

The Effect of Ultra Large Container Vessels on Cranes and Infrastructure

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Erik Soderberg is Liftech's president and a structural engineer with 22 years of experience in the design, review, and modification of a variety of structural and crane related systems including over a hundred container cranes, over a dozen bulk loader structures, and over two dozen wharves. Other structures include crane lift and transfer systems and concrete and steel floats.

Liftech Consultants Inc. is a consulting engineering firm, founded in 1964, with special expertise in the design of complex marine structures. Our experience includes structural design for wharves and wharf structures, heavy lift structures, buildings, container yard structures, and container handling equipment. Our national and international clients include owners, engineers, operators, manufacturers, and riggers.

This presentation provides an overview of some effects of ultra large container vessels (ULCVs or vessels) on existing STS cranes and wharf infrastructure. Costs presented in this presentation are estimates of construction costs based on recent projects and do not include other costs. Actual costs will vary.

Overview

Section 1: Vessel Changes

Section 2: STS Crane Requirements

Section 3: Infrastructure Requirements

Section 1: Vessel Changes

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Ultra Large Container Vessels



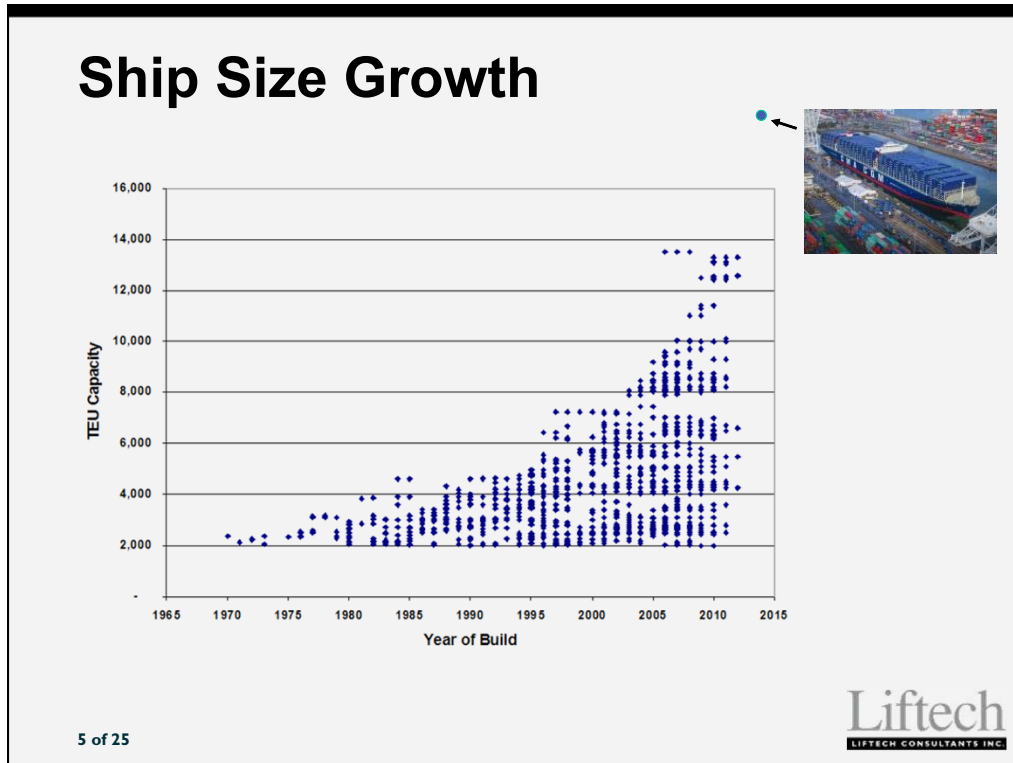
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CMA CGM Benjamin Franklin at Port of Long Beach

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4 of 25

Vessels with capacities nearing 20,000 TEU have arrived and more are on the way. Many operators and ports are asking how these vessels will affect their STS cranes and wharves. These vessels will typically affect existing STS cranes and infrastructure.



