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LIFTECH CONSULTANTS INC.

QUAY CRANE PRODUCTIVITY

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Quay crane productivity has always been one of the critical components of terminal productivity. But the crane is, of course, only one of the terminal elements that controls production. Now, however, with ten to twelve thousand TEU ships coming over the horizon, within the next decade crane productivity may become the limiting component of the terminal's production.

Photo 1: The First Quay Crane, Matson, 27.5 Ft Box, 70 Ft Outreach, 1958

Photo 2: Ship 17-Wide, 20-40-45-53 Ft Box, 6000 TEU, 2002

Ship Turnaround Time and Quay Production

Increased production is always desirable, but for large ships it is necessary. It will take nearly four days to service a 12,000 TEU ship exchanging 75 percent of its containers, using 6 cranes producing 30 lifts an hour. Increasing production to 55 moves an hour cuts the turnaround time to a little less than two days.

Table 1 shows some typical turnaround times for various vessels and crane lifts per hour.

Table 1
Vessel Turnaround Time vs. Lifts per Hour

Vessel Size TEU	6,000	8,000	10,000	12,000
Cranes	4.0	5.0	6.0	6.0
Lifts per Hour	Vessel Turnaround Time, Hours			
20	96	103	107	129
30	64	69	71	86
40	48	51	54	64
50	39	41	43	51
60	32	34	36	43
Parameters: 1.75 TEU per lift. Turnover 75%. Two eight hour shifts/day.				

Table 1 shows quay production. This paper, however, is about quay crane production. Now and forever, the crane's production will never exceed that of the quay. Both the quay and the cranes need attention. This paper discusses only the cranes.

Some improvements increase production incrementally, by five to twenty percent, other improvements make a quantum jump, by twenty-five to forty percent. Comments are presented to help you make estimates of expected quay crane production.

For simplicity, the cranes are discussed as an isolated entity without regard to the yard capabilities. The quay crane production numbers are based on the assumption, unrealistic today, that the yard can keep up with the quay crane. The crane numbers are calculated using Liftech Consultants Inc.'s crane simulation program CraneSim©, Figure 1. In most terminals today, the actual productivity is as low as 65 percent and as high as 80 percent of the computed number.

CraneSim computes the production of the isolated crane entity, assuming the quay operation is always able to

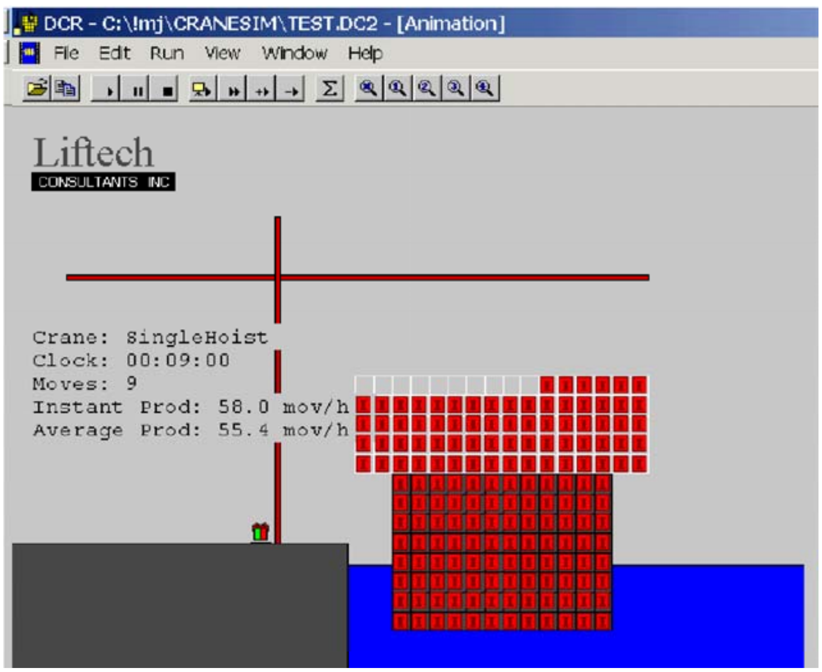
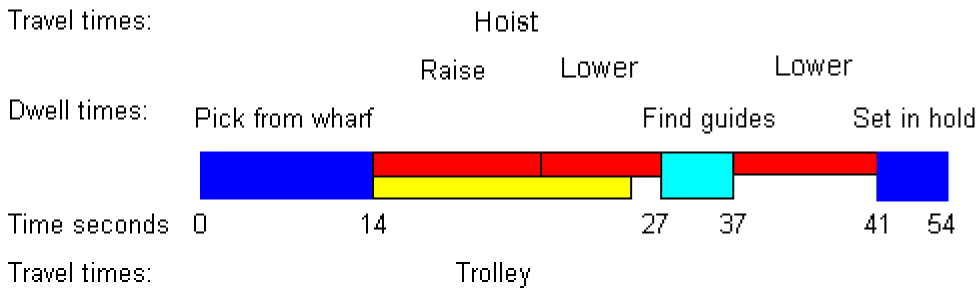


Figure 1: CraneSim©

deliver or remove a container when the crane needs the service. You can observe your operation, collect speeds and acceleration data, and, using CraneSim or hand calculations, make your own estimates of expected quay crane productivity.



