Liftech

LIFTECH CONSULTANTS INC.

SUPER PRODUCTIVE CRANES

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INTRODUCTION

Super productive quay container cranes come in many forms: Panamax, post-Panamax, machinery on trolley, rope towed trolley, single hoist, and dual hoist plus the new ideas: rubber tired cranes, elevating girder cranes, dockside bridge cranes, and the Paceco Supertainer®. The productivity varies. Based on ideal conditions, the calculated production of advanced quay cranes is sixty-seven moves per hour while loading and unloading a sixteen-container-wide post-Panamax ship. The yard cannot keep up with the cranes. In actual, less than ideal conditions, maximum production realized is limited to about forty moves per hour.

One reason that the calculated crane production is so much higher than the real production is that the calculations are based on the assumption that a chassis, strad, or AGV will always be ready to service the crane. Of course, this doesn't happen. The crane often waits for service. Effective crane design requires the designer to understand that the cranes are part of the terminal system. The best design will produce a crane that fits into the system rather than one with a calculated high productivity assuming the crane will never wait for service. The crane should mesh with the system.

One approach to solving the integration problem is to design the entire system to work like a giant materials-handling machine. Some rather ingenious totally integrated machine systems have been proposed. In the 1960's, a Paceco\Kaiser Industries team developed a system of storage racks serviced by bridge cranes. The Robotics Container Handling Company's "machine" uses transporters and a rack storage system. The Reggiane Octopus™ is yet another machine. Totally integrated systems produce a continuous flow of containers that, in theory, greatly increase throughput. A major disadvantage to a giant machine, however, is that all of the components must work in unison. If one component fails, the system fails. If one component is delayed, the whole system is delayed. And flexibility is lost; continuous systems can only be used for the market and system envisioned. Even though

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there are significant disadvantages to such expensive machines, a sophisticated continuous system will someday be the best choice to service a few specialized markets.

But what will happen in the meantime when service to the quay is improved? What crane will be suitable then? The traditional segmented systems will be improved and refined. This paper presents some ideas and comments about the improvements that could be made to conventional quay cranes used in a segmented system. Tables of component weights and quay crane loads are included.

TAKE A SECOND LOOK

Since many quay cranes exist, we are tempted to make cranes bigger and more powerful without making fundamental changes. We could overcome the temptation by ignoring what we have now and starting over with a blank sheet of paper. Or we could look at what we have now, and instead of making bigger and more powerful cranes, make some significant improvements. The latter approach is taken in this paper.

The typical quay crane includes one main hoist with the hoist machinery on the trolley or with the hoist on the frame. The trolley may be rope towed or driven. Power is transmitted to the trolley through a festoon system or collectors. These typical cranes make up the overwhelming majority of cranes, and this will continue for many years. (Figure 1 and Figure 2)

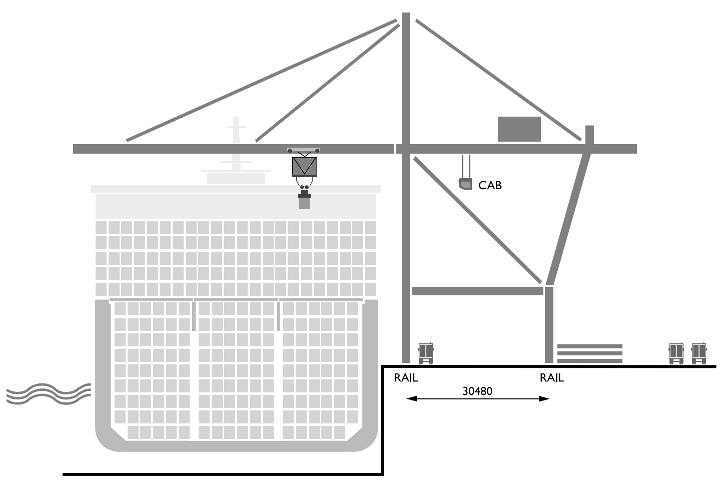

Figure 1: Conventional 22 wide

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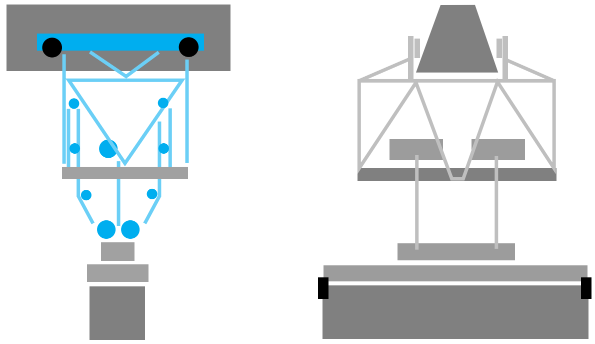

Figure 2: Machinery trolley

Significant recent developments in crane design include sophisticated electronic load control systems, power transmission through an inductive current loop, and wave-guides in place of fiber optics. Rapidly developing improvements in electronics and optical and acoustical equipment will reduce dwell times and increase productivity. But even with all the advancements, the real productivity of single hoist dockside cranes will be limited to 40 to 50 moves per hour because of service to the quay.

