Supply Chain Design under Uncertainty

Locating LNG distribution centers in a growing uncertain market

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INTRODUCTION

Today, there is a growing demand for natural gas/LNG as an energy source. According to the International Energy Agency (IEA (2011)), the global use of natural gas will increase by more than 50% from 2010, and will account for 25% of global fuel consumption by 2035. The future increase in demand is related to uncertainty, where IEA has presented three different scenarios in figure 1 below.

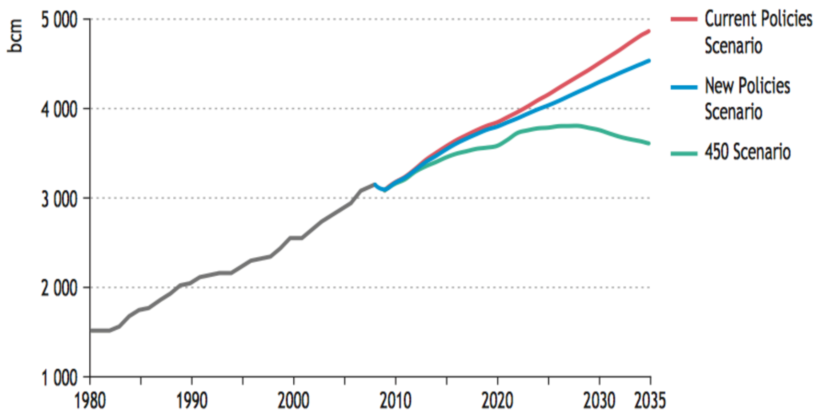

Figure 1 Worlds natural gas demand by scenario, IEA (2011).

The overall objective of the thesis is to develop a model that can help decision makers to design a profitable supply chain for an uncertain future gas demand, using operational analysis. A part of the scope will be to examine the value of considering the uncertain future.

PROBLEM DESCRIPTION

The problem is established from a "Gas Distribution Company" point of view, where the company is responsible for purchase, distribution and sale of natural gas. The gas demand in the problem is considered uncertain and can vary between time periods and customers.

The problem is to determine whether and where to construct import terminals given an growing uncertain future demand, when the goal is to maximize profit. Import terminals are defined in the problem as distribution centers between the LNG liquefaction plants and the end-customers.

The distribution method in this problem is restricted to LNG transportation with ships and trucks. Pipeline distribution is therefor excluded from the problem.

Figure 2 show the supply chain defined in the problem, where the LNG is exclusively transported by ships (ST) from liquefaction plants (LP) to import terminals (IT) and re-distributed by trucks (TT) to end-customers (EC). It is also possible to expand the import terminals if required, referred to as terminal expansion (TE).

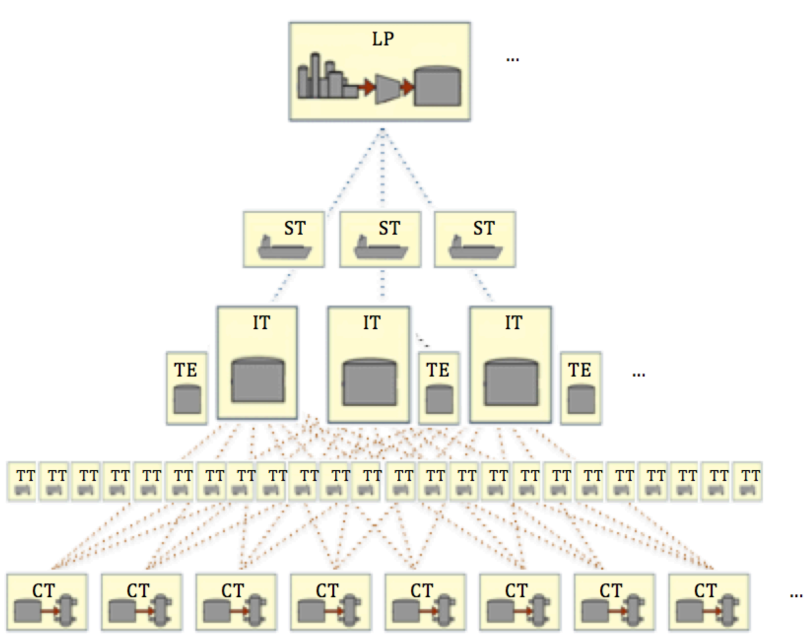

Figure 2 LNG Supply Chain.

METHODOLOGY

Operational analysis is used to solve the problem described in the problem description. Location analysis is the name of the branch within operational analysis that is used. Both a deterministic and stochastic model formulation is developed. This is required if one should be able to calculate the value of the stochastic solution.

The uncertainty in the problem is captured in the stochastic model using a scenario approach with a two-stage recourse model. Figure 3 show the scenario tree in the model, where stage 1 represents the time period where you have to make decisions about constructing import terminals on the basis of three different scenarios with equal probability. Stage 2 represents the time period where the demand is revealed. The time between stage 1 and stage 2 is defined as the lead-time for constructing import terminals. The number of scenarios in this thesis is based on the predictions presented by IEA in the introduction.

