Allocation of emergency response assets in the Barents Sea

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Introduction

The main strategy for oil spill preparedness is to oppose the spill as close as possible to its source, this requires a quick response time. A hub solution is introduced in order to allocate required assets for emergency response as near as possible to the operating installations. The hub will operate as an extension to the onshore base in order to reduce the response time and possibly strengthen the overall preparedness system.

A general formulation of the problem is developed and presented in order to give an overall understanding of the scope and limitations to the problem. This formulation of the problem is then simplified and reformulated to a Set Partitioning Problem, and solved in two steps.

In the first step, the preprocessing phase, parameters are stated and calculated and used as input to the second step, the mathematical problem. In the preprocessing phase, the locations for the installations are decided and a hub grid is generated. The grid represents all possible locations where a hub can be located. Distances between hub locations are calculated, as well as the response time. These values are used as input for step two of the solution approach. As a final preparatory input, maximum allowable response time for the different operational phases, or critical levels are stated and bound to the operating installations. Solving the mathematical problem, one single hub is allocated at one of the generated site possibilities that meets all requirements and minimizes the response time.

Objective

The overall objective in this thesis, is to develop an optimization model in order to locate the optimal location for emergency response assets when minimizing response time. The aim is to utilize this model as an analysis tool when the hub solution for emergency preparedness in the Barents Sea is evaluated.

Mathematical formulation

Input	Description
Sets	
I	Set of installations, indexed by i
J	Set of potential facility sites, indexed by j
K	Set of critical levels, indexed by k
P	Set of periods, indexed by p
V	Set of Vessels in fleet, indexed by v
I_{kp}	Set of installations with critical level k in period p, indexed by i, where $I_{kp} \subset I$
Parameters	
D_{ij}	Distance between installation i and potential facility site j
R_k	Maximum allowable response time for critical level k
N^i	Number of installations
N^h	Number of hubs to be located
S_v	Service speed for vessel v
F_v	Release time for vessel v
T_v	Deployment time for vessel v
Decision Variables	
x_j	1 if the extended base is located at potential facility site j 0 if not
y_v	1 if vessel v is chosen 0 if not
z_{ij}	1 if installation i are served by facility site j 0 if not
δ_{jv}	1 if extended base is located at potential facility site j and served by vessel v 0 if not

For period p = p $\qquad p \in P$

Minimize total response time

$$\sum_i \sum_j \sum_v \left(\frac{D_{ij}}{S_v} + T_v + F_v\right)\delta_{jv} \tag{6.1}$$

S.t

$$\sum_j x_j = N^h \qquad j \in J \tag{6.2}$$

$$\sum_j z_{ij} = 1 \qquad i \in I \tag{6.3}$$

$$\left(\frac{D_{ij}}{S_v} + T_v + F_v\right)\delta_{jv} \le R_k \qquad i \in I_{kp}, j \in J, k \in K, v \in V \tag{6.4}$$

$$z_{ij} - x_j \le 0 \qquad i \in I, j \in J \tag{6.5}$$

$$\sum_v \delta_{jv} - x_j \le 0 \qquad v \in V, j \in J \tag{6.6}$$

$$\delta_{jv} - y_v \le 0 \qquad v \in V, j \in J \tag{6.7}$$

$$x_j \in [0,1] \qquad j \in J \tag{6.8}$$

$$y_v \in [0,1] \qquad v \in V \tag{6.9}$$

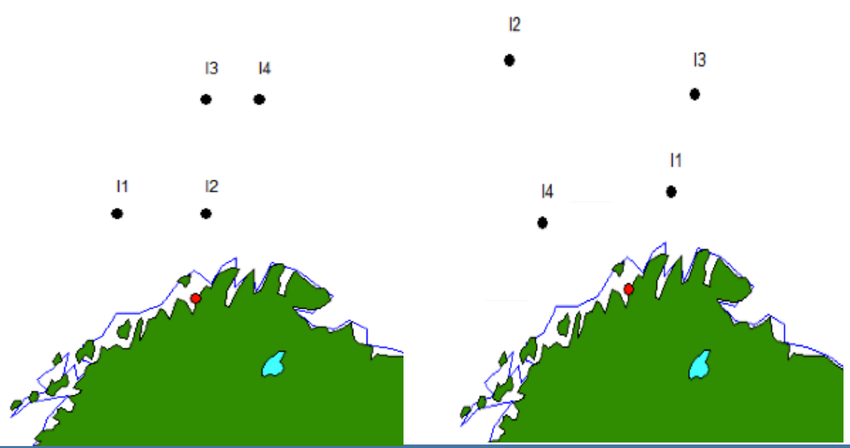
$$z_{ij} \in [0,1] \qquad i \in I, j \in J \tag{6.10}$$

$$\delta_{jv} \in [0,1] \qquad j \in J, v \in V \tag{6.11}$$

The objective function (6.1) minimizes the total response time between installations and the extended base. The period p indicates in what period the location is found. Constraint (6.2) makes sure that exactly *Nh* hubs are located. Constraint (6.3) ensures that every demand is assigned to some facility. Constraint (6.4) makes sure that the response time between the installation and the base, is less than the maximum allowed response time for an installation. The critical level where the installation is operating in the current period, is considered. Constraint (6.5) allows assignment only to sites at which hubs have been located. Constraint (6.6) allows one vessel to serve one chosen hub location. Constraint (6.7) ensures that if a vessel is chosen, it is assigned to a located hub. Constraints (6.8), (6.9), (6.10) and (6.11) are integrality constraints for the decision variables.

Base case

The figure illustrates the location of the installations for two scenarios. The hub is allocated when the total response time is minimized.



Result and Conclusion

The figures illustrates the optimal locations for the hub when the total response time is minimized. Several locations are chosen for the two scenarios as the installations operate under different critical levels with assigned maximal response time for different periods in time. The results presented, indicate that the response time will be considerably reduced when a hub solution is utilized, compared to serving the installations from an onshore base. With the stated requirements however, one single hub will not be able to cover the installations in all scenarios.