SUPPLY CHAIN SIMULATION

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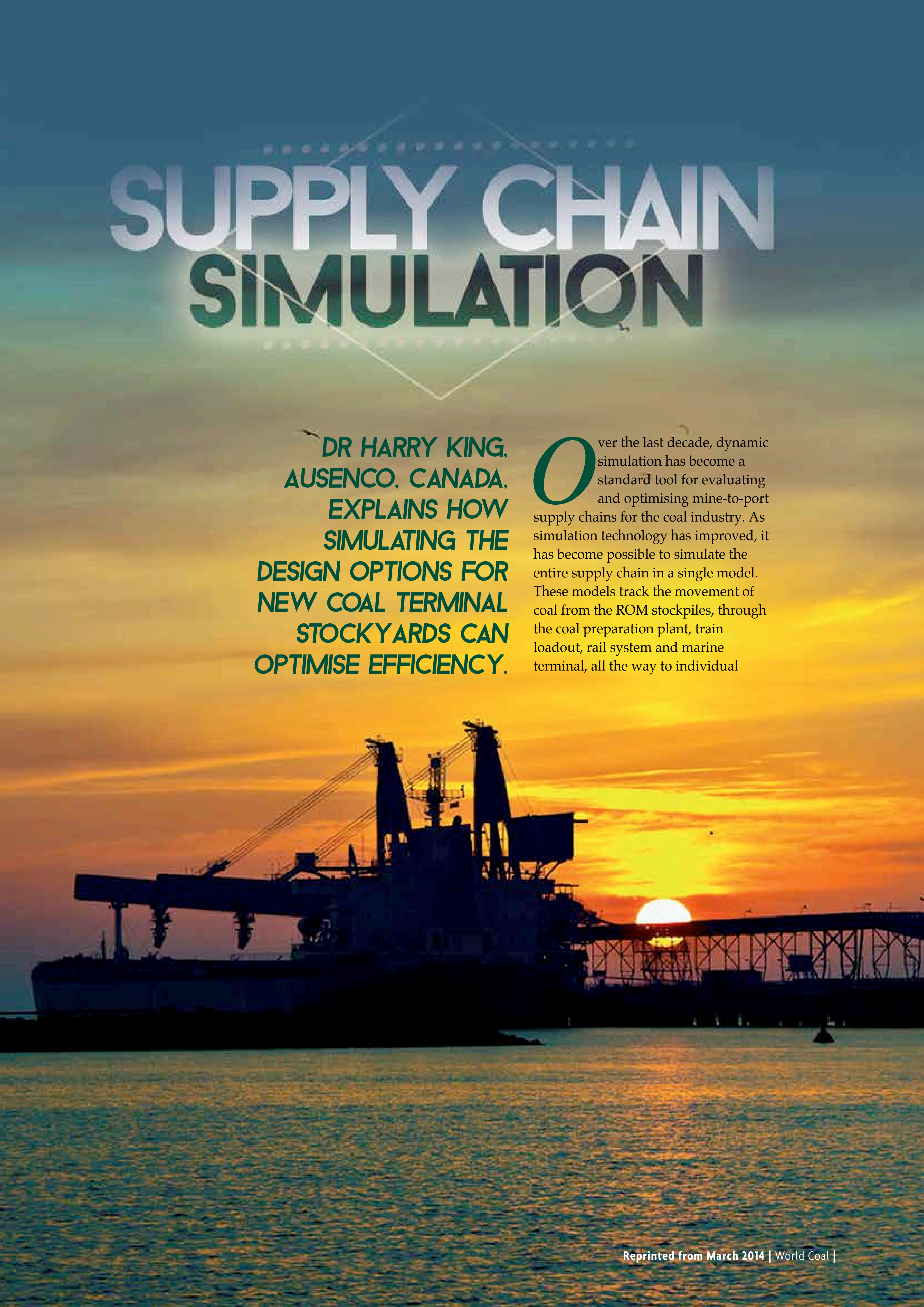
EXPLAINS HOW SIMULATING THE DESIGN OPTIONS FOR NEW COAL TERMINAL STOCKYARDS CAN OPTIMISE EFFICIENCY.