Cycle time from the wharf to the inside the ship's hold. Notice the hoist and trolley times are parallel and the Dwell times are in series. The longer parallel time governs. The travel times vary. Depending on the location of the container the hoist or trolley time will govern.

Figure 2: An Example Half-cycle Timeline

CraneSim computations use random times for dwell times and calculated times for travel times. Figure 2 is presented for understanding the timeline but only represents a small portion of the simulated operation.

Where only an unloading cycle is discussed, the statements apply just as well to the loading cycle, and vice versa. The goal is to help the reader understand the issues.

Think seconds per move

We usually discuss production in terms of lifts per hour: frequency. To better evaluate production, we should think in the inverse, i.e. hours per move—or better yet, seconds per move, which is the reciprocal of the frequency, i.e. the period.

Table 2
Frequency vs. Period

Frequency:	Lifts/hour	30	45	60	75	90
Period:	Seconds/lift	120	80	60	48	40

Although the calculation is simple, Table 2 is presented to illustrate the difficulty in attempting to decrease period as the period decreases. Considering that dwell times, starting and stopping motions, finding spots on the vessel and quay, and checking clearances—whether automatically or manually—takes about 30 seconds, we can see that to achieve 40 seconds, only 10 seconds is available to actually move the load. Even a 48-second period leaves only 18 seconds to move the load. Notice, however, that this is nearly twice as long as for the 40-second case.

Conventional Cranes

For a conventional post-Panamax crane, such as the new Hanjin and SSA cranes in Oakland and Long Beach, and the Maersk cranes in Los Angeles, the computed average period while completely unloading a bay is 72 seconds. The actual period including yard and other normal delays will be about 140 percent of this, or 100 seconds (36 lifts per hour).

Photo 3: Port of Oakland Berth 57 Cranes, 213 Ft Outreach, 100 ton Cargo Beam, 2002

These periods would be much longer if hoist and trolley speeds and accelerations were not significantly increased. For some crane operators, the automatic trolley drive helps, but up to now, the primary emphasis to decrease period has been increased speeds and accelerations.

Production Improvements

Today, production has been improved by increasing speeds and accelerations. Further improvements will require some fundamental changes to the conventional quay crane.

Incremental Improvements

The following concepts improve production by 5 to 20 percent.

