Simulation modeling helps oil producer plan for the future

In complex, dynamic industrial environments, simulation modeling can act as a crystal ball for the future

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Introduction

The results of simulation modeling have been applied successfully for over a decade to help petroleum companies meet their long-term strategic production goals. Simulation modeling has been used to optimize storage, pipelines, and the export facilities required to accommodate additional production capacity; to plan capital projects in anticipation of demand; and to evaluate the impact of crude segregation alternatives on future facility requirements.

While it can't actually predict the future, simulation modeling is the best tool available to help oil production companies prepare for any eventuality that is likely to affect their complex operations.

Why not just use spreadsheets?

One major oil producer has used simulation modeling on two separate occasions to estimate the capital and operating costs of alternative facility layouts.

The first time was in 1997, when the company planned to expand its throughput of a single type of crude. Simulation modeling helped the company design the optimal configuration of additional storage tanks, berths, pipelines, and pumps. The model helped the company meet its strategic expansion goals by efficiently analyzing the complex interactions of the company's operations.

Ten years later (in 2007), when the company was ready for its next expansion phase, it again used simulation modeling. The company was evaluating multiple types of crude and needed a reliable model to compare the costs of crude segregation alternatives and other infrastructure options.

Spreadsheets are too limited to analyze and model facility needs; they simply cannot account for the variability and complexity introduced by the many events – both scheduled and random – that are intrinsic to a firm's operations. Because of the high cost of new facilities, the company wanted to make sure that it got its expansion plans right the first time. Simulation modeling is ideal for complex operations where spreadsheets are inadequate. Reliance on simplistic calculations could lead to underestimating capacity or cost, which ultimately results in higher costs. A simulation study, on the other hand, lets companies explore many different alternatives, pinpointing the benefits and disadvantages of various facility layouts with a high degree of accuracy.

The macro-level simulation modeling used by this oil producer (a confidential AECOM client) is different from the micro-level type of simulation modeling commonly used to help establish production schedules based on reservoir conditions, or to analyze specific refinery processes. Macro-level simulation modeling helps companies understand system bottlenecks, analyze future storage and export facility needs, and then design an optimized facility.

Figure 1. The software can model the implications of taking a infrastructure component, such as this single-point mooring, out of commission.

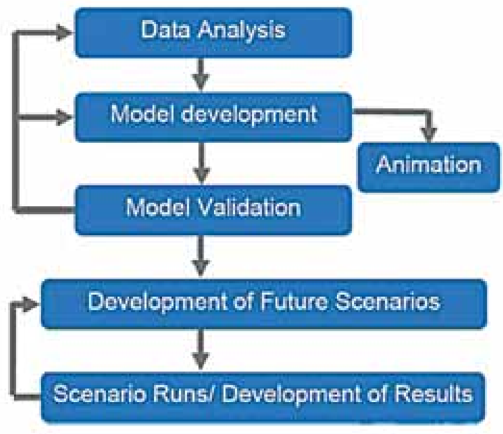

Figure 2. Flowchart showing the simulation modeling process.

Another application of macro simulation modeling is to prepare for the challenge of having an infrastructure component, such as a pier or single point mooring (SPM) (see Figure 1), taken out of commission for an extended period of time (such as for rehabilitation or replacement). Modeling helps establish whether the remaining infrastructure is sufficient to accommodate the ongoing workload. If the answer is no, additional components are incorporated in the simulation until the desired results are achieved.

How simulation modeling works

The first step is to simulate the existing facilities, capacity, and production flow, using the best information currently available. This creates a modeling test case that can serve as a starting point. If (after iterative refinements) that model turns out to be a close match to the actual field experience of facility personnel, it verifies that the model is correctly designed, at least for the existing scenario. After establishing that the model is true to current circumstances, the key model inputs can be varied to reflect the different scenarios the company wishes to analyze. Figure 2 shows flow chart of the simulation modeling process.

