OPTIMISING SHORE POWER THROUGH BERTH SIMULATIONS

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INTRODUCTION

Connecting vessels to shore power when berthed has many benefits but adoption is throttled by, amongst others, high investment costs. This research study, conducted by the collaboration of Royal HaskoningDHV and Portwise, explores the potential of optimising shore power systems configuration in container terminals by using berth simulations.

Shore power systems provide shoreside electrical power to a ship at berth, reducing fuel consumption, exhaust emissions and noise generation. Traditionally, these systems are designed to allow for the highest flexibility of vessel berthing. This results in a high number of shore power zones, each being a designated area along the quay where a maximum of one vessel can be powered at the same time. Expensive electrical infrastructure is required for each shore power zone.

The combined expertise of Portwise and Royal HaskoningDHV in container terminal operations and electrical infrastructure design raised the hypothesis that the investment into electrical infrastructure can be optimised by predicting where and when vessels will require a shore power connection point, through berth planning simulations. This white paper confirms the hypothesis, with the achievable optimisation depending on local conditions.

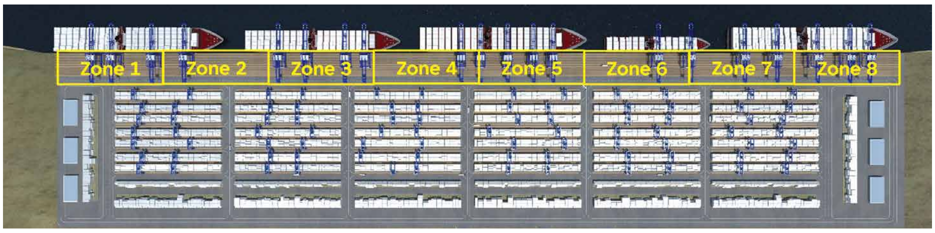


FIGURE 1. The layout of the generic study case container terminal with 8 shore power zones

DEFINITION OF A GENERIC STUDY CASE

To evaluate the effectiveness of our optimisation method for shore power system configuration, we defined a generic and representative case study. We consider a large container terminal with a continuous quay, capable of serving the largest container vessels in the world. The case study terminal has the following parameters:

- Volume: 5 million TEU per year over the quay (TEU factor 1.75).
- Quay length: 2,000 metres.
- STS cranes: 20 working at a productivity of 25 GMPH (through the ship).
- Container vessel range: vessels with cargo capacity from 500 TEU to 24,000 TEU, with call sizes being on average 60 per cent of vessel capacity which is reflective of a busy hub-spoke transshipment terminal. Seasonality is accounted for keeping the same number of weekly calls and varying the vessel call size.
- Simulation length: 1 year.

This is a relatively large but not uncommon container terminal size. The layout of the considered terminal with eight shore power zones is shown in Figure 1.

Two different vessel mixes are compared:

- Scenario 1: Mix of deepsea + feeders, with 16 deepsea vessels and 14 feeders per week.
- Scenario 2: Only deepsea vessels, with 22 deepsea vessels per week.

The mooring margin on both sides of vessels is assumed to be 15 metres for feeder and 25 metres

"SHORE POWER SYSTEMS PROVIDE SHORESIDE ELECTRICAL POWER TO A SHIP AT BERTH, REDUCING FUEL CONSUMPTION, EXHAUST EMISSIONS AND NOISE GENERATION."

SYSTEM ELEMENT	COST REDUCTION [M EUR]			
	for countries with 50Hz grid + for countries with unstable 60Hz grid		for countries with stable 60Hz grid	
	fixed connectors	mobile connectors	fixed connectors	mobile connectors
FREQUENCY CONVERTER STATIONS	1.5	1.5	0.8	0.8
DISTRIBUTION NETWORK	0.3	0.3	0.3	0.3
VESSEL CONNECTION POINTS	-	0.4-0.8	-	0.4-0.8
TOTAL (FOR REDUCTION OF ONE SHORE POWER ZONE)	**1.8**	**2.2-2.6**	**1.1**	**1.5-1.9**

TABLE 1. Potential cost optimisation by the reduction of one shore power zone

for deepsea vessels. This means that there must be at least 30-50 metres between two vessels. All vessels must receive shore power, with the shore power connection point located at the stern for both feeders and deepsea vessels. One shore power zone can provide power to at most one vessel, which can connect in the full zone, either through a mobile connector or through a sufficient number of fixed connectors. Finally, no hindrance is assumed from tide, wind, or quay crane breakdowns, focusing on considering the isolated effect that shore power zone configuration has on the vessel berth planning.