Eventually service to the quay will be improved. What then? What crane will be suitable?

FIRST, CONSIDER THE CRITERIA

The crane must be productive, economical, reliable, and maintainable, and the crane must integrate with the yard operation. A buffer, either in the yard or on the quay, must be available to even out the flow between the yard and the quay.

Economy requires reasonable initial and operating costs. The initial costs include the cost of the crane plus the infrastructure. The initial cost of the crane can be estimated by the dead weight, but only roughly, since the cost of a unit weight of machinery is several times the cost of a unit weight of structure. Even though the cost of the infrastructure varies considerably, the increased infrastructure cost due to a much heavier crane is usually not large compared to the initial and operating cost of the cranes. The operating costs include maintenance, labor, and the cost of delays due to down time.

A FEW SIMPLE CHANGES MAY HELP

CONSIDER 45720 MM GANTRY RAIL GAGE

What is the appropriate gantry rail gage: 15240, 24500, or 30480 mm? Why not 45720 mm?

If the gage is increased to 45720 mm, the waterside wheel loads are reduced for both operating and stowed conditions. Since an additional intermediate backstay reduces the weight of the trolley girder, the crane weight is only slightly increased. The wide gage crane is simpler and more stable. The sum of the maximum landside and waterside quay reactions decreases, since the moving load reactions decrease. (Figure 3)

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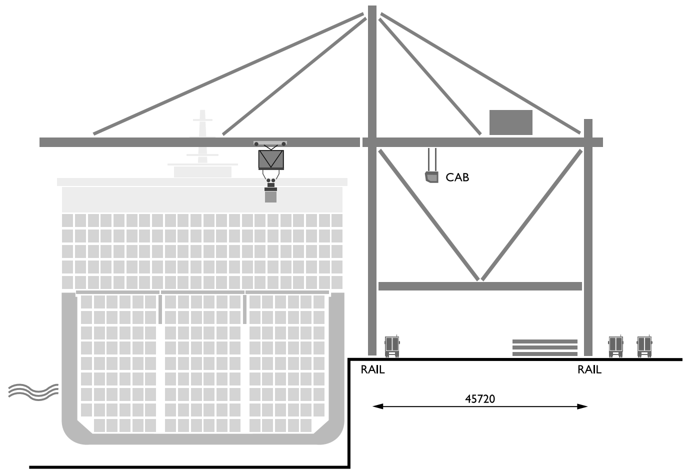

Figure 3: Conventional wide gage crane

The moving load reactions are decreased since:

Waterside rail load = Moving load × [Outreach from the waterside rail + Rail gage]/Rail gage

The landside rail load is:

Landside rail load = Moving load × [Backreach from the waterside rail]/ Rail gage

The wide gage container crane increases the size of the tunnel under a row of cranes. The yard space "lost" to the quay is not really lost. The space for the landside leg and the hatch covers is only rearranged.

Usually the space between the legs is used for container transfer vehicle traffic. One lane per crane is desirable. This provides room for the container transfer vehicles to queue up and provides a buffer between the yard and the crane. Hatch covers are stowed on the ship, crane, or quay. The simplest and most effective method is stacking the hatch covers on the quay landside of the quay traffic. Vehicles travel in the tunnel formed by the gantries and in traffic lanes landside of the hatch covers.

Increasing the gage is a minor improvement. Now consider the next step.