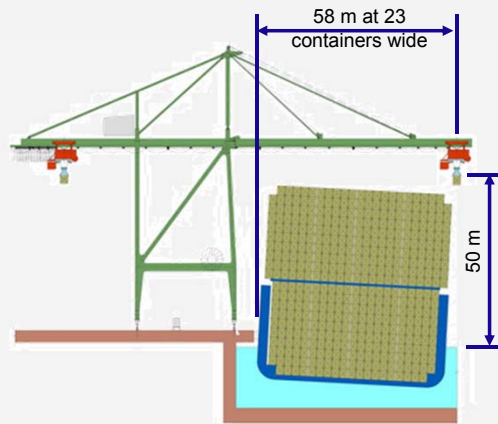
This is a graph of container ship sizes and the year the ships were built.

Ship sizes have recently grown more rapidly than expected.

Section 2: STS Crane Requirements

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ULCV Crane Requirements



Notes:

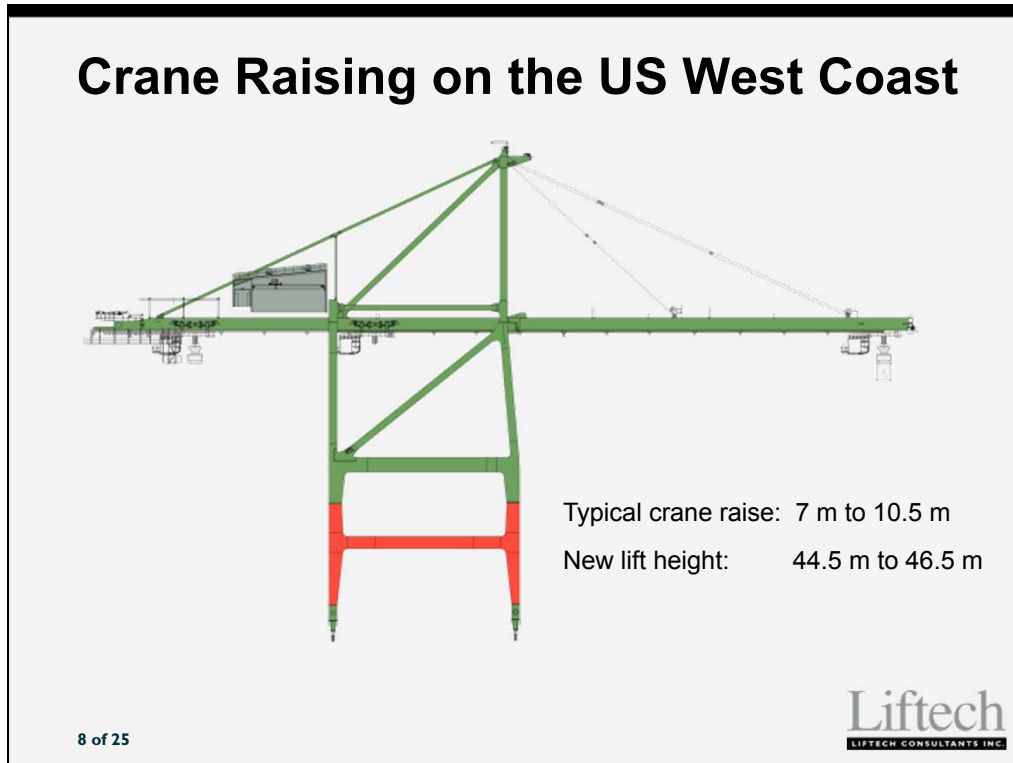
1. Outreach based on 1 degree list and 1 m trolley overrun.
2. Lift dimensions depend on operations; amounts shown are approximate. Dimensions shown are based on: 8.5' tall top box with 1' clear, 1 degree list, and 12.5 m of draft.