Over the last decade, dynamic simulation has become a standard tool for evaluating and optimising mine-to-port supply chains for the coal industry. As simulation technology has improved, it has become possible to simulate the entire supply chain in a single model. These models track the movement of coal from the ROM stockpiles, through the coal preparation plant, train loadout, rail system and marine terminal, all the way to individual



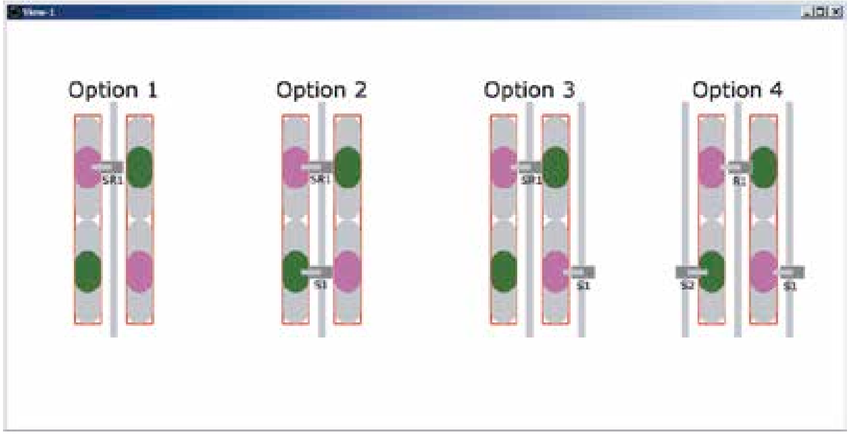


Figure 1. Modelled stockyard options.

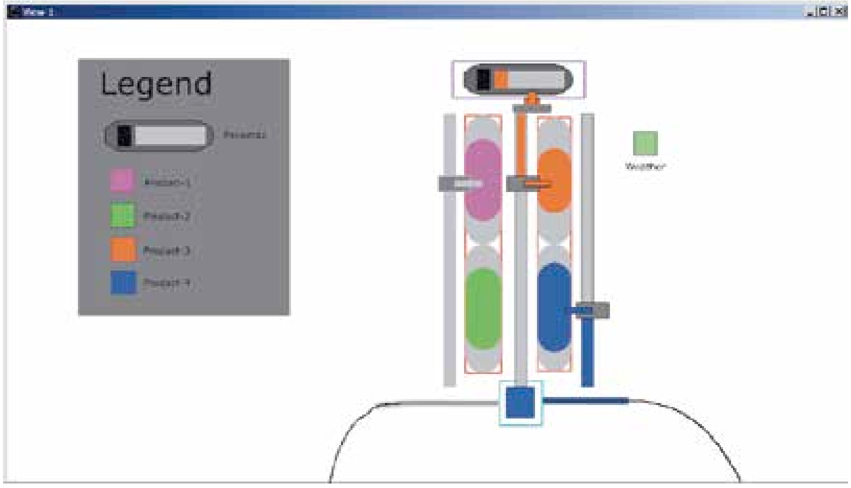


Figure 2. Model for Option 4.

ships. Navigational restrictions, such as tides, third party vessel traffic and weather restrictions, are usually also modelled. This approach captures the subtle interactions between sub-systems and allows the entire supply chain to be holistically optimised.

Each component of the supply chain is modelled in great detail. One of the most difficult components to model correctly is the marine terminal stockyard. This article illustrates how a detailed simulation model can be used to evaluate stockyard design options for a feasibility or pre-feasibility study of a marine terminal, as part of a larger supply chain.

The options

Typically, there are four options for a greenfield high-throughput terminal:

- A single stacker/reclaimer accessing two stockpile rows, with one on each side.
- A stacker and a stacker/reclaimer that share the same berm and access two stockpile rows, with one on each side.
- A stacker and a stacker/reclaimer on two separate berms with two stockpile rows on either side of the stacker/reclaimer. The stacker can access only one of the two stockpile rows.
- Two stackers and a reclaimer on three separate berms that access two stockpile rows, with one on each side of the reclaimer.

In some cases, it is possible to provide the entire storage capacity in a single, long stockpile row with a reclaimer on one side and a stacker on the other. This option is similar to Option 3, but without the stockpile row on the left of the stacker/reclaimer. This design has many advantages, but is rarely possible due to limited terminal space.