ELEVATE THE LANDSIDE GANTRY RAIL

Another improvement is to support the landside crane legs on an elevated rail girder. This allows traffic to leave the quay at any point between columns. (Figure 4)

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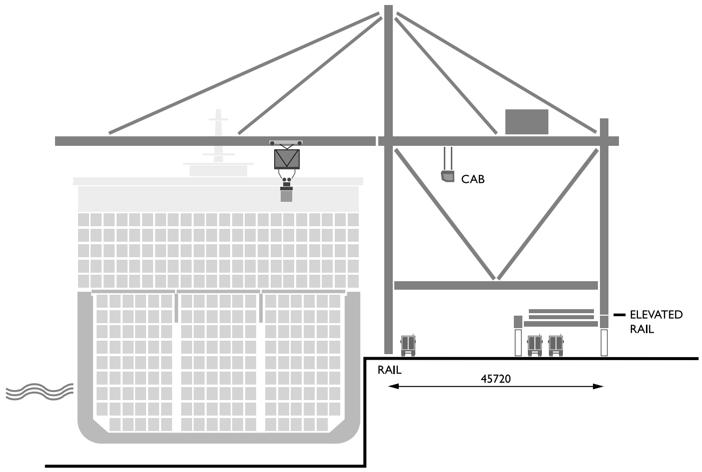

Figure 4: Wide gage with elevated rail

The elevated girder will increase the quay cost. But since the crane girder is required either way, the increase is small. The advantages of increased access to the yard and increased structural rigidity may justify the added cost. The structural rigidity is increased because the landside leg is shorter.

ELEVATE THE LANDSIDE PLATFORM

The hatch covers could be stowed on a raised platform. Since container traffic can travel under the platform, the yard area used by the landside traffic lane can be recovered. The increased useable yard area will offset the cost of the platform.

ELEVATE THE TRAFFIC LANES

Elevated landside traffic lanes can reduce the demand on the yard. In effect, the cranes will be serviced by two yards. If the traffic on the elevated lanes eventually goes to grade level, long ramps will be required. The elevated roadway concept is workable, if the traffic is directed to the yard on elevated roadways.

DOUBLE TROLLEYS

What if the productivity of a single hoist is not enough? Will a double trolley crane help?

Yes. We suggest that two trolleys operate on the same runway. The electronic, optical, and acoustical systems, which will eventually lead to a driverless crane, will provide control sufficient to keep the trolleys and the suspended loads from colliding without seriously increasing cycle time. (Figure 5)

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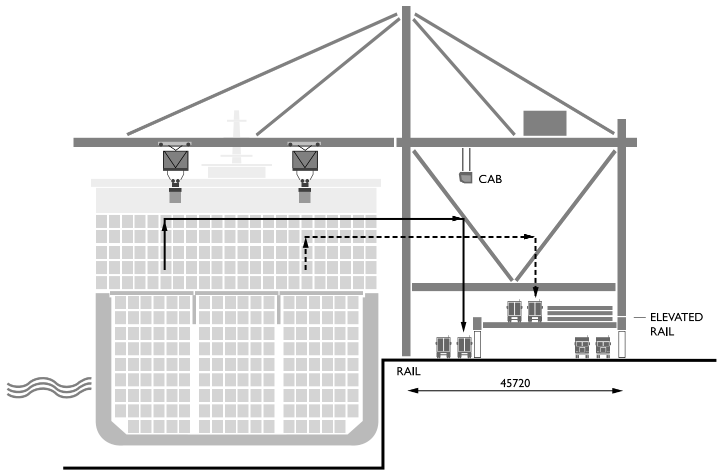

Figure 5: Double trolley crane

Interestingly, operating double trolleys is not an entirely new idea. The Ansaldo cranes at the Sea-Land Kaohsiung terminal are designed to carry two trolleys on a single runway.

One operator may be enough, if some automation is used. Two cabs and two operators may be needed. The operator's cab or cabs will be located off the trolley runway on independent rails. If two cabs are used, one can be on each side of the trolley runway girder. An independent cab runway is already being used successfully on the VIT dual hoist cranes. New cranes, including those at Port of Oakland, Virginia International Terminals, and American President Lines, are designed to carry the operator's cab on an independent runway when automation makes this desirable.

For double trolley operations, the landside trolley will transfer containers from the landside half of the ship to extreme landside lanes, and the waterside trolley will operate from the waterside half of the ship to the waterside lanes. Since a trolley should not carry a container over personnel, some of the transfer vehicles will need to wait for the waterside trolley to pass. This will reduce production, but not significantly. An elevated landside platform reduces the need for the transfer vehicles to wait for the landside trolley to pass.

One difficulty with two trolleys is load control and control of micro motions. For instance, if one trolley needs to move in the gantry direction, the other trolley should not be disturbed. This and other control problems require sophisticated load control systems on each trolley which will increase the weight of the trolley. Machinery trolleys with no special load control systems weigh 55 to 75 tons. If special load controls are added, the weight increase will be from 10 to 20 tons depending on the sophistication of the motions.

The quay loads will be increased, but not unreasonably. See the estimated weights section on page 8.

