A tool to schedule vessel sailings and container flows for recurring transports of full and empty containers between a single source and a single destination.

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**Introduction**

This report describes a tool that supports the decision on the timing of vessel sailings from port A to port B, and vice versa, where the vessel transports full containers that are loaded at port A and are unloaded at port B. The unloaded containers are next put on trucks for transport to a number of destinations close to port B, are immediately emptied at these destinations, and are transported back to port B for being loaded again on a vessel that, after being loaded, sails back to port A.

At port B, a kay and a crane are used to unload full containers from the vessel to a drop position under or besides the crane, and load empty containers from a pick-up position under or besides the crane to the vessel. A reach stacker is used to bring full containers from their drop position on the kay to a buffer, from their drop position directly to a truck, or from the buffer to a truck. Trucks are used to bring the full containers to their destinations and return the empty containers to the kay at port B, either to the buffer or to the pick-up position on the kay. The reach stacker is used to bring the empty containers from the truck to the buffer, from the truck to the pick-up position, or from the buffer to the pick-up position.

The whole system consisting of containers, vessel(s), crane, and trucks, serves to bring a more or less regular stream of goods that is available at port A, to the destinations close to port B. The containers, the vessel, the kay, the crane, and the reach stacker are owned; the trucking activities are subcontracted.

Given a forecast of the volume of the stream of goods over a planning horizon, the operator of the system has to decide on the number of vessels, the number of cranes, the number of reach stackers, the sailing schedule of the vessel(s), the loading and unloading processes, the truck hiring per unloading process, and the number of containers. He operates under a constraint on the amount of time that a full container is allowed to wait at port A, and faces unloading and loading costs at port B that depend on the day of the week and the time of the day. His aim is to minimize the costs of vessel sailings and unloading/loading, under the condition that all demand is served and no full container waits longer than the allowed time at port A.

**The Tool**

The tool consists of four modules that must be used iteratively in order to arrive at a close to optimal solution.

**Module 1: The number of vessels needed**

Module 1 calculates the number of vessels needed to serve the demand, and the minimum and maximum number of sailings per vessel over a specific horizon. It takes the demand (in pieces or kg) per day as given, and uses the container capacity (pieces of kg per container) and the vessel capacity (number of containers per vessel) to determine the minimum interval between successive vessel departures from port A that are needed to serve all demand within the service constraint. A lower bound on this interval is the maximum time that a full container is allowed to wait for loading at port A. Next, the module calculates the turnaround time of a vessel, which is equal to the time to load the vessel at port A, sail to port B, unload the vessel at port B, load the vessel at port B, sail to port A, and unload at port A. If the turnaround time is smaller than the minimum time between successive departures at port A, only one vessel is needed to serve the demand. If the turnaround time is larger, more vessels are needed; the module calculates the minimum number of vessels needed.

Assuming that each vessel sails at the same frequency, the module calculates the minimum number of sailings required from the maximum time that a full container is allowed to wait at port A, and the maximum number of sailings possible, from the vessel turnaround time and the length of the horizon.

**Module 2: Selects vessel arrival times to minimize operating costs at the Port**

Since vessels come in discrete numbers, and have a given capacity for loading containers, the solution from module 1 is likely to contain slack in terms of the number of sailings and load of each sailing to serve total demand. This provides opportunities to use this slack to generate a sailing schedule that avoids as much as possible loading at expensive times.

Given the minimum and maximum number of sailings over the horizon from module 1, module 2 takes the required number of vessels, the vessel turnaround time, and the minimum interval between successive departures as inputs, and uses the slack time over the planning horizon to select vessel arrival times at the kay at port B that minimizes the operating costs at port B.

Input to this module are the hourly operating costs of the crane as a function of the day of the week and the hour of the day, and the variable costs of sailing a vessel from A to B. The module assumes fixed vessel unloading and loading time, independent of the number of containers to be unloaded and loaded.