7 of 25

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For a 3 m crane rail setback from the face of the fender, the outreach required is about 61 m.

For a crane rail elevation 3 m above the design high water, the lift height is about 47 meters.



For these scheduled raises, we have seen up to 10.5 m raises to bring the lift height up to about 46.5 m.

The raise height is typically limited by the infrastructure:

- Crane girder structure capacity

- Pile capacity – typically limited by soil capacity

Crane Raise with Jacking Frames



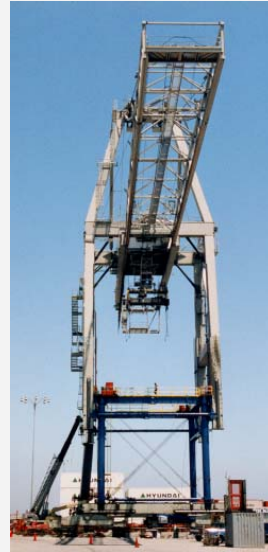
9 of 25

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There are now many raise systems facilitating the modification of existing cranes.

Crane Modifications - Some Considerations

1. Design ship
2. Stability, ballast, and wheel loading/girder capacity
3. Construction impact to terminal operations
4. Electrical system upgrade?
5. Seismic upgrade?
6. Main hoist drum - rope capacity
7. Boom hoist lift capacity
8. Other – see speaker notes



10 of 25

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For the design ship, the decision is whether to design for an imminent larger ship or an even larger unknown future ship.

The crane wheel loads should be calculated to determine if the existing girder rated capacity will be adequate, or if a girder capacity study should be initiated to determine if strengthening will be required.

The terminal operator will want to know how the modification work will interfere with operations. Typically, modifications can be limited to a portion of the terminal by rearranging cranes during modifications.

The electrical system should be evaluated. Systems more than ten years old are often upgraded.

Incorporating seismic upgrades into the modifications, particularly for older cranes designed to more lenient criteria, is often worthwhile as the modifications are mostly limited to the portal frame of the crane, which will be modified in the raise.

Other considerations:

Boom extension:

1. Fatigue reliability
2. Method: Extend girder or local modifications to trolley, stops, and end platform
3. Tie-downs & stowage socket capacity
4. Gantry drives & brakes

Crane raise:

1. Tie-downs & stowage socket capacity
2. Gantry drives & brakes
3. Platforms, stairs, and ladders
4. Elevator
5. Lighting levels after raise
6. Service hoist
7. Limit switches and software
8. Spreader cable reel capacity
9. Cable reel – increase or maintain cable distance

Cost to Modify Existing Cranes

Cost can vary significantly depending on:

- Scope of structural modifications

- Location and local labor

- Scope of mechanical and electrical modifications such as rope drums, trolley cable reel, machinery house service cranes, cabling, lighting, access ways, new wire rope, etc.

Estimated cost per crane for short raise with low labor cost – around US\$1.5M

Estimated cost per crane for tall raise with boom extension and high labor cost - US\$4-5M

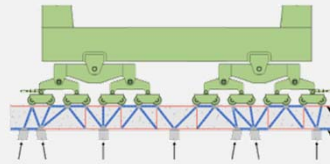
11 of 25

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Costs to modify existing cranes vary significantly depending on the scope of modifications; location and local labor; and to a lesser degree the associated mechanical, electrical, and other modifications, such as to rope drums, trolley cable reel, machinery house service cranes, cabling, lighting, access ways, new wire rope, etc.

Estimated costs per crane vary from about US\$1.5 million for a short raise with low labor cost to about US\$4.5 million for a tall raise with a boom extension and high labor cost.

Section 3: Infrastructure



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Berth Space

ULCV lengths are not much longer than the previous generation.

Some berths require additional length – a costly option.

Less costly – install more compact crane stops closer to wharf end; add a mooring dolphin beyond the wharf (*see next slide*).