Because the quality of a simulation's output is determined by the quality of the input, the modeling has to be performed in close coordination with facility staff. Every facility is unique. The potential variables are many and diverse, such as the number of workdays per week, the length of time it takes to perform maintenance activities, and the best practices that are currently in place or planned (e.g., the amount of reserve that is kept in the storage tanks). It's important to know exactly how a facility operates before assigning ratios and mathematical properties to components and events in order to run the simulation.

The basic process of simulation modeling is relatively simple:

(1) Develop and apply a starting set of pertinent parameters and associated values (including historical data) for testing purposes

(2) Run the simulation to verify that the parameters are valid and realistic

(3) Use the results to assess whether the proposed infrastructure is sufficient.

If there are bottlenecks, add to the infrastructure, explore various scenarios, and repeat the simulation until the most efficient outcome is obtained. Once optimal operation and storage results have been identified, the company can cost out the capital expenditures associated with the optimized solution.

In our example case, the oil producer's facility simulation incorporated the following key components:

- Product types
- Vessel types and arrival sequences
- Vessel loading and unloading data
- Parcel size distribution
- Use of piers vs. SPMs
- Facility downtime due to scheduled or random events

Inside the simulation model, each discrete event is assigned a mathematical model. These models are connected to each other mathematically, with a certain probability of occurrence or co-occurrence. Because certain physical simulation parameters (ships, pumps, pipelines, SPMs, piers, etc.) are assigned icons to render visual representations, the simulation physically demonstrates how the operation is working.

Figure 3 shows a screen capture of the simulation model elements. All events are modeled against time, creating a simulated operation that runs right before your eyes. At any given time, the clock can be stopped and the output examined. In short, the model creates a real-time, realistic rendition of the operating facility under the conditions specified. This simulation protocol also works for container terminals and other complex facilities.

The modeling generates various events that have been specified, along with their probability of occurrence. For example, in a country with frequent bad weather, the average number of bad weather days (based on historical data) can be programmed into the model. The simulation then generates those types of meteorological events to assess their impact on loading and unloading operations.

For each tanker type, the probability of early, on-time, or late arrival is incorporated into the model as well. This data is important because costs rise if tankers have to queue up and wait.

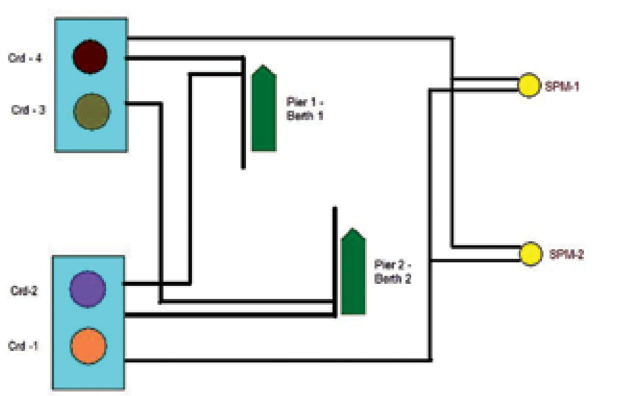

Figure 3. Screen capture of the simulation model scenario.

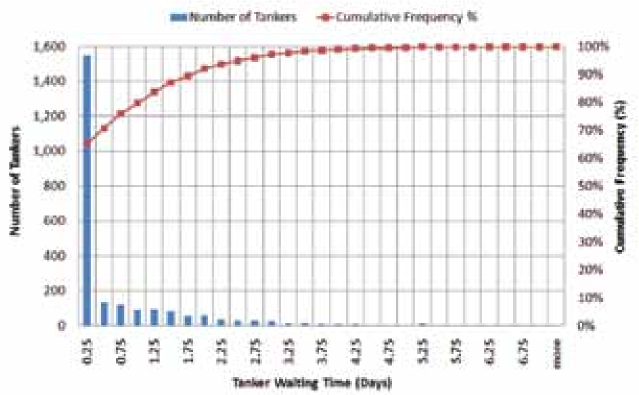

Figure 4. Sample simulation model output of tanker wait-time distribution.