**Module 3: Calculates and shows available stocking capacity**

In the previous modules, it is assumed that containers and buffer capacity for stocking containers are amply available. This however is not true. At any point in time, the total number of containers in the system is a given constant, as is the capacity for stocking containers at port A and port B. Module 3 takes as input the total number of containers in the system and their positions at the start of the period considered, and, using the output of module 2, maps on an hourly basis the number of containers on each of the following positions:

* In the buffer at port B
* Under the crane at port B
* On trucks to and from destinations at port B
* On a vessel
* In port A

Module 3 first takes the number of containers on the arriving vessels in port B. Given these numbers and the trucking plan (opening times of destinations, turnaround times of trucks, maximum number of trucks to be used), the module calculates the stocking volume of full and empty containers at port B

The module shows any overrun of available stocking capacity or any underrun of number of containers needed for loading. In case of over- and/or underruns, the operator can change the sailing schedule, the number of containers to be loaded at any arrival at port A or Port B, or the number of containers in the system, to remove the over- and/or underruns from the plan. The module does not provide decision support for finding optimal changes in the plan for removing the over- and/or underruns.

**Module 4: Shows the estimated total time for unloading and loading each vessel.**

The actual vessel unloading and loading times depend on the number of containers to be unloaded and loaded, and on the unloading and loading capacity of the kay under the crane. If insufficient unloading and loading capacity is available under the crane, the container must be dropped besides the crane, where there is only one drop position available. The container dropped there must be removed by the reach stacker to the buffer before the next container can be dropped. This process however may be interrupted due to unavailability of the reach stacker, since the reach stacker is also involved in the loading and unloading of trucks and gives priority to trucks. This may slow down the unloading process.

The intensity of truck arrivals over time depends on the terms in the contract with the trucking subcontractor. Thus, the operator must be able to evaluate different trucking contracts with respect to the possible interference with the unloading process for specific arrivals, since the vessel sailing schedule assumes a fixed amount of time for the unloading/loading process at the kay of port B.

Module 4 takes an arriving vessel with a specific number of containers to be unloaded and loaded, and evaluates the duration of this process as a function of the number of cranes used for loading and unloading, and the number of trucks hired for bringing containers to and from their destinations. The module assumes that ample containers are available at port B for loading the vessel.

Specifically, module 4 takes as input the arrival times of the vessel(s) and the number of containers on each arriving vessel from module 3. As a decision input, it takes for each arriving vessel the number of trucks at their duty times hired for bringing containers to their destination and returning them to the port. Given the number of containers on the vessel and their destinations, the module first calculates the return-arrival times of the trucks at the port.

These return-arrival times are input to an Excel simulation model that simulates the unloading and loading of each arriving vessel, showing the interruptions of the unloading and loading process due to arriving trucks. This simulation results in an estimate of the total unloading and loading time for each vessel arrival. These estimates can be checked with the unloading and loading times used in the sailing schedule of module 2. In case of an unacceptable difference, adaptations must be made, either in unloading and loading times in schedule from module 2, or in the number and duty times of trucks. Such changes however require reconsidering of the resulting container flow via the application of module 3 the new schedules.

**Decision tool**

The decision tool designed for SCS Multiport is upgraded to a generic version according to the above descriptions of the conversion factory project.

Comparing this generic tool with the tool for SCS Multiport, there are no large changes in the function. Input lists are adapted in order to fit into the situations of any different users. Names of stakeholders are consistent with the names appear in the above description of the project and specific company names are avoided.

The tool is developed in Excel with visual basic for application. The above described modules are associated with various sheets in the Excel tool.

* Module 1: sheet of strategic planning
* Module 2: sheet of scheduling, sheet of scheduling (method 2). The planner can use and compare two methods for scheduling the ships, one of which is near-optimal solution.
* Module 3: sheet of container flow. Before running this module, the input setting from the sheet of truck plan must also be checked.
* Module 4: sheet of terminal operation.
* Finally, the import KPIs are calculated and shown in the sheet of control panel.

For more details of how to use the tool, please check the final report of the project of SCS Multiport (Appendix V).