13 of 25

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Today's ULCV lengths are not much longer than those of the previous generation. However, some existing berths still require additional length—a costly option. A less costly option, if practical, is to add a mooring dolphin beyond the wharf so the vessel can be located closer to the end of the wharf.

Some additional STS crane travel length on the wharf can usually be obtained with relatively little cost by installing more compact crane stops and relocating stops closer to the end of the wharf.

Mooring Dolphin

Add a mooring dolphin beyond the wharf so the vessel can be located closer to the end of the wharf.



Mooring Dolphin at IMTT Port of Richmond

14 of 25

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Mooring dolphin at IMTT Port of Richmond.

Berthing Fenders

UCLV berthing velocities and angles are typically much less than those in traditional design guidelines.



Consider recent data when determining berthing energies.

A cost-benefit analysis may justify the acceptance of existing systems.

15 of 25

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Fender energy required for vessel berthing is primarily influenced by vessel approach velocity perpendicular to the wharf and vessel mass. Current ULCV displacements are significantly more than the design mass used for many existing fender systems; however, the approach velocity for the ULCVs is less, reducing the increase in required energy. It is often practical to continue using existing fender systems with acceptable risk of damage to the fender system, wharf, and vessel structure, but with a plan to replace the existing systems with higher energy systems if damage does occur. The cost of replacing the current fender system is usually not justified by the cost of improbable future damage.

Berthing data for the larger ships indicate that the berthing velocity and angles are significantly less than recommended in design guidelines for smaller ships. Additionally, contacting only a single fender is significantly less probable than for smaller vessels.

If replacing fender systems, if practical, we suggest replacing with deeper fenders to limit the fender reaction on the wharf and vessel structures. If larger fender reactions result, confirm that the wharf structure is adequate. Typically, only local strengthening of the wharf is required, at a moderate cost.

Bollards

Increased mooring forces may require higher-capacity bollards. Installing higher-capacity bollards requires relatively little cost unless the wharf structure needs strengthening.



Consider site-specific wind speeds and directions when determining required bollard capacities.

16 of 25

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The wind area of today's loaded ULCV is significantly more than that of the original design ship used for most existing mooring systems. Forces of up to 250 t per bollard can occur for common design winds and mooring line arrangements (t = metric tonne). Additionally, ship captains may have concerns about relying on older, lower capacity bollards and can decide they are not willing to moor their ship to a particular system.

Consider site-specific wind speeds and directions based on historical data when determining required bollard capacities, as these may justify significantly lower loads.

New bollards with increased capacity are relatively inexpensive. Strengthening the wharf locally is costly, with costs varying significantly depending on the existing structure. An economical strengthening approach that has worked on several older wharves consists of drilling holes into the wharf structure and installing grouted high-strength reinforcing.

Arrangement and Bitt Loading



17 of 25

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Consider potential mooring line arrangements. Be aware that actual arrangements may differ from ideal.

Also be aware that for double bitt bollards, the bitt load rating is half that of the bollard, e.g., a 200 t double bitt bollard will have a bitt rated load capacity of 100 t.

Wheel Loads

Wheel loads may exceed the design or rated capacity of existing wharf girders.

Options to address excessive crane loads include:

- Optimize crane design

- Analyze or load test structure & foundation (*see next slide*)

- Strengthen existing girders

- Replace girder systems with new, stronger systems

- Increase crane rail gage for new cranes

18 of 25

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STS cranes suitable for up to 23-wide vessels typically have larger wheel loads than existing cranes procured for smaller design vessels. Wheel loads may exceed the design or rated capacity of existing wharf girders. Options to address excessive crane loads include:

- Optimizing the crane design to reduce crane reactions and better suit the distribution between available landside and waterside girder capacities