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Boom deflections could cause problems when two trolleys are operating simultaneously over the ship. The deflections can be significantly reduced - practically eliminated - by an active assist link like the one developed by Mitsubishi Heavy Industries and Liftech Consultants Inc. for the new PSA cranes.

The realistic productivity of the double trolley crane will be 45 to 70 moves per hour. New yard systems will be needed before double trolley cranes are practical.

THE ULTIMATE QUAY, FOR NOW

How many cranes can work effectively on one quay? The practical limit is six cranes servicing one ship on one quay. If the yard works well, traffic can get on and off the quay, and if the stow plan is just right, cranes could operate on alternate hatches.

What if this isn't productive enough? The ship could be serviced from both sides in a slip. This creates many problems but has some advantages. If berthing space is limited, the slip allows more ships per unit length of the quay envelope. The width of the slip plus the two quays is less than the length of the ship. With six double trolley cranes per side, less than the absolute maximum but more than is practical in a real operation, and each dual hoist crane producing 55 moves per hour, the productivity is 660 moves per hour total. This seems unrealistic now, but it could be done. If more cranes are used, the productivity gets higher. It's worth thinking about. (Figure 6 and Figure 7)

How wide should the berth be?

At least 60 meters. This will accommodate ships with 22 containers on deck. It would also allow two smaller vessels to use the slip. But with the overlapping booms, imagine the interference problems.

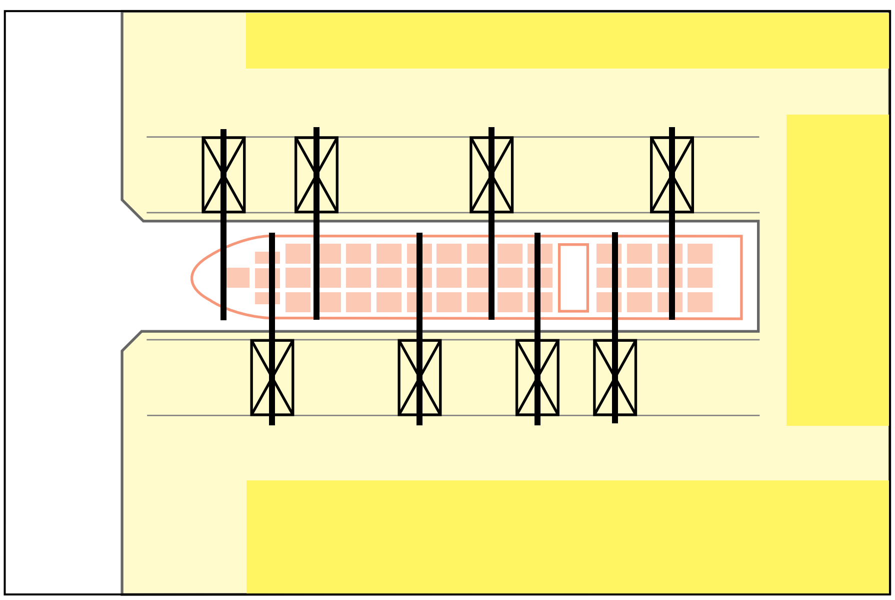

Figure 6: Slip plan

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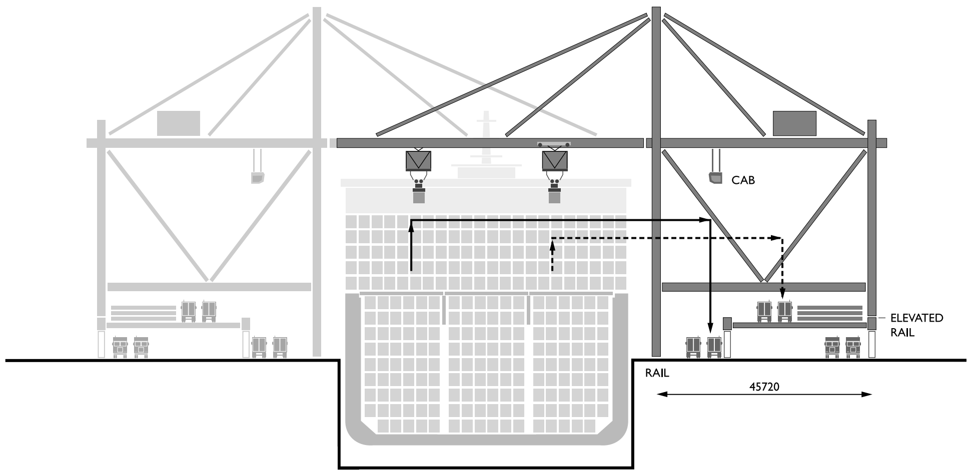