Figure 1 shows the basic layouts for these options, as displayed in Ausenco simulation software. Each option offers the same coal storage capacity for the terminal, but the capital cost and performance of the options vary significantly:

- Option 1: the least expensive, but its throughput capacity is limited by the conflicting demands for stacking and reclaiming through a single yard machine. The order of magnitude cost for a 1 km long stockyard would be approximately US$ 90 million.[1]
- Option 2: allows simultaneous stacking and reclaiming for approximately 50% of the time, depending on the locations of the piles being stacked to or reclaimed from. The cost of the additional stacker and related factors increases the order of magnitude cost to approximately US$ 120 million.
- Option 3: allows simultaneous stacking and reclaiming for approximately 50% of the time, depending on the locations of the piles being stacked to or reclaimed from. The cost of the additional stacker, berm, conveyors and transfer tower increases the order of magnitude cost to approximately US$ 150 million.
- Option 4: simultaneous stacking and reclaiming is always possible. The cost of two additional stackers, two additional berms, additional conveyors and transfer towers increases the order of magnitude cost of this option to approximately US$ 185 million.

Given the large differences in CAPEX between these options, it is important to choose the right one for the terminal being designed. This is where dynamic simulation can be used to determine the practical throughput capacity so that the most economical option with sufficient throughput

