logistical problems can be simplified and described as mathematical models. Such models can be used to find solutions that potentially result in improved logistic elements. The figure below illustrates a traditional supply scenario between one onshore supply base and three offshore installations, where one or several PSVs shuttle between the units.



An extension of the conventional supply illustrated above, one can make use of a hub network. A proposed system with a hub-network is illustrated below. A big vessel, a hub, shuttles between an onshore supply base to a given offshore position. From this position PSVs load cargo to supply the offshore installations.



Motivation

Optimizing supply logistics can result in potentially great cost savings. A hub system can under the right circumstances reduce a firms total transportation cost. The aim of this thesis is to study whether or not it is cost-efficient for Statoil to make use of a hub system in the Barents Sea.

The optimal location for an offshore supply base shall be determined. Additionally, if there exist an optimal solution that includes a hub network, the optimal hub location shall be determined.

Limitations

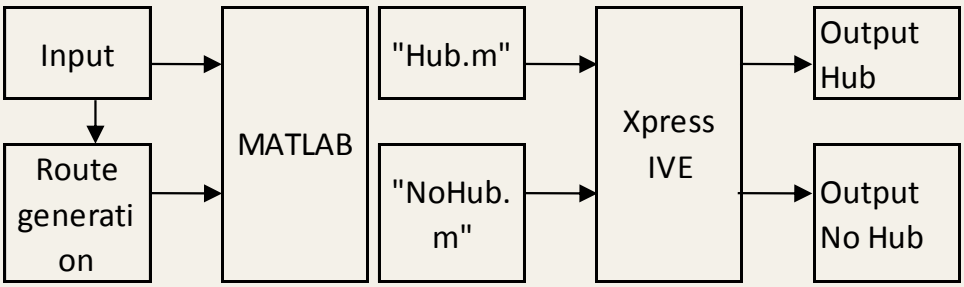
A base case constitute as basis for the study in this report. It comprise a set of seven potential onshore basis, three offshore installations and a generated set of 12 possible hub locations in the Barents Sea. The Opening hours on all elements are assumed to be 24/7. The problem is assumed to be deterministic where the location of one hub and one onshore supply base only are to be determined.

Solution Approach

To asses the objective of these master thesis a two phase solution approach has been conducted. The preprocessing phase constitute route generation and various calculations used as input in phase two. In phase two a mathematical optimization model is defined. This is a partitioning problem where transportation costs are minimized.

The commercial software MATLAB® has been used during phase 1 of the problem. Xpress IVE is used during phase 2 of the problem.

During the preprocessing two different MATLAB® scripts are generated. One representing the base case with a hub-network, the other one is a version of the base case where hubs are excluded. Data from the two scripts are implemented separately as parameters in the same optimization model. The results based on each of the two scripts are finally compared. This process is conducted a certain number of times where location for the offshore installations varied. The solution approach is given in the following flow chart.



Mathematical model

The mathematical model, phase 2 of the problem, is presented as follows:

Sets

- H set of different hub locations, indexed by h
- B set of different base locations, indexed by b
- R set of routes between hub and installation(s), echelon 2, indexed by r
- P fleet of possible PSV's p that can be used on echelon 2, indexed by p
- I set of installations, offshore platforms, indexed by i
- K set of times a route r can be sailed per period, indexed by k

Parameters

- T_{hr} duration on route r originating and ending at hub location h , echelon 2 (phase 1)
- C^{ET} cost for hiring and using a PSV per period, echelon 2. Including operational and chartering costs
- C_{bh}^{EO} cost for sailing between base b and hub h per period, echelon 1. Including chartering costs. (phase 1)
- C_b cost for making use of supply base b per ton cargo transported from base
- W constant, limit on sailing hours per period
- S_i required number of demanded weekly services for installation i
- A_{ir} if installation i is visited on route r , 0 otherwise (phase 1)
- Q_p deck load capacity for PSV p , echelon 2
- D_i demand at installation i per period
- M^P constant, big number
- M^r constant, big number

Variables

- $\delta_h =$ 1 if hub location h is used
0 otherwise
- $\gamma_b =$ 1 if base location b is used
0 otherwise
- $\alpha_p =$ 1 if PSV p is used, echelon 2
0 otherwise
- $\rho_{bh} =$ 1 if a vessel shuttle between base b and hub h , echelon 1
0 otherwise