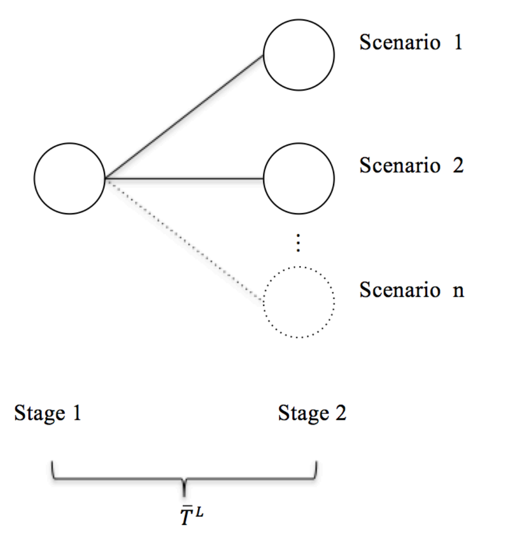

Figure 3 Scenario tree with a two-stage recourse model

Both models are implemented in the commercial optimization software Xpress-IVE and tested in a computational study, where the future gas demand in Norway is used as example. All other parameters are assumed on the basis of available information.

RESULTS

The results are illustrated in figure 4 and figure 5, where the deterministic and stochastic solution is presented respectively. The profit in the deterministic solution was as expected better than the stochastic solution, because the deterministic model only optimize with respect to one future demand situation, while the stochastic solution optimize with respect to three completely different scenarios.

The deterministic solution chose to construct two import terminals in time period 1, while the stochastic solution chose to construct three import terminals in time period 1. The supply chain designed in the stochastic solution has thus found out that you will profit more with three import terminals for the normal and high scenario, than you will loose in the low scenario.

The value of the stochastic solution (VSS) and the expected value of perfect information (EVPI) was calculated to respectively 0.68% and 1.93%.

RESULTS CONT.

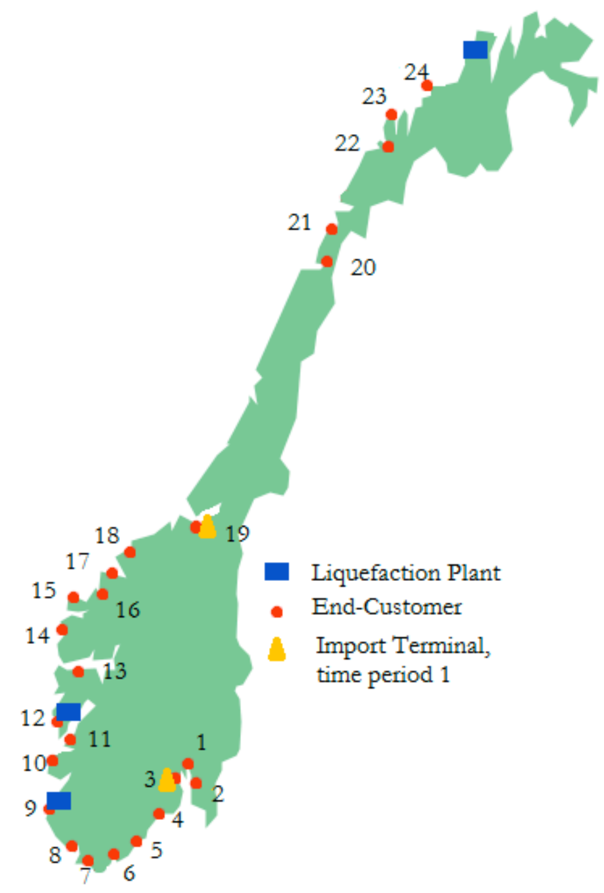

Figure 4 Deterministic solution.

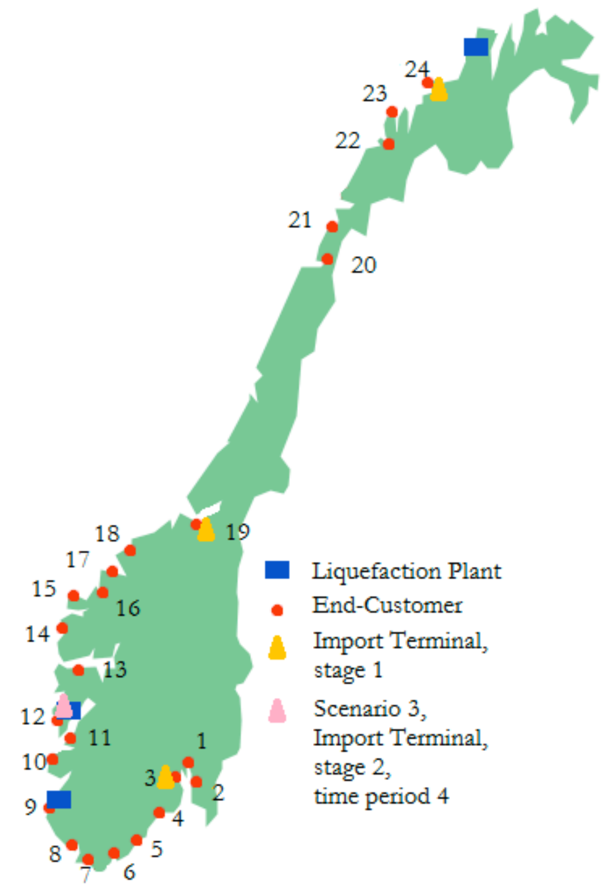

Figure 5 Stochastic solution.

CONCLUSIONS

The primary objective in this master thesis was to develop a model that can help decision makers to design a profitable supply chain for an uncertain future gas demand. Both a deterministic and stochastic model was developed and the results were compared. The VSS turned out to be low, due to the structure of the problem, where there is a large degree of flexibility in the way you can construct and expand import terminals inn all time periods.

It would therefore be sufficient to use a deterministic model in a situation like the one described in the computational study. The VSS would increase in a situation with longer lead-time and decreased in a situation with shorter lead-time.

LITERATURE CITED

IEA (2011). Are we enetering a golden age of gas?, International Energy Agency.

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