POTENTIAL CAPEX SAVINGS

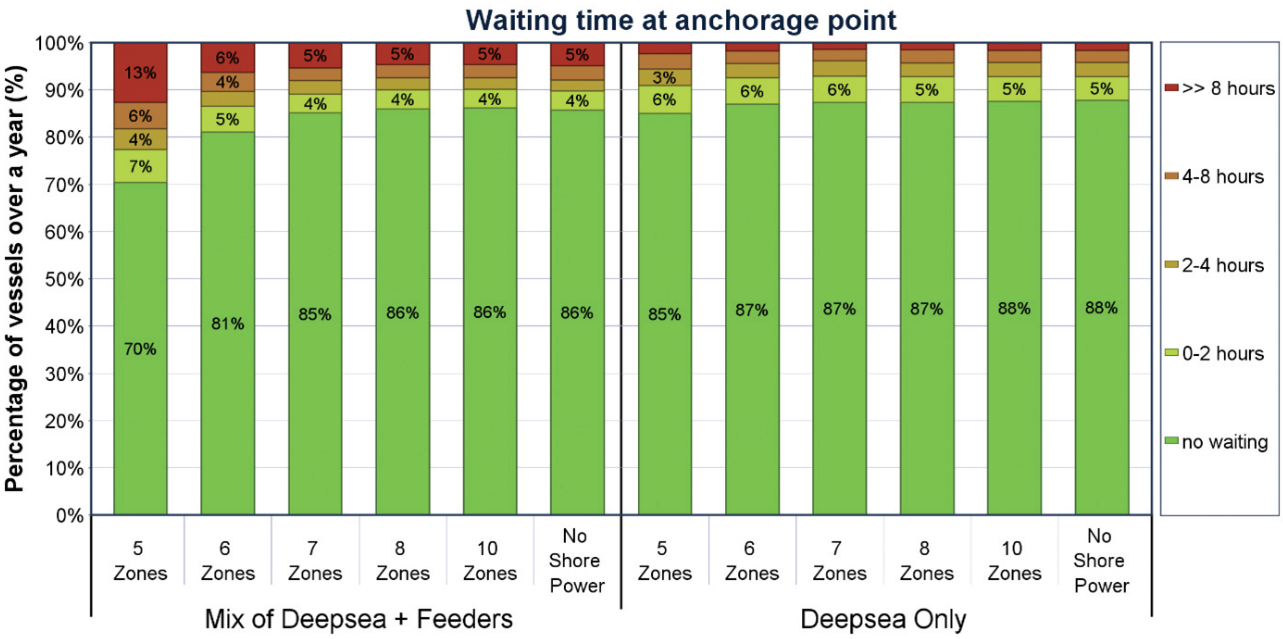
The electrical infrastructure required for supplying shore power includes a general power grid connection, intake station, substation, converter stations, distribution network and vessel connection points. The number and design capacity of these components depends on the number of shore power zones. If the shore power system configuration could be constructed using one less shore power zone (e.g. having seven shore power zones on the terminal instead of eight), the saved investment associated with this is estimated at €1.1 million - €2.6 million ($1.2 million – $2.8 million) (see Table 1). This saving primarily involves the reduction of system components such as converter modules, distribution networks, and connection points. Project conditions are important, particularly the nation's grid frequency and frequency stability, and use of either fixed vessel connectors or mobile vessel connectors.

BERTH SIMULATIONS

Berth simulations were conducted for the case study as discussed earlier. The results, as expected, indicate that the vessel mix plays a crucial role in determining the number of shore power zones required. For the same throughput, larger vessels and call sizes result in fewer shore power zones needed, since fewer vessels can then be berthed simultaneously due to their greater length.

Consequently, shore power zones are unlikely to be a bottleneck for this vessel mix, as terminals that handle smaller vessels will experience shore power-induced waiting times.

The simulation model used is Portwise's well-verified simulation tool TRAFALQUAR, which simulates a year's worth of vessel arrivals



and quay operations. Vessels are generated based on a weekly arrival pattern of the vessel mix discussed above. Arrival times deviate stochastically from the planned time, and vessels enter the simulation at the anchorage point, where they may have to wait for berth space before sailing to the terminal. Deepsea vessels are prioritised over feeders with a 12-hour look-ahead window. Upon arrival at berth, vessels are handled by several quay cranes depending on quay crane availability, vessel size, and service level agreements. After service, vessels are unberthed and leave. Each replication simulates one year of vessel arrivals, with 10 replications conducted per experiment to obtain statistically reliable average results.

The waiting time for vessels offshore is highly dependent on the number of shore power zones, as can be observed in Figure 2. This figure shows a histogram of vessel waiting times at the anchorage point for two different vessel mixes and for different numbers of shore power zones. Vessel waiting time is logically lowest without shore power since vessels never have to wait for an available connection.

The ideal number of shore power zones matches the vessel waiting times of the "No shore power" scenario. Scenario 1 (Mix of deepsea + feeders) requires eight shore power zones to achieve this, whilst scenario 2 (deepsea only) requires six zones. This demonstrates that the vessel mix is a crucial factor in determining the optimal shore power system configuration.