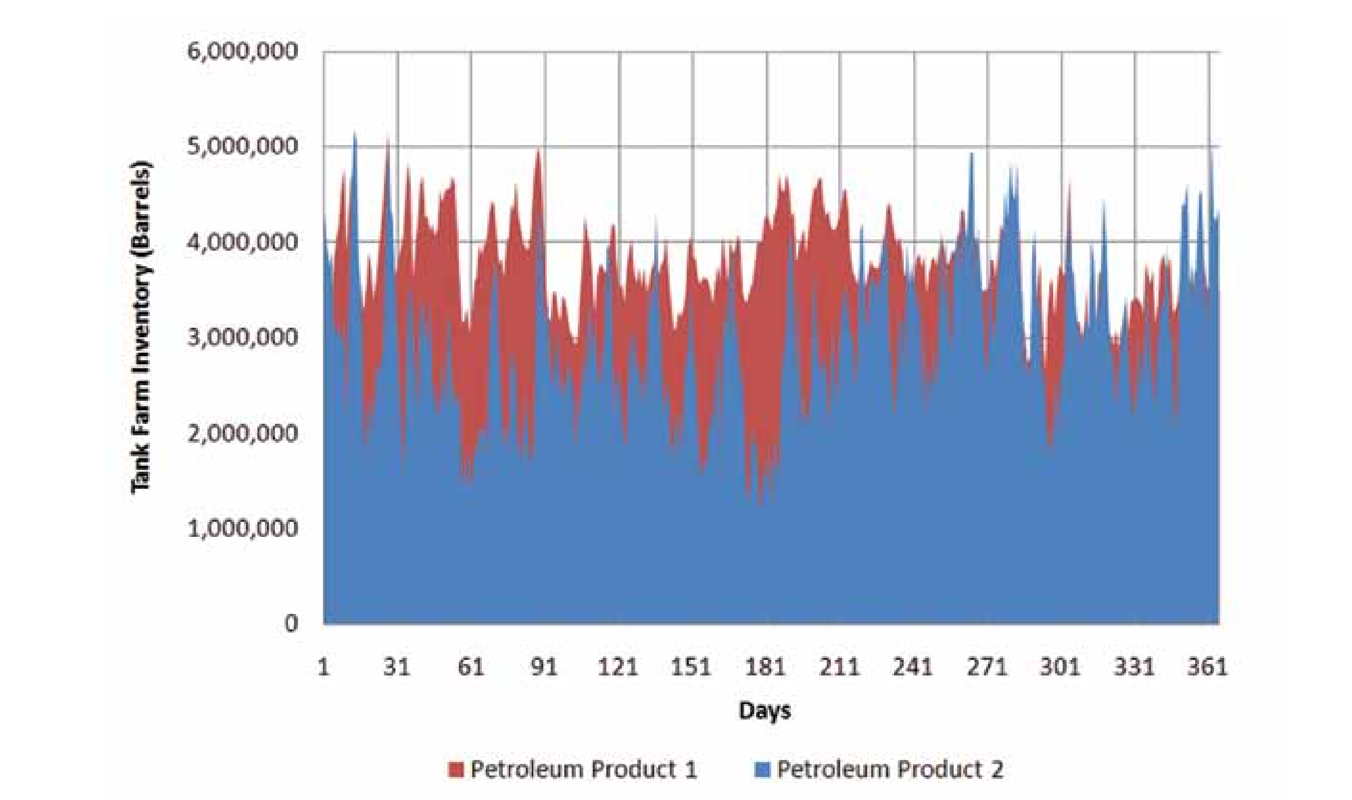

Figure 5. Simulation model output of tank farm inventory variation.

Figure 4 shows a sample simulation model output of number of tankers waiting to get service and extent of wait. Because demurrage charges can be a huge operating expense, the oil producer wanted to analyze the impact of adding berths to reduce those penalties. The potential savings in annual operating costs helped the company determine the optimum facility configuration.

