Advanced maritime operations in civil engineering

The railway bridges in Stockholm city centre are to be replaced. Needless to say, this is a very sensitive operation and the Swedish Transport Administration wanted to acquire as much information about the problem as possible, as early as possible. One way of managing the impact of the operation on traffic was to transport and install the bridges over water. SSPA used its know-how of maritime operations and state-of-the-art simulation tool SEAMAN to help our client save money and manage the risks involved in such an operation. After the project, our client felt that they had a much better understanding of the problem and could start the bidding process with more confidence.

In these simulations, it was assumed that the barge will be using winches connected to the shoreline and anchors for positioning. The tugs will be disconnected from the barges before this critical section. Illustration: SSPA

Replacing an old bridge is never easy. But what if you are doing it in the heart of a large city where the transports cannot be permitted to disturb regular traffic too much? And what if one of the bridgeheads is located within metres of an 800-year-old building? And what if you have a very short timeframe for completing the work? In such a case, you need to take the operation to a whole new level. So before the Swedish Transport Administration invited bids for the project with the help of SWECO, they both decided put some of their assumptions to the test.

Background

The Swedish Transport Administration was tasked with upgrading the rail bridges at Getingmidjan in the heart of Stockholm. The operation will effectively divide the rail network of central Sweden in two. Work is to be performed on and in the vicinity of the oldest part of Stockholm, Riddarholmen, with some buildings dating back to the 13th century. In short, this is a very sensitive situation. The Swedish Transport Administration asked SWECO to help them prepare the request for proposal. SWECO saw that one way of meeting the tight deadlines without disturbing the city traffic is to transport all the heavy parts by water. But is that even possible? They contacted SSPA for help with the maritime parts of the project, and we got down to work.

The idea

One way of replacing the bridge segments is to transport them from the Baltic Sea through the locks at Södertälje and onto Lake Mälaren. The bridge segments will then be assembled into complete bridges in a suitable location on the lake. These bridges will in turn be loaded onto barges, manoeuvred through the archipelago into Stockholm and put into the correct position. Does this sound complicated? SWECO wanted to know exactly how complicated it was, or indeed whether it was even possible. The whole operation was to be set up in a simulated world where it would be carried out repeatedly to find an answer.

Is it possible?

To check whether the proposed idea was feasible, SWECO turned to SSPA. The operation was analysed and divided into several phases:

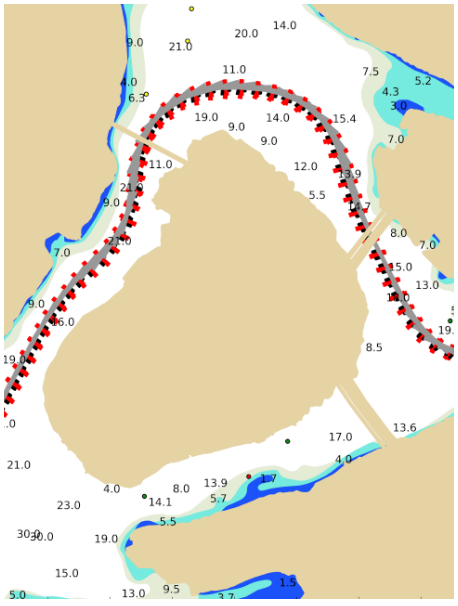
1. Transport the bridge segments through the locks and canals at Södertälje.
2. Assemble and prepare the bridge segments for final transportation.
3. Transport the assembled segments to the mounting area of the bridge
4. Manoeuvre the barges into position and lower the bridge onto its supports.

SSPA did research on what barges and tugboats could be used for the transportation through to the assembly area and from the assembly area to the bridge mounting area. These vessels were then used in simulations. In addition to the mathematical simulations

in each phase, a 3D model was created for the final positioning of the bridge.

1. Transportation through the locks

A geometric analysis was carried out for how the barges, bridge segments and tugboats would make it through the locks in Södertälje. In addition to lock passage, fast-time simulations of the entire passage were also run using SEAMAN. It is not the first time that this tool has been used for simulations of lock operations. For example, it has been used for simulations of ships transiting the Panama Canal, and for ships in Södertälje as well. This time the simulations showed that passing the locks is possible under the assumptions of this project.



One example of a difficult manoeuvre is when the bridge and barges are moved around the island of Stora Essingen. Illustration: SSPA

2. Preparing the bridge segments

The bridge segments will be arriving at Lake Mälaren on flat-top barges positioned in a way that is suitable for transport and passage through the lock. Before final positioning of the bridge, they will need to be assembled and reloaded onto barges in another configuration more suitable for the bridge-positioning operation. This could be done on shore, but also on water by moving them from one set of barges to another. To make sure that it is possible, SSPA performed simulations of this advanced barge-to-barge operation.

3. Transportation to the bridge site

There are a number of waterways into central Stockholm from Mälaren. But in this case, we will manoeuvre two barges and a large bridge with two tugs. This means that any route chosen for the transportation had to be evaluated with diligence. Simulations were run using various wind conditions to find out whether the transport is feasible. The height of bridges along the route is a limiting factor, as well as the width of the fairway. One example of a difficult manoeuvre is when the bridge and barges are moved around the island of Stora Essingen.

4. Positioning the bridge at the bridge site

During the final phase of the operation, the barge carrying a bridge will be positioned so that the bridge can be lowered directly into its final position. This is high-precision manoeuvring of a very heavy vessel with a very narrow margin for error. In these simulations, it was assumed that the barge will be using winches connected to the shoreline and anchors for positioning. The tugs will be disconnected from the barges before this critical section.

How do you control up to eight winches that are to pull with different forces to control not only the heading of the barge, but also its position at the same time? Is it possible to do it automatically so that a large number of simulations can be performed quickly? In this case, SSPA created an autopilot function based on the same principles used to control thruster allocation in spaceships. But instead of a thruster creating the force, a constant-tension winch does. The control algorithm will move the barge into position at the bridge site. When the barge is accurately positioned, the bridge will be lowered slowly into its final resting position. The eagle has landed.

Result

SSPA was able to use its know-how of maritime operations to identify a number of operations that were obviously not feasible. Using the simulator tool SEAMAN, we tested these operations thoroughly until we were convinced that they were possible, or suggested modifications to make them possible. At the end, our clients SWECO and the Swedish Transport Administration felt that they had a much better understanding of the problems inherent in this type of solution. And the more you know, the better you can handle the RFP, Request for proposals. You can save money and manage the risk better. With that knowledge, they felt comfortable putting out a request for proposals for replacing the bridges.

What methods will the bids propose? We don't know yet. But we do know that transporting the bridges on water is one way to do it.

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Linus has a degree in Engineering Physics from the Chalmers University of Technology. He has a background in mathematical modelling, control algorithms and simulations applied to the maritime domain. He is currently leading the development of SSPA's simulation tool SEAMAN and was project manager for SSPA's part of the Getingmidjan project.

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SEAMAN SIMULATION

Simulations are an efficient tool for maritime infrastructure development projects. The output will directly support clients in their decisions on alternative layouts of ports, fairways and terminals. SSPA has decades of experience and records supporting clients worldwide. For each simulation assignment, SSPA communicates with the client to ensure that the simulation has the right level of detail with regard to both accuracy and cost-efficiency. To reach the appropriate level, there are a number of areas that SSPA tailors to the client's needs: Ship Dynamics, Modelling, Instrumentation, Visualisation and Analysis.