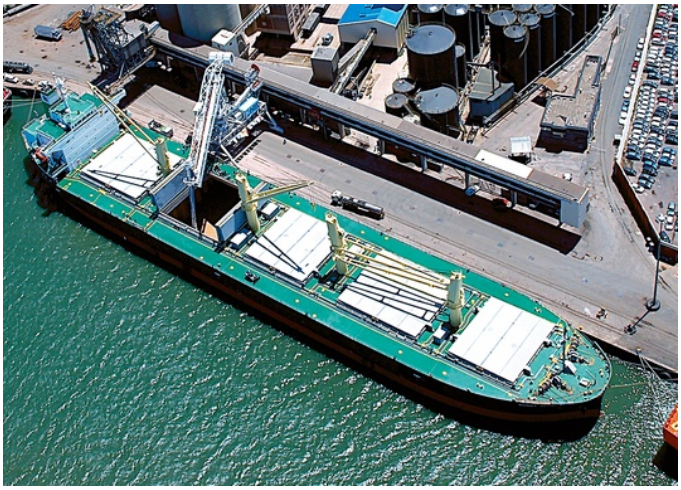
Optimal Ship-Unloading Solutions

Large quantities of bulk grain are transported in ships. These ships can hold different kinds of grain in up to a dozen hatches and could be damaged in the event of excessive ship tilt or wall stress between hatches.

The port receiving the grain employs its available configuration of unloaders, bulldozers, and conveyors to unload the ship as quickly as possible. Up to four different unloaders are available that move laterally but cannot cross each other. At low grain levels, bulldozers hoisted into the hatch shovel the grain toward the take-up point of the unloader. Up to four conveyors transfer grain from the unloaders to silos.

All this complexity must be managed for unloading grain-laden ships at minimum time and cost without exceeding safety and other constraints. Bühler AG has developed a decision support tool that is used by both sales and technology staff to optimize unloading.



A five-hatch ship with a single unloader digging in hatch 4

An unloader using its take-up point to dig into the grain in a hatch

Two bulldozers feeding residual grain to the take-up point of an unloader in a hatch

Decisions: Investment and Unloading Sequence

Port personnel must use their experience and know-how to decide the unloading sequence for an incoming ship. They also must decide which changes in (or which new) unloader-bulldozer-conveyor configuration they should invest in. For this purpose, they need to know the expected performance of a projected configuration for a reference ship.

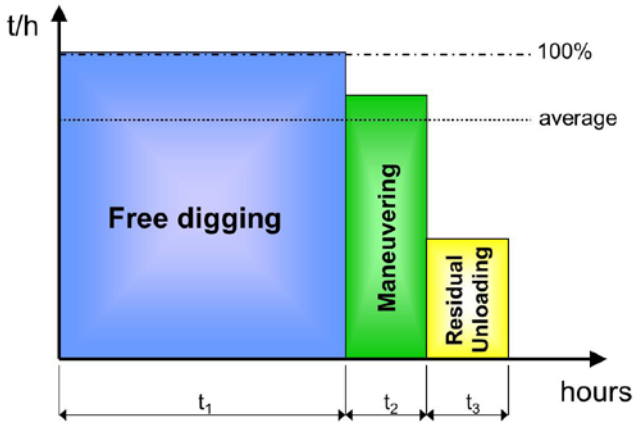
Challenges for a Decision Support Tool

A tool to support the above decisions must address several challenges:

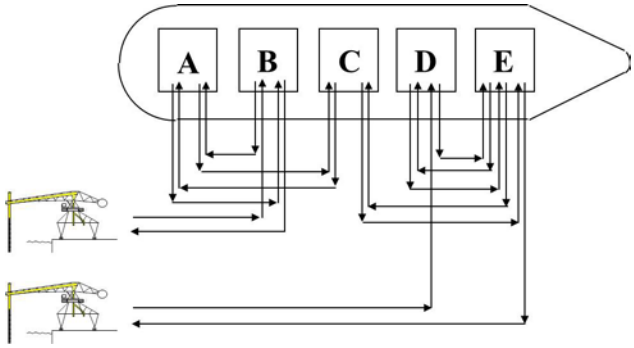
- Find a sequence to minimize unloading time.
- Compute ship tilt and wall stresses dynamically and respect their limitations.
- Account for the three unloading phases in a hatch, with decreasing unloading rate (see figure on next page) and dynamic transition criteria: free digging, maneuvering the take-up point, and residual unloading using bulldozers to shovel grain to feed the take-up point.
- Respect limitations on receiving conveyors.
- Ensure that unloaders do not cross each other.
- Allow two unloaders to service the same hatch together.
- Include unloader travel time between hatches.
- Use different unloading rates for different grains and hatch geometries.
- Enable a variety of ships, grains, unloaders, bulldozers, and conveyors.
- Minimize computation time for interactive use.
- Animate results for verification and credibility.

