

## SUPPLEMENTAL DATA

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# Design and Construction Risks for a Shipping Port and Container Terminal: Case Study

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**Table S1.** Shipping Port and Container Terminal: Specific Design and Construction risks

Level 1 & Level 2	Level 3: Risk category	Level 4: Individual risks
Breakwater: Design risks	Specification compliance	<ul style="list-style-type: none"> <li>• Additional design measures required to treat long wave action</li> <li>• Concrete Armour Unit specification compliance</li> <li>• Severe long-term beach erosion due to port layout and design</li> </ul>
	Completion delays	<ul style="list-style-type: none"> <li>• Delayed geotechnical and bathymetric surveys</li> </ul>
Breakwater: Construction risks	Placement of rock by split barges, trucks, cranes	<ul style="list-style-type: none"> <li>• Delays during construction of beach crossing</li> <li>• Deterioration of armour stone rock during handling</li> <li>• Excessive loss of material during rock placement</li> <li>• Traffic congestion on breakwater</li> <li>• Rock loading onto split barges bottlenecks</li> <li>• Rock placing delays by cranes on breakwater</li> <li>• Temporary jetty out of operation (weather / maintenance issues / damages by vessels)</li> <li>• Offshore barge working problems and delays</li> </ul>
	Concrete armour units	<ul style="list-style-type: none"> <li>• Concrete Armour Unit production delays</li> <li>• Concrete Armour Unit placement delays</li> </ul>
	Natural environment	<ul style="list-style-type: none"> <li>• Overtopping of breakwater during construction</li> <li>• Rock core damaged / exposed after severe storms</li> <li>• Insurance claims not paid due to concrete armour units not in place to protect breakwater</li> <li>• Settlement of the breakwater requiring more rock</li> <li>• Sea bed changes during construction (siltation)</li> </ul>
Health, Safety and Environment		<p>Marine operational risks:</p> <ul style="list-style-type: none"> <li>• Fire at sea</li> <li>• Wildlife - sharks</li> <li>• Vessel collision incidents</li> <li>• Damage of dredger and other vessels during storms</li> <li>• Vessels grounding</li> <li>• Storm warning procedure not in place</li> <li>• Safe human accessibility of marine plant</li> </ul>

Reclaimed land: Design risks	Site conditions	<ul style="list-style-type: none"> <li>Existing shoreline / underestimation of work to prepare the project site</li> </ul>
Reclaimed land: Construction risks	Dredging of reclaim material	<ul style="list-style-type: none"> <li>Dredging permitting and approval delays</li> <li>Dredging starts late (dredger not available)</li> <li>Dredger production rates lower than expected</li> <li>Sand Borrow royalties exceeding budget</li> <li>Sand location further than planned</li> <li>Heritage finds under water</li> <li>Damages to existing underwater pipelines and communication cables</li> <li>Disruption of commercial shipping lanes by dredging activities</li> </ul>
	Discharge or reclaimed material	<ul style="list-style-type: none"> <li>Bund wall collapsing</li> <li>Bund weir overflow</li> </ul>
	Health, Safety and Environment	<ul style="list-style-type: none"> <li>Turbidity caused by dredging exceeding approval limits</li> <li>Dredger damaged by debris/wrecks</li> </ul>
Entrance canal & basin: Design risks	Design	<ul style="list-style-type: none"> <li>Dredging depth disagreement</li> <li>Dredging volume uncertainty</li> <li>Navigational aid specifications unclear / late</li> </ul>
Entrance canal & basin: Construction risks	Dredging of sand and rock	<ul style="list-style-type: none"> <li>Over dredging (outside specification)</li> <li>Cutter Suction dredger required and not available</li> </ul>
	Natural environment	<ul style="list-style-type: none"> <li>Seabed changes (siltation)</li> <li>Harder rock which require underwater blasting</li> </ul>
Quay wall: Design risks	Design	<ul style="list-style-type: none"> <li>Stability in design / Movement of quay wall</li> <li>Sea bed changes requiring design changes</li> <li>Efficiency of concrete plug between caissons</li> </ul>
Quay wall: Construction risks	Fabrication of caissons	<ul style="list-style-type: none"> <li>Late start of casting of caissons</li> <li>Suitability of ordered caisson formwork</li> <li>Caisson concrete mix design confirmation delays</li> <li>Caisson casting quality</li> <li>Caisson production rates</li> </ul>
	Dredging and preparation of the quay wall trench	<ul style="list-style-type: none"> <li>Trench levelling machine late</li> <li>Trench tamping &amp; levelling quality problems</li> <li>Dredging of quay wall trench starts late</li> <li>Dredging of quay wall trench taking longer than planned</li> </ul>

	Placement of caissons	<ul style="list-style-type: none"> <li>• Caissons semi-submersible barge not on site in time</li> <li>• Caisson semi-submersible barge stability during loading</li> <li>• Quay trench filled by sand from reclamation activities</li> <li>• Caisson loading delays onto semi-submersible barge</li> <li>• Caissons abortive work / placed caisson needs to be re-positioned</li> <li>• Caisson placement delays at sea (wave action / inclement weather)</li> <li>• Caisson settlement and displacement</li> <li>• Caisson backfilling quality</li> <li>• Quay wall stability after dredging</li> <li>• Late completion of break water</li> </ul>
	Geotextile	<ul style="list-style-type: none"> <li>• Backfill geotextile specification and placement method</li> <li>• Damages to geotextile during piling</li> </ul>
	Capping beam	<ul style="list-style-type: none"> <li>• Position of cast-in items</li> </ul>
	Health, Safety and Environment	<ul style="list-style-type: none"> <li>• Caisson crane accidents</li> <li>• Safety supervision during moving of caissons</li> </ul> <p>Additional marine risk:</p> <ul style="list-style-type: none"> <li>• Ship-to-shore crane delivery ship draught too deep</li> </ul>
Container yard and buildings: Design risks	Scope definition	<ul style="list-style-type: none"> <li>• Container terminal design assumptions</li> <li>• Late design changes by client and port authorities</li> <li>• Military / coast guard requirements and approvals</li> </ul>
	Design interfaces	<ul style="list-style-type: none"> <li>• Pavement storm water pipe alignment with quay wall design</li> <li>• Rear crane beam / Services alignment</li> <li>• Ship to shore crane power supply turnover pits alignment</li> </ul>
Container yard and buildings: Construction risks	Commissioning and operational readiness	<ul style="list-style-type: none"> <li>• Ship-to-shore cranes late</li> <li>• Construction and container traffic interaction during commissioning (port will go-live when construction is not complete)</li> </ul>