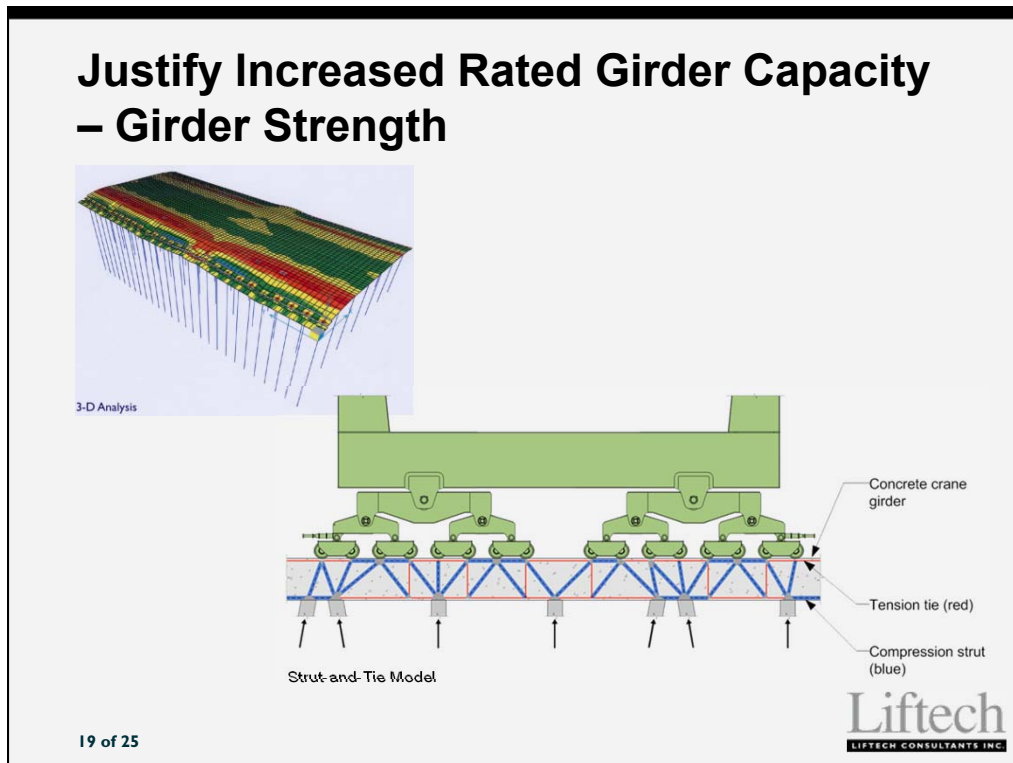
- Analyzing or load testing the existing structure and foundation to justify increasing the rated capacity

- Strengthening the existing girders

- Replacing girder systems with new, stronger systems

- Consider increasing the crane rail gage for new cranes, as this can reduce wheel loads and will permit additional truck lanes for operations

Optimizing a new crane design or a crane modification design will reduce wheel loads some, but there are limits. Typically, this option is only worthwhile if the existing crane wheel loads are not significantly greater than the girder's rated capacity.



We have evaluated many existing wharves. In most cases, the rated girder capacities can be increased by using more modern analysis methods.

Finite element analyses are particularly worthwhile when the girder is integrated into a deck or have cross beams that permit load distribution.

Strut-and-tie analysis is worthwhile when the shear strength calculated using more conventional methods is inadequate.

Other methods are available.

The engineering costs to evaluate an existing girder structure are typically a fraction of strengthening costs, and some of the engineering effort can be applied to the strengthening design if needed.

A feasibility study by a structural engineer is a good first step to decide if this approach is practical. Feasibility study costs will vary, but are typically less than US\$30,000. If feasible, studies to justify additional capacity, typically involving one or more types of analyses, are often US\$50,000 to US\$100,000 and are usually successful.