The simulation modeling identified the additional pipelines, SPMs, pumping stations, and storage tanks that this oil producer would need to accommodate its strategic expansion plans. Based on these results, the company analyzed and priced the most viable alternatives, considering capital investment, maintenance, and demurrage costs. A sensitivity analysis followed, which suggested some modifications to refine the two or three best configurations. The company identified the most cost-effective, functionally optimal scenario as a basis for further development and front-end engineering and design.

An additional benefit of simulation modeling is that it can determine the most effective method of phasing in components to create the optimal future network. In other words, it can

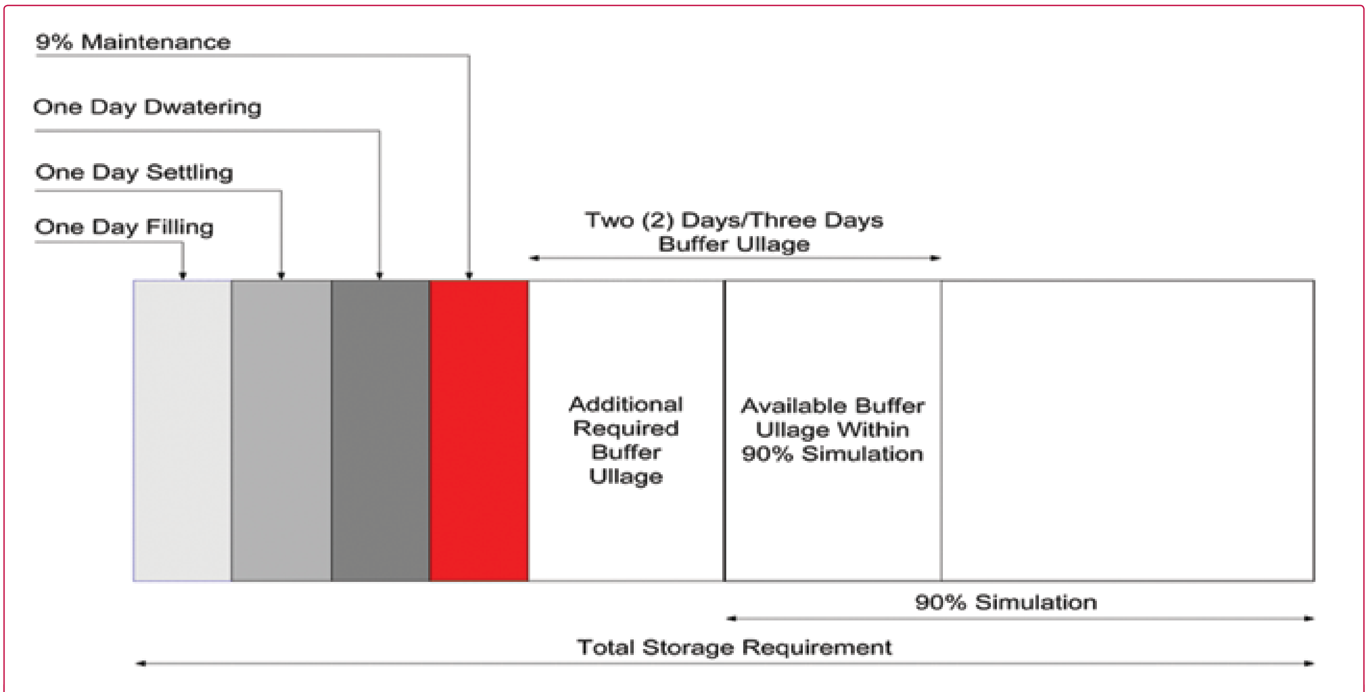

Figure 6. How simulated storage results can be used to determine total storage requirement.

determine the intervals at which infrastructure needs to be added to accommodate expected production increases over time. The oil company, for example, wanted to supply crude to new refineries and power plants being built in the region, and the modeling showed what facilities it would need to add and when.

What if . . . ?