The tool should enable users to determine the unloading time and sequence for an incoming or reference ship. It should also be able to optimize the configuration of unloaders (number, types, and positions), bulldozers, and conveyors and allow tradeoff between unloading time and investment cost.

Contributors: Robert Haymoz and Mukul Agarwal, Bühler AG, Switzerland



A typical pattern of unloading rate (tons per hour) versus active unloading time for a hatch



A possible unloading sequence using two unloaders for five grain hatches

Solution Strategy

For a given ship and unloader-bulldozer-conveyor configuration, the tool simulates the entire unloading while making event-triggered decisions based on evaluations of multiple heuristic criteria. It also iteratively optimizes the relative weights of the criteria.

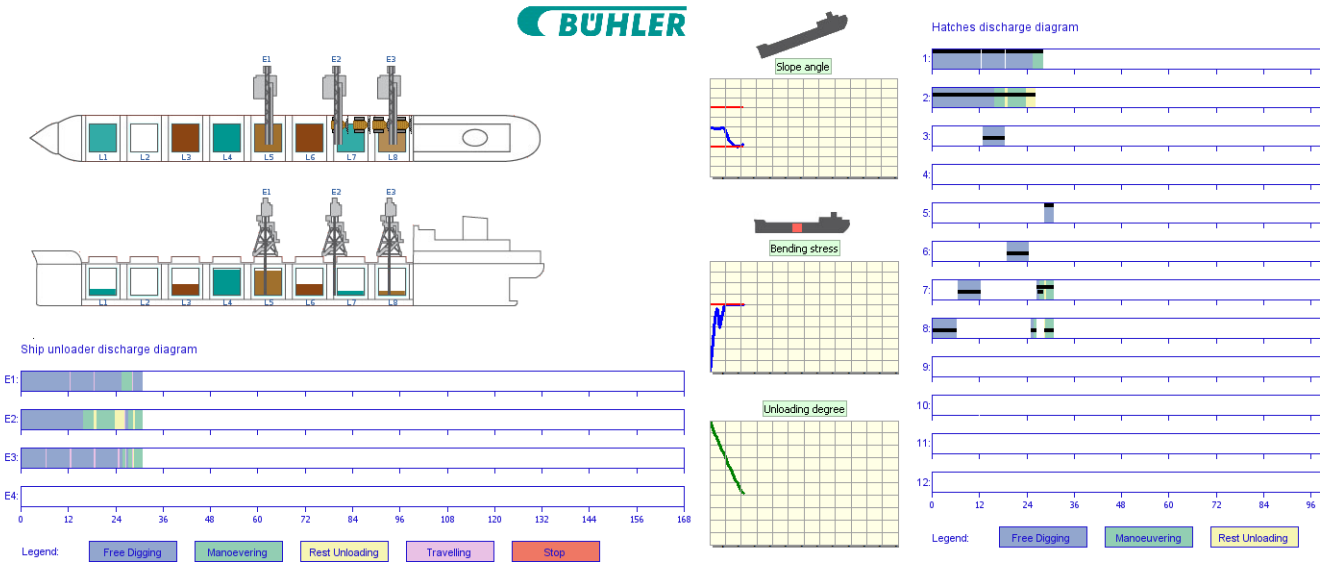
In addition to this "inner-loop" process, an outer genetic-algorithm-based loop optimizes the unloader-bulldozer-conveyor configuration. Semiautomated operation is also possible—for example, if an investment-performance tradeoff is not given, the tool can optimize just the unloader positions, allowing the user to manually, and iteratively, explore options for the rest of the configuration.

Application of the Ship-Unloading Tool

Since 2008, sales and technology personnel at Bühler AG have used the tool routinely for two purposes:

1. About 50 times a year, sales personnel use the tool to determine the performances of manually proposed unloader-bulldozer-conveyor configurations so as to select and convincingly present the best options to port customers worldwide. The tool enables sales personnel to do each job in half to one day instead of a week and to guarantee performance with lower risk.

2. Technologists use the tool to advise customers how to modify their manual unloading strategy. The optimization features of the tool enable up to 30 percent faster unloading of ships.



For a real or projected unloader-bulldozer configuration, the tool uses event-triggered heuristic-criteria-based decisions to unload a simulated ship in the shortest time while observing limits on ship tilt and wall stress. The tool outputs the best unloading procedure and the attainable performance (total unloading time).

For more information, visit http://www.buhlergroup.com.