Figure 7: Slip with double trolleys

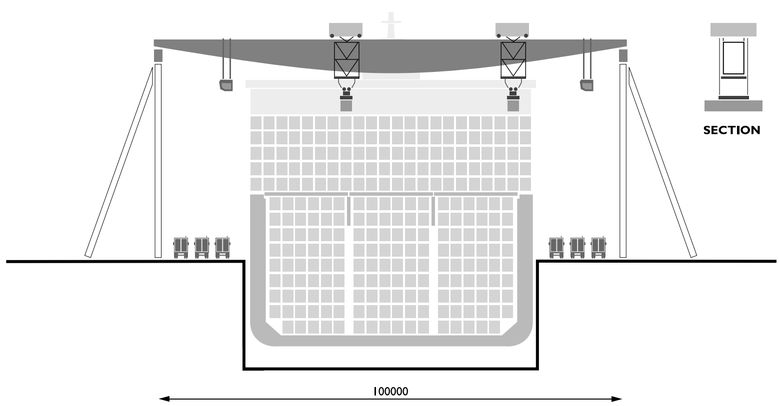

Figure 8: Slip with bridge crane

Would a bridge crane be better?

I think not. The bridge cranes would span 100 meters at least. And this doesn't consider where to store the hatch covers. The runways will be costly. The greatest disadvantage would be that the cranes could not pass the ship superstructure or each other. (Figure 8)

ESTIMATED WEIGHTS

The weights in the tables are based on some recent Liftech Consultants Inc. projects. The magnitudes are reasonable but will vary, depending on the site requirements. The crane weights are for monogirder cranes, which are somewhat lighter than twin girder cranes with the same performance.

The weights are for cranes with usual stiffness. If increased stiffness is needed, the weights will increase.

Notice the improvement in the gantry rail loads with the increased gage. The

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increased gage does not increase the overall crane weight significantly if an intermediate landside backstay is used. The stay reduces the moment in the girder, so the stay weight is balanced by the reduced girder weight.

TROLLEY AND MACHINERY WEIGHTS		
	ROPE TROLLEY Hoist on Frame	MACHINERY TROLLEY Hoist on Trolley
WEIGHT OF THE MAIN HOIST COMPONENTS ON THE FRAME, METRIC TONS		
	MAIN HOIST AND ELECTRICAL EQUIPMENT	ELECTRICAL EQUIPMENT
	40	10
WEIGHTS ON THE TROLLEY – MOVING LOAD, METRIC TONS		
Trolley Weight	15	55 to 75
Lift System: Lift Beam Plus 20/40 Spreader	17	17
Lifted Load	41	41
TOTAL MOVING LOAD WITHOUT IMPACT	73	113 to 133

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TYPICAL MACHINERY TROLLEY CRANE WEIGHTS AND RAIL LOADS				
	SINGLE TROLLEY		**DOUBLE TROLLEY**	
RAIL GAGE, MM	**30480**	**45720**	**30480**	**45720**
Component	**Weight, metric tons**			
Upper Works	38	50	57	75
Trolley Girder	160	160	220	220
Boom and Stays	147	147	220	220
Machinery House	95	95	95	95
Landside O Frame, Total	232	232	232	232
Waterside O Frame, Total	228	228	228	228
Portal Tie, Lower Diagonal, and Miscellaneous	200	230	200	230
TOTAL WEIGHT WITHOUT TROLLEYS	**1100**	**1142**	**1252**	**1300**
Landside Trolley, Loaded, Moving Load	123	123	123	123
Waterside Trolley, Loaded, Moving load			123	123
MAXIMUM LANDSIDE RAIL LOAD, DEAD LOAD PLUS MOVING LOAD	**575**	**540**	**560**	**525**
MAXIMUM WATERSIDE RAIL LOAD, DEAD LOAD PLUS MOVING LOAD	**1020**	**980**	**1425**	**1335**

Notes:
Loads are working loads without load factors.
Inertia loads are not included.
For the double trolley cranes, the relative positions of the trolleys are controlled.

Although 1345 tons is sizeable, it is practical. For example, the new quay at Massport for the Paceco Corp/Liftech Consultants Inc. low profile cranes can support this load.

CONCLUSION

We have introduced some approaches, ranging from modest changes to what today seems a bit of a dream. To get to where we are going, we must aim above the target, and then having thought of more than we need, we will better understand what we need.

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