One of the most powerful capabilities of simulation modeling is that it can run "what-if" scenarios and make complex interactions predictable. For example, using ship arrival statistics (fine-tuned by size of ship), simulation modeling can analyze what would happen if a ship's late arrival were to create a conflict in berth assignment or offloading equipment with other ships already scheduled for that day. The program also shows the effects of hypothetical circumstances such as equipment failures, regular and unscheduled maintenance shutdowns, weather events, and bigger what-ifs, such as changes in demand.

The oil company in question analyzed about 20 different scenarios because it wanted to make sure its new facilities would accommodate every likely combination of circumstances. Thus, one what-if analysis evaluated the impact of crude segregation alternatives. The simulation model is flexible and can include multi-crude supply points.

Other what-if analyses examined the impact of changing vessel arrival patterns on storage needs and whether additional berths, SPMs, gravity pipelines, or pumps would be needed to accommodate the increased throughput. For every what-if scenario examined, the modeling process identified alternative infrastructure components (e.g. berths vs. SPMs) and the impact of each on the operation (e.g. vessel waiting time and demurrage charges).

The simulation also provided a detailed daily inventory of the oil in all the tank farms, which facilitated the analysis of tank capacity needed to accommodate inventory fluctuations. Figure 5 shows a sample output of tank farm inventory variation for two petroleum products over a year. An optimal phasing plan to implement new infrastructure components was also developed after simulating and comparing the impact and costs of various phasing options for the upgrade process.

The run time of the simulation model will vary, depending on how far one wants to peer into the future. For instance, you can determine the average or maximum utilization of a berth over the course of a year or five years, or anywhere in between. Depending on the location of the berth, the simulation also determines the number of additional pipelines needed, and even their diameter and length.

The what-if scenarios run for the oil company were defined based on the availability of current infrastructure. For instance, upgrading an existing berth may require that the facility be taken offline for two or three months. That has to be considered because, once you turn on the production flow, it's difficult to shut it off. The company wanted to make sure that it had sufficient capacity to handle ongoing production while it was making changes to the network.

Once all the likely what-ifs had been considered, the company compared the costs of alternative facility configurations and performed economic analyses. For example, one configuration could have triggered $100,000 a year in demurrage penalties; but if it cost $100 million less to build an additional berth or SPM, it could still be the best option. The final decision is always up to the facility manager.

So, who needs simulation modeling?

Simulation modeling can work for any oil-producing company because the basic nature of such operations does not change. However, the precise array and attendant values of the variables will change; the power of simulation modeling is that it can account for any and all pertinent variables. The basic flow of the commodity in landside and waterside operations remains the same in all oil companies, but their vessel arrival patterns, parcel size distribution, need for pumps (versus reliance on simple gravity), and weather events may differ. It's just a matter of plugging the appropriate information into the model.

Because a good model is completely flexible, you can adjust it with new parameters from year to year based on the reality of what is happening on the ground, and the simulation will produce updated results for a new cycle of planning. Figure 6 shows graphically how simulated storage results are used to determine the total oil storage requirement. And with the increasing sophistication of both the modeling techniques and the platforms used to run simulations, the next stage of simulation modeling technology will not be confined to long-range planning; simulations will have the speed, flexibility, and responsiveness to be used for everyday tactical analysis and decision making, as well as for training.

A common-sense approach

Simulation modeling is a great way to optimize the infrastructure and processes of any complex, multi-action, labor-intensive operation. But as with any tool, it has to be used with great care.

First, don't buy simulation software off the shelf and expect miracles from it; modeling has to be tailored to the variables and site parameters that make each facility unique. Second, don't forsake common sense. Make sure the parameters that go into the model are realistic, and don't automatically assume that the output represents some kind of "ultimate truth" just because it came from a computer.

And what does simulation modeling cost? Very little, compared to the infrastructure investment that is at stake. Spreadsheets may be cheap, but they generally lack the sophistication to generate realistic plans – a failing that could be very costly in the long run. Sophisticated simulation modeling, on the other hand, will facilitate the cost-effective, long-range implementation of the most efficient infrastructure. It's the closest thing companies have to a crystal ball.

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