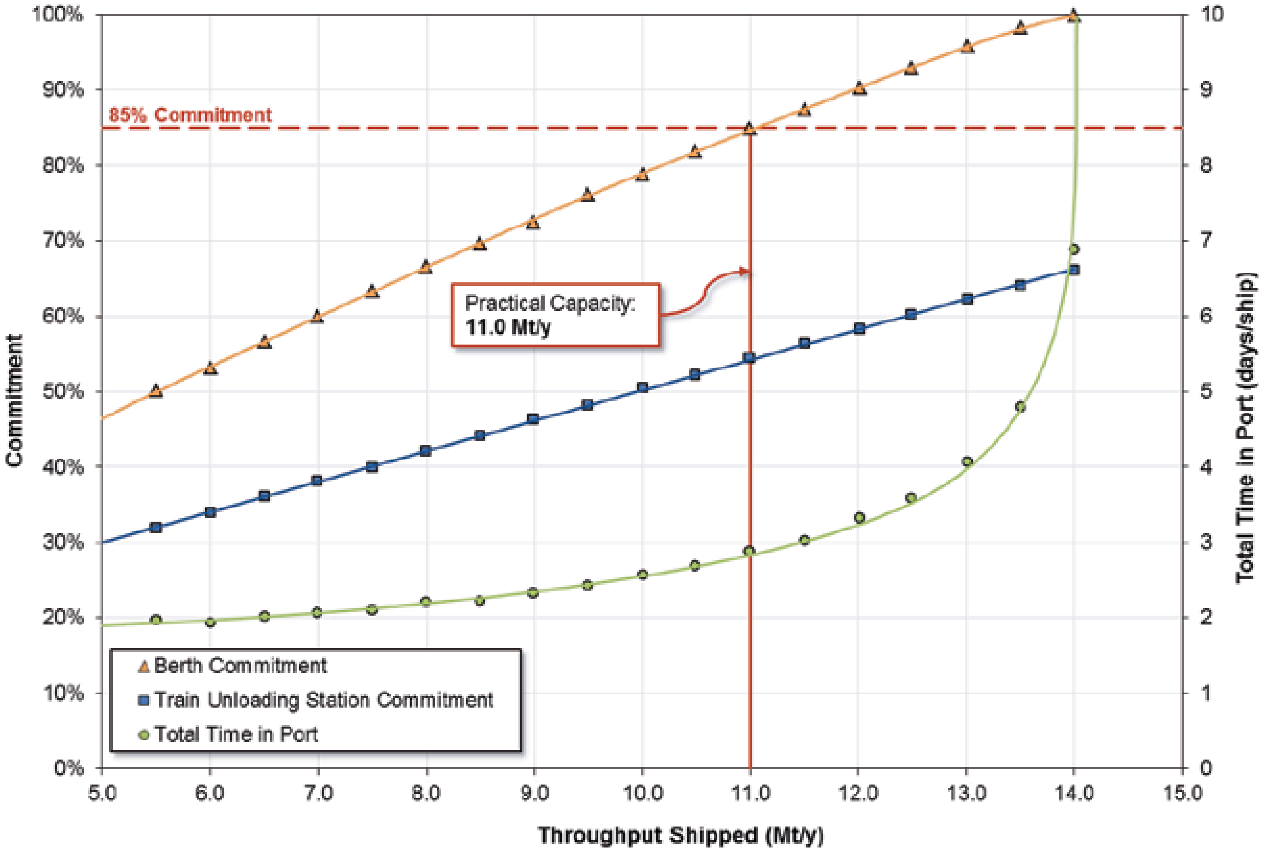


Figure 3. Key performance indicators for Option 1.

capacity can be selected. However, to evaluate these options, the simulation must include a higher level of detail than is normally provided. It must include the individual yard machines, as well as their access to individual stockpiles and the position of each machine on its berm. It is not sufficient to model the stockyard as a collection of abstract bins containing each grade of coal.

To demonstrate how such a simulation model could be used to evaluate stockyard design decisions, Ausenco has analysed a representative example coal terminal. Each of the four stockyard options were simulated to determine the terminal's practical throughput capacity. The difference in throughput capacity between the options could then be compared to the relative cost for each option.

Coal terminal simulation

The example coal terminal assumed four grades of coal with equal throughputs. The stockyard was 1 km long, with four stockpiles divided between the two rows, similar to Figure 1. Total stockyard capacity was 450,000 t, consisting of both live and dead storage, while also allowing for a suitable gap between adjacent stockpiles. Through-loading from the train dumper to the shiploader was permitted when the grades required by the ship happened to match the grade being unloaded. When conflicts occurred between stacking and reclaiming, priority was given to train unloading, unless the ship had already loaded 80% of its total cargo.

Modelled trains carried 12,000 t of coal and had bottom gates that allowed them to be unloaded at an average net rate of 6000 tph. A delay of 30 min was allowed between unloading the last tonne of coal from one train and unloading the first tonne of coal from the next train, when available. A stacker or stacker/reclaimer was reserved during this time to allow for repositioning and other preparations.

Panamax ships requiring 70,000 t of a single grade were assumed for the model. The reclaimers and stacker/reclaimers were assumed to have a peak rate of 6000 tph and an average net rate of 4000 tph. An additional 14.5 hours/ship of non-loading time was assumed to account for hatch changes, pre- and post-loading times and miscellaneous stoppages, etc.

An allowance of 8 hours/week of scheduled maintenance was allowed for each of the inloading and outloading systems. Unscheduled maintenance (breakdowns) occurred based on the operating hours for the inloading and outloading system, assuming 90% and 85% reliability, respectively. Finally, weather closures were assumed to stop both inloading and outloading for 5% of the year (about 18 days/year). Many other inputs were required to complete the

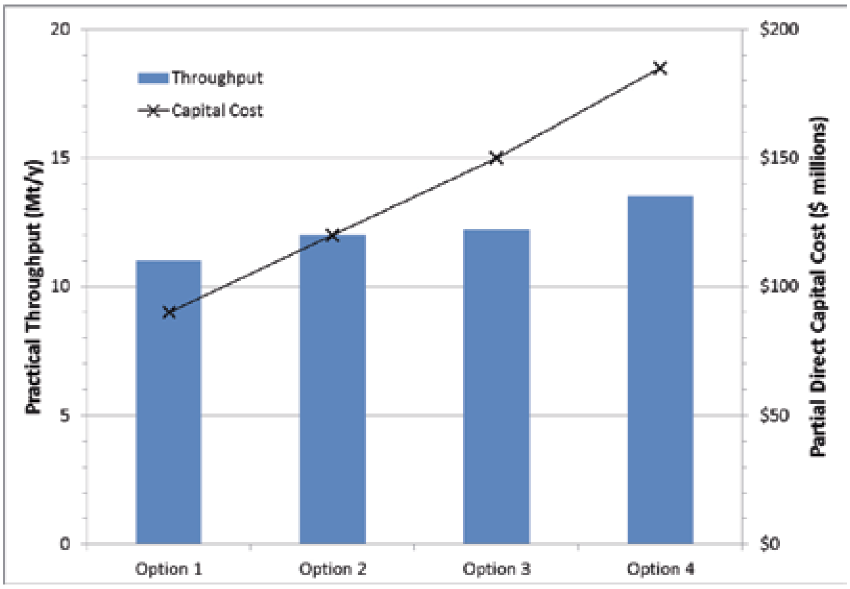


Figure 4. Comparison of stockyard options.

specifications for the model, but these had only a small effect on throughput and for brevity are not listed.

