Planning Tank Farms for a Pipeline

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The Eilat-Ashqelon pipeline in Israel connects Eilat on the Red Sea with Ashqelon on the shore of the Mediterranean. Oil tankers form the east unload at the terminal in Eilat, from where the oil is pumped through the pipeline to Ashqelon, where it is loaded on other tankers to be transported to its final destinations. The arrival times of tankers are pre-scheduled well ahead but still deviations are quite common. There are many oil types and some strict rules about which pairs could not be mixed together. Each tanker in Ashqelon has to load oil of some pre-specified type and according to its capacity. Times for loading and unloading tankers depend on capacity in a known way, but may vary very significantly due to sea conditions, which may delay or even stop operation temporarily. Due to these uncertainties and operational constraints tank farms have been established at both ends of the pipeline serving as moderating buffers. Clearly the need for storage tanks varies with the annual amount of oil through the pipeline, but decisions on constructing new tanks are quite hard due to the very high construction costs. This work was aimed at providing a planning tool for decision-makers to determine when, where and how many new tanks should be constructed.

The first phase of the research was dedicated to studying some possible measures of performance for the pipeline system. Such measures would be used as optimization criteria for the planning tool. Any measure of performance is strongly linked with the particular policies of system operation: a good plan for tank construction would result in overall positive economic indicators only when combined with suitable operation procedures. Since determination of such procedures was beyond the scope of the present research, it was presumed that operation procedures would be selected to best fit the infrastructure at any future time. After analyzing several performance parameters, in the specific organizational and environmental context of the pipeline system, it was concluded that the right measure for the system is the average length of tanker queue in Ashqelon.

The tanker queue in Ashqelon depends quite significantly on seasonal effects since one of the major reasons for delay is high sea condition, under which it is impossible to bind tankers to berths. The arrival of tankers to ports may be modeled as a stochastic process with parameters that can be adequately estimated from past data. A simulation model has been designed in order to analyze the queue behavior under various values of the governing parameters. The model consists of the following components:

- given structure of ports and tank farms
- a process that represents sea conditions at both ports
- a process that represents tanker arrivals
- technical parameters of tanks, pumps and flow rates
- prevailing constraints on storage and mixing
- A set of operating policies and procedures.

The simulation model had to consider a period of several years, since parameters vary significantly by season and there are random fluctuations among years. It was found that the system behavior depended quite significantly on its initial conditions, like the amount of oil in various tanks, the number of tankers in each port and others. To remove that influence the simulation model was run to cover some initial span of years to let the system stabilize, and data collection for the analysis was initiated only for the following sequence of years, after the system came to steady state.

An important phase in model development was the calibration of parameters according to past data. Also, various sensitivity tests were conducted in order to assure that the response of the model to variation in parameters is consistent with past experience of people that had been familiar with the pipeline system for many years. During these tests a closer look into specific details was adopted, but once the model has gained its credibility it was run in the fast mode to cover a period of many years in a reasonable length of time.

The developed model was fast enough and reasonably sensitive to enable estimation of performance dependence on varying parameters. As a result, a trade-off between the investment in new storage tanks and the savings on reduction of tanker waiting times could be effectively analyzed. The analysis was aimed at obtaining a long-term policy for constructing new storage tanks, namely well-based decisions as of when, where, which and how many such tanks should be constructed, depending on predictions on expected annual utilization of the pipeline.

Special attention was given to methods of presenting results. The complicated dependence of queue lengths on parameters of the involved stochastic processes, as well as the influence of adding new tanks, is quite abstract in the context of common managerial decision making. Therefore some special means of presentation were developed to help decision-makers adopt model recommendations.

Another issue was the interpretation of the possibility to remove tanks from farms. Although this is an acceptable degree of freedom from the mathematical model point of view, it cannot be processed without suitable economic interpretation. After analyzing this issue, a suitable economic interpretation was proposed, which resulted in enriching the model with a new aspect that was not considered at all in the initial problem formulation.

The model and its results have been successfully implemented and applied by the company that operates the pipeline system.