Mathematical model

$$\min Z = \sum_{p \in P} C^{ET} \alpha_p + \sum_{b \in B} \sum_{h \in H} C_{bh}^{EO} \rho_{bh} + \sum_{b \in B} \sum_{i \in I} C_b D_i \gamma_b \quad (4.1)$$

$$\sum_{h \in H} \sum_{p \in P} \sum_{r \in R} A_{ir} x_{prh} \geq S_i \quad i \in I \quad (4.2)$$

$$\sum_{h \in H} \delta_h = 1 \quad (4.3)$$

$$\sum_{b \in B} \gamma_b = 1 \quad (4.4)$$

$$\sum_{h \in H} x_{prh} - M^P \alpha_p \leq 0 \quad p \in P, r \in R \quad (4.5)$$

$$\sum_{h \in H} \sum_{r \in R} x_{prh} - M^P \delta_h \leq 0 \quad p \in P \quad (4.6)$$

$$\gamma_b = \sum_{h \in H} \rho_{bh} \quad b \in B \quad (4.7)$$

$$\delta_h = \sum_{b \in B} \rho_{bh} \quad h \in H \quad (4.8)$$

$$\sum_{r \in R} T_{hr} x_{prh} \leq W \quad p \in P, h \in H \quad (4.9)$$

$$\sum_{p \in P} \sum_{r \in R} \sum_{k \in K} q_{iprk} \geq D_i \quad i \in I \quad (4.10)$$

$$q_{iprk} - M^r \beta_{prk} \leq 0 \quad i \in I, r \in R, p \in P, k \in K \quad (4.11)$$

$$\sum_{k \in K} \beta_{prk} = \sum_{h \in H} x_{prh} \quad r \in R, p \in P \quad (4.12)$$

$$Q_p \geq \sum_{k \in K} \sum_{i \in I} q_{iprk} \quad r \in R, p \in P \quad (4.13)$$

$$q_{ipr,k+1} \leq q_{iprk} \quad i \in I, p \in P, r \in R, k \in (K-1) \quad (4.14)$$

$$\beta_{pr,k+1} \leq \beta_{prk} \quad p \in P, r \in R, k \in (K-1) \quad (4.15)$$

$$\delta_h \in [0,1] \quad h \in H \quad (4.16)$$

$$\gamma_b \in [0,1] \quad b \in B \quad (4.17)$$

$$\alpha_p \in [0,1] \quad p \in P, r \in R \quad (4.18)$$

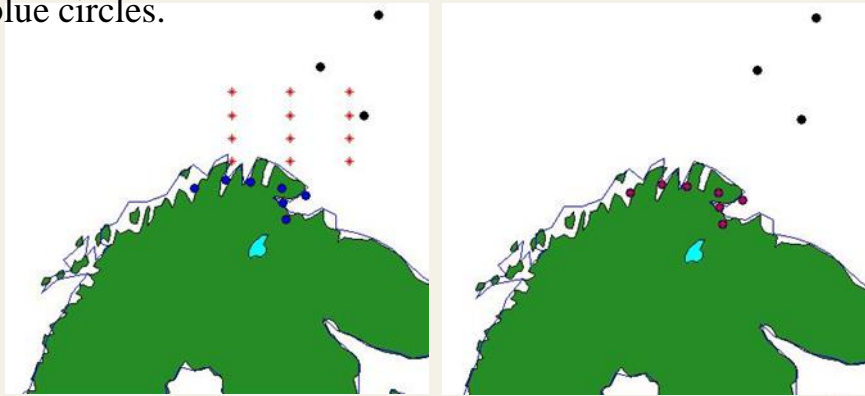
$$\rho_{bh} \in [0,1] \quad h \in H, b \in B \quad (4.19)$$

$$x_{prh} \geq 0 \text{ integer}, \quad p \in P, r \in R \quad (4.20)$$

The objective function (4.1) minimizes the total costs of operating the vessels and bases in a logistic hub network. Service constraints (4.2) assure that each platform is serviced at least the number of times required per period. From constraints (4.3) one assures that only one hub is used. Exactly one onshore service base is ensured by constraints(4.4). The coupling constraints (4.5) ensure that if at least one route r is selected, then the corresponding binary variable is used. They ensure vessel existence for the vessels that are given a route. (4.6) assure that the same hub is used both in echelon 1 and 2. Base existence constraints (4.7) impose that if a base b does not exist, no shuttle will sail from the given location. Additional it ensure that if there exists a connection between a base b and a hub location h , the given base is chosen. Correspondingly, the hub existence constraints (4.8) assure that if a given hub is not used, no shuttle vessel shall sail to the hub. Restrictions (4.9) ensure that the duration on all routes sailed by each PSV are within the given time period. Constraints (4.10) ensure that each installation is delivered at least the amount of cargo it requires. Constraints (4.11) and (4.12) are coupling constraints. Capacity constraints (4.13) ensure that for each route, the total supply delivered at the installation(s) does not exceed the capacity on the vessel. (4.10) together with (5.13) secure consistency between demand at installations and capacity at vessels. (4.14) and (4.15) are anti-symmetry constraints used on variables indexed by k . (4.16) to (4.22) impose binary and integer restrictions on the variables.

Base case

The figures illustrate the base case with and without hub network respectively. The red stars illustrate the potential hub locations. The black circles illustrate the offshore installations, while the onshore bases are represented by the blue circles.



Conclusion

Under the given assumptions and simplifications, it is not cost efficient to make use of a hub-network with three offshore installations. Use of hub-network is relevant for a certain number of offshore installations in combination with certain distances between the installations.

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