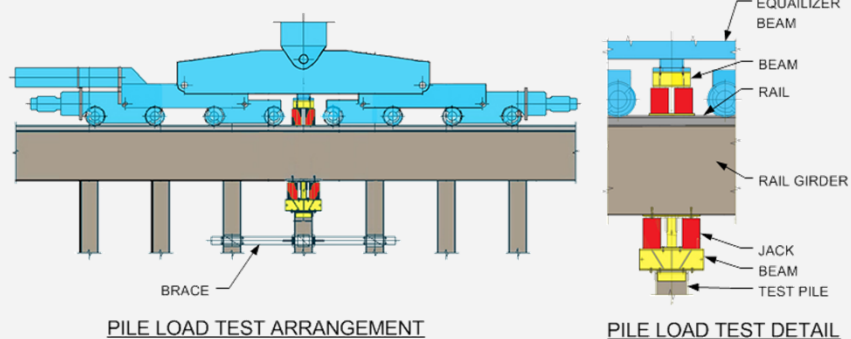
Strengthening or replacing a wharf girder will require significant costs and often requiring new piling. If this is required, and in particular if new cranes will be procured, building a new landside girder and procuring larger gage cranes can limit girder construction costs, reduce crane wheel loads, and increase the truck lane space between the crane legs.

Justify Increased Rated Girder Capacity – Piling Capacity

Analyze pile driving records

Pile dynamic analysis through testing

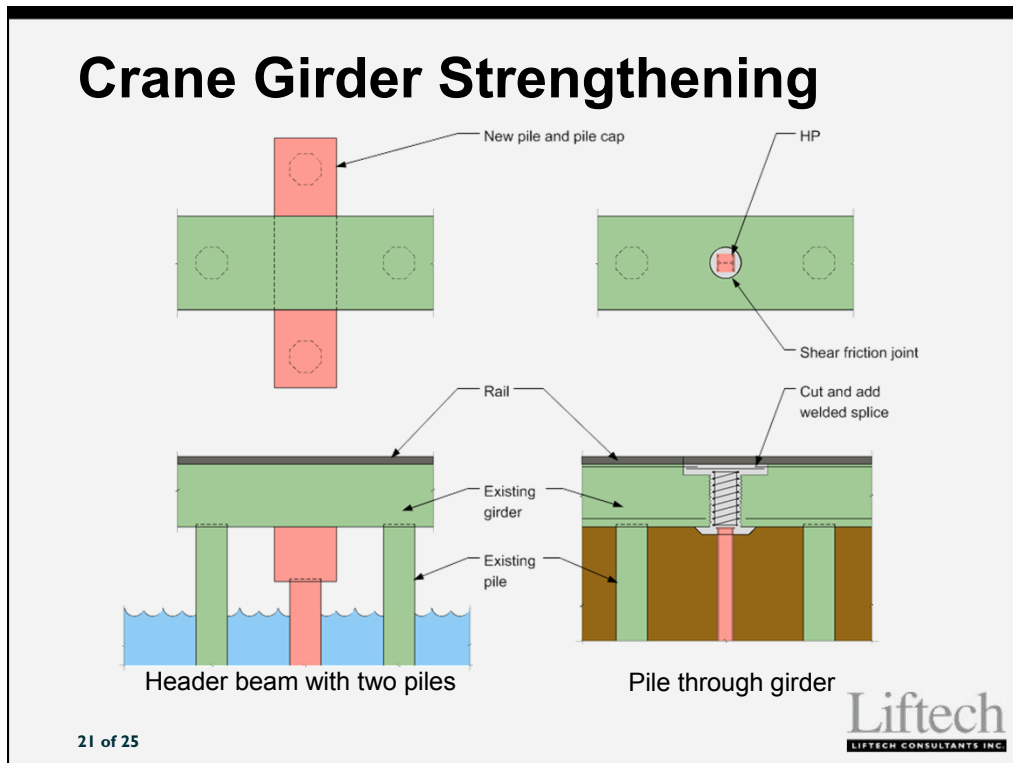
Load test



20 of 25

Pile driving records may justify greater loads. When we analyze the girder, we usually increase the allowable pile load by averaging the capacity of five or more piles.