MULTI-CRITERIA ANALYSIS

Determining the optimal number of shore power zones requires a comprehensive view of all relevant aspects. When reducing the number of shore power zones, it's essential to consider whether the system can still deliver satisfactory vessel service levels, berth planning flexibility and berth planning redundancy, whilst also estimating the potential cost savings involved. The outcome of this process will vary greatly from one terminal to another due to differences in technical parameters (such as the current and projected vessel mix, power grid frequency and stability) and commercial factors (including required vessel service levels, their valuation, acceptable waiting times, and related costs). From a berth planning perspective, it can be generally stated that the more feeder (i.e. smaller) vessels a terminal expects, the more shore power zones are required.

FIGURE 2. Waiting time at anchorage for two vessel mixes and varying number of shore power zones

An example of a Multi-Criteria Analysis for defining the optimum shore power system configuration is shown in Table 2, considering various relevant aspects.

For scenario 1 (Mix of deepsea + feeders) it is expected that reducing the number of shore power zones would lead to cost savings in electrical infrastructure; however, this could be outweighed by the negative effects of increased vessel waiting times, reduced flexibility in berth planning, and decreased redundancy in the event of a shore power zone malfunction.

For scenario 2 (deepsea only), an overall positive effect is expected, driven by significant CAPEX reduction (e.g. savings of €1.1 million - €2.6 million per shore power zone, as discussed earlier), with acceptable downsides on other aspects. The optimal shore power system configuration in this example is seven shore power zones for scenario 1 and six shore power zones for scenario 2.

The vessel mix has a strong impact on the outcome of the analysis, and this underlines the importance of assessing each terminal separately, including the relevant boundary conditions and management preferences for weighing how important each aspect is.

CRITERIA	VESSEL MIX SCENARIO								
	SCENARIO 1: 16 deepsea vessels + 14 feeders per week					**SCENARIO 2:** only deepsea vessels (22 per week)			
	5 zones	6 zones	7 zones	8 zones (Base case)	10 zones	5 zones	6 zones	7 zones	8 zones (Base case)
CAPEX REDUCTION (for electrical infrastructure)	+6	+4	+2	0	-4	+6	+4	+2	0
OPEX REDUCTION (for electrical infrastructure)	+3	+2	+1	0	-2	+3	+2	+1	0
VESSEL'S SERVICE LEVEL (resulting in bigger vessel's waiting time and increased related costs)	-6	-3	-1	0	0	-2	0	0	0
FLEXIBILITY FOR VESSEL BERTHING AND **REDUNDANCY** IN CASE OF SHORE POWER ZONE MALFUNCTION	-5	-3	-1	0	+1	-3	-1	0	0
TOTAL	-1	0	1	0	-5	+4	+5	+3	0

CONCLUSIONS

This paper presents a novel approach for optimising the configuration of shore power systems in container terminals by using berth simulations. The study demonstrates that the number and design capacity of shore power zones can be reduced by predicting the vessel berthing patterns and demand for shore power connections along the quay, resulting in significant cost savings in electrical infrastructure (as large as €1.1 million - €2.6 million per shore power zone). The study also proposes a multi-criteria analysis framework to evaluate the trade-offs between different shore power system configurations, considering various technical, operational, and commercial aspects. The study also shows that the optimal number of shore power zones depends on the terminal's specific characteristics and preferences.

The tooling developed by Portwise and Royal HaskoningDHV for "Optimising shore power through berth simulations" can effectively be used for studying and determining the optimum shore power system configuration.

TABLE 2. Example Multi-Criteria Analysis of shore power zones optimisation

"THE NUMBER AND DESIGN CAPACITY OF SHORE POWER ZONES CAN BE REDUCED BY PREDICTING THE VESSEL BERTHING PATTERNS AND DEMAND FOR SHORE POWER CONNECTIONS ALONG THE QUAY, RESULTING IN SIGNIFICANT COST SAVINGS IN ELECTRICAL INFRASTRUCTURE ."

ABOUT THE AUTHORS:

Jan Kees Krom is a skilled and experienced container terminal planner and project manager. During the last 11 years, he has successfully worked on complex multi-disciplinary projects, leveraging his expertise in container terminal planning, equipment selection, automation, and simulation. He is a member of PIANC Working Group 208: "Planning for Automation of Container Terminals".

Pim van Leeuwen is a consultant and project manager at Portwise. For the past five years, he has designed, analysed and simulated container terminals, bulk terminals, and warehouses. Pim is a PhD candidate at Erasmus University Rotterdam, specialising in optimisation for marine logistics.

ABOUT THE COMPANIES:

Portwise, formerly part of TBA Group, is a world-leading consultancy and simulation firm that combines extensive automation and operational knowledge with proven simulation tools to create a future-proof plan for port, terminal or warehouse operations.

Royal HaskoningDHV is a global leader in maritime consultancy, design, and engineering. With more than 140 years of experience, they optimise marine facilities globally, offering master planning, digital design, and construction services. Their goal of "Enhancing Society Together" drives sustainable, efficient, and connected maritime solutions.

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