Figure 2 shows the completed terminal model for Option 4. In the figure, a train is unloading Product-4 (blue), which is stacked to the stockpile on the bottom right. Meanwhile, a panamax ship is loading Product-3 (orange) from the stockpile on the top right.

The practical throughput capacity for each option was determined by making a series of 10 year simulation runs over a range of throughputs. Key performance indicators (KPIs), such as berth commitment[2] and train unloading station commitment, as well as average ship time in port, were used to determine the practical throughput capacity for the modelled terminal.

Considerable judgement is required to select the thresholds that determine the practical throughput capacity for a particular type of marine terminal. For a modern coal terminal with a low amount of weather downtime, Ausenco typically uses a threshold of 85% for both berth commitment and train unloading station commitment. This amount allows for sufficient latent capacity for the terminal to catch up after unexpected outages and also allows for the normal amount of monthly throughput fluctuations over the year. Even though berth commitment may average 85% over the year, it is not unusual for a terminal to operate at 100% commitment during peak periods lasting several weeks.

Figure 3 shows the simulation results for Option 1. For this terminal design, berth commitment reached its 85% threshold at approximately 11 million tpa. Commitment for the train unloading station was lower, indicating that the terminal's bottleneck is shiploading, rather than train unloading. At this throughput, the average time for a ship in port was about three days. Ships spent about one day of this time waiting for their turn to berth. The rapid rise in average total time in port at higher throughputs confirms that 11 million tpa is a reasonable maximum throughput for this terminal.

Similar graphs were prepared for the other stockyard options. Options 2 and 3 had throughput capacities of about 12 million tpa, while the most expensive option, Option 4, had a throughput capacity of 14 million tpa. These throughput capacities are compared to the CAPEX for each option in Figure 4.

Analysis

Clearly, Option 1, with a single stacker/reclaimer, offers the best value for this case. However, many factors might change this result. For example, a slower train unloading rate would increase the amount of conflict between stacking and reclaiming, reducing the throughput for Option 1, but would have no effect on Option 4. Increased conflict between stacking and reclaiming would also occur with additional coal grades, since this would reduce the amount of through-loading that could be done.

A single stacker/reclaimer might be the least expensive choice for first phase of a greenfield terminal, but it might not be the best choice if an expansion to a second or third phase is planned over a short timeline. For a larger stockyard with more stockpile rows, the cost premium for stockyard options with stackers and reclaimers is reduced compared to the stacker/reclaimer option because each stacker can be shared between adjacent rows. Furthermore, it is far easier to manage a large terminal with many stockyard machines if there is no conflict between stacking and reclaiming operations.

Finally, it is important to note that the required throughput capacity for a coal terminal is normally determined by the economics of mine production, not the other way around. If the required throughput for the modelled terminal is greater than the 11 million tpa capacity of Option 1, it will be necessary to consider either a higher reclaiming rate or one of the other stockyard options or a combination of both. There is no general rule indicating that one stockyard design is always best.

Conclusion

This article has shown how dynamic simulation can be used to analyse the complex design choices involved in the engineering of a marine terminal. With sophisticated simulation technology available today, it is now possible to model the detailed layout of a terminal's stockyard and quantify the benefit of one stockyard design against another.

Notes

1. These order of magnitude costs assume easy site conditions and exclude indirects, contingencies or risks, etc. They are intended only to illustrate the cost differences between the four options.
2. Berth commitment is one of the best ways to measure the total usage of a berth. It is the percentage of time the berth is occupied by a ship, reserved for a ship that is in the process of berthing or de-berthing or closed for use by weather, maintenance or a breakdown. Train unloading station commitment is defined in an analogous way.