The pile capacity can be determined by breaking the pile from the girder and performing a load test by jacking against the girder or performing a CAPWAP test.



Crane girder strengthening can be accomplished in many ways. A common method is to drive piles on either side of the girder and install a header beam between them.

Liftech has two current projects where we are considering coring a hole through the girder, installing an H-pile, roughening the cored wall of the girder, and connecting the load from the girder to the pile with shear friction. The substantial longitudinal girder reinforcing will provide the required confinement forces. A similar approach has been successfully used in the offshore oil industry with grouting between the platform leg jacket and the leg.

Summary

ULCVs affect STS cranes and wharf infrastructure.

STS crane outreach 23 containers wide, 58 m from fender face.

STS crane lift height above high water about 50 m.

Increased vessel lengths are limited but may be significant.

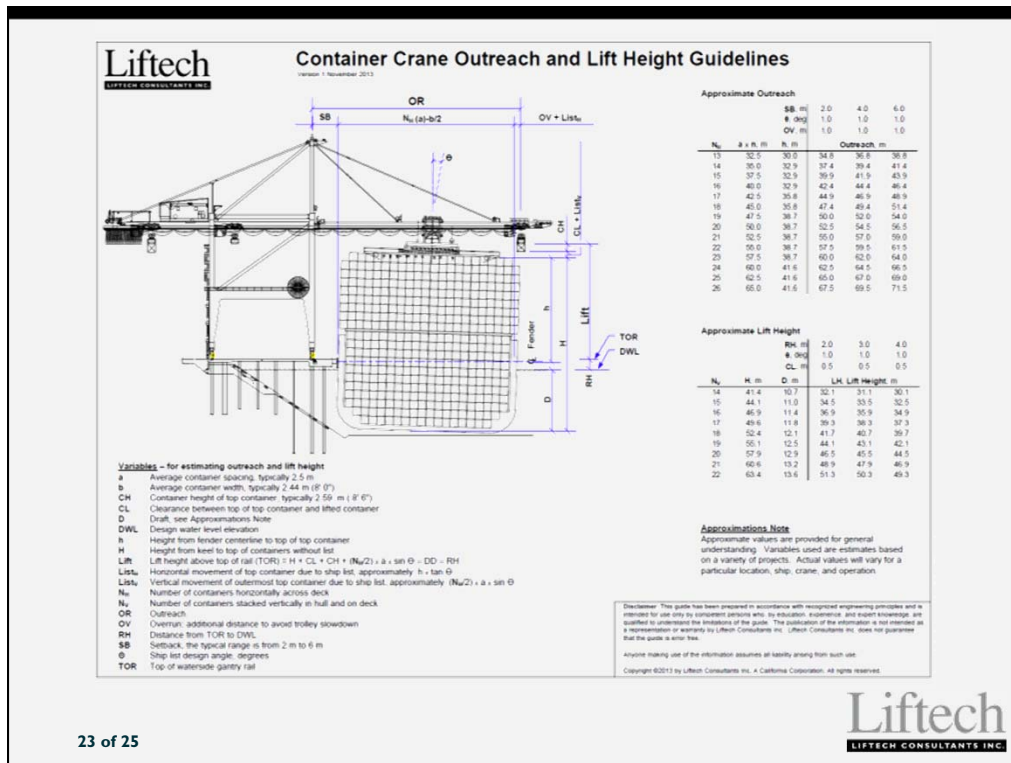
Consider low-cost modifications, such as new and relocated crane stops and mooring dolphins beyond wharf end.

Fenders for smaller 12,000 TEU-range vessels may be adequate.

Increased mooring forces may require larger bollards. Costs are limited unless wharf strengthening is required.

Consider performing a crane girder study to justify additional capacity before strengthening or replacing.

Consider performing a study to determine your terminal requirements and the most cost effective approaches.



23 of 25

The presented handout provides some guidance on outreach and lift height and was developed to supplement this presentation. It is available on our website.

Thank You

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