VPA VIT Elevating Girder Crane

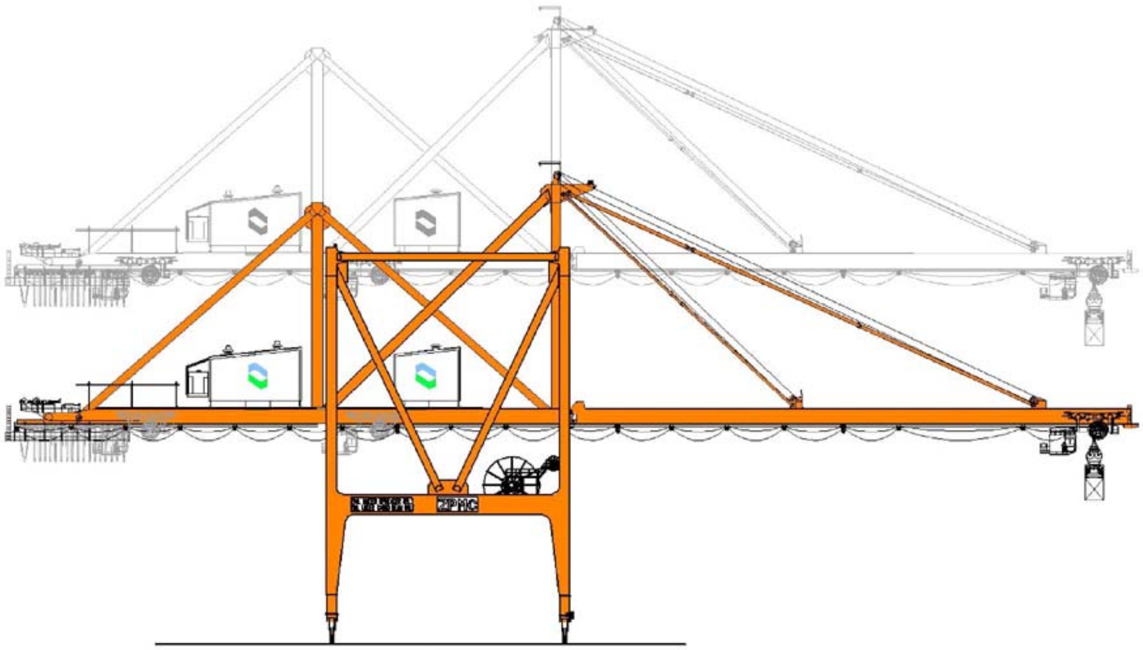


Figure 3: Elevating Girder Crane

The elevating girder crane is identical to the conventional quay crane with one notable exception. The upper works can be raised or lowered before vessel service operations begin. The upper works can be parked at five levels so the lift height is 20, 25, 30, 35, or 40 meters (65 to 130 feet) above the quay. This reduces the distance from the trolley to the spreader and improves load control. Production is increased about five percent for a 17-wide vessel and about twenty-one percent for barges.

The crane weighs and costs about twenty percent more than a conventional crane. Only one operator is needed. Additional maintenance is required for the upper works lifting and locking components.

Tandem Forties Spreader

Bromma and Maersk have been jointly developing a spreader capable of handling tandem forties. The spreader will pick two forty-foot containers in each lift. The spreader includes a side shift mechanism that balances the difference in container weights.

The spreader in development is not complete, so the cost and detailed specifications are not available. The spreader will increase production

Photo 4: Tandem Forties

for some operations, but until the development is completed, we will not be able to estimate the increased productivity.

Automation

Automation continues to evolve and will continue to improve productivity, although marginally. A detailed discussion of automation is beyond the scope of this paper.

Quantum Jump Improvements

The following concepts increase production by 25 to 40 percent.

Dual Hoist

Photo 5: VPA Dual Hoist Crane 1985

Photo 6: HHLA Dual Hoist Cranes 2002

Dual hoist cranes were developed in the 1980's, first by ECT Rotterdam, then by Virginia Port Authority and Maryland Port Authority. Although the cranes could actually produce 45 to 50 moves per hour, the yard could not keep up, so the system did not meet expectations.

Dual hoist cranes are heavy and expensive and require two operators and more maintenance. In practice, dual hoist cranes were not economic.

Today, dual hoist cranes may be making a comeback. One operator is needed on the ship trolley. The shore hoist may be fully automated using modern technology. The HHLA terminal in Hamburg, Germany purchased dual hoist cranes. Time will tell if these prove to be economic.

Dual Trolley

The SeaLand Ansaldo cranes in Kaohsiung, Taiwan are designed to carry two trolleys. The initial installation included only the ship trolley. The second trolley was planned so that it would operate only on the landside of the waterside rail. The shore trolley was never installed.

The existing quay capacity limited the weight of the crane, so extraordinary efforts were made to limit the weight: the machinery house was designed round to reduce wind load, the boom was articulated to meet aircraft clearance requirements, the articulation mechanism was a light weight linkage, and the structural sections were optimized.

The second trolley requires a second operator. Since the second trolley is at the crane girder level, the second trolley operator is far above the quay, making load control difficult.

Today, a dual hoist crane will be more productive than a dual trolley crane. The initial and operating cost of the two crane styles are the same. There is no apparent advantage to the dual trolley crane.

Paceco BufferStation©

Paceco has developed a quay supported machine, the Paceco BufferStation. The buffer is a rubber tired gantry that receives the container from the ship trolley and transfers it to the quay. This machine converts a conventional crane to a dual hoist crane.

The buffer can operate on most existing quays without overloading the quay. Since the buffer is on rubber tires, it can be inserted and removed as needed and can be moved out of the way for maintenance. The buffer will require a second operator.

The buffer blocks some of the wharf. This is partially offset by placing the IBC removal platform on the machine. The platform also keeps the IBC workers off the quay.

Simulation indicates that the BufferStation will increase the production of a single hoist to match a dual hoist crane.

Figure 4: Paceco BufferStation©

Ship-in-a-Slip

This rather simple concept places cranes on both sides of the ship, doubling the total production. The slip width can handle ships up to 22-wide. The quay cranes operate very close to each other. Lasers and other fail-safe devices prevent collision.

The cranes are conventional. Five cranes can move around the corner and work on the ship and the marginal quay.

Photo 7: Ceres Amsterdam Ship-in-a-Slip

Simulation indicates that, with all cranes operating, the total production will be 300 lifts per hour. In addition to increased production, the ship in a slip provides more berths per length of bulkhead line.

The Amsterdam terminal is inland within the Dutch dike system, where there is little current and tide, so the ship can be easily maneuvered into the slip. In other locations, the sea conditions may be a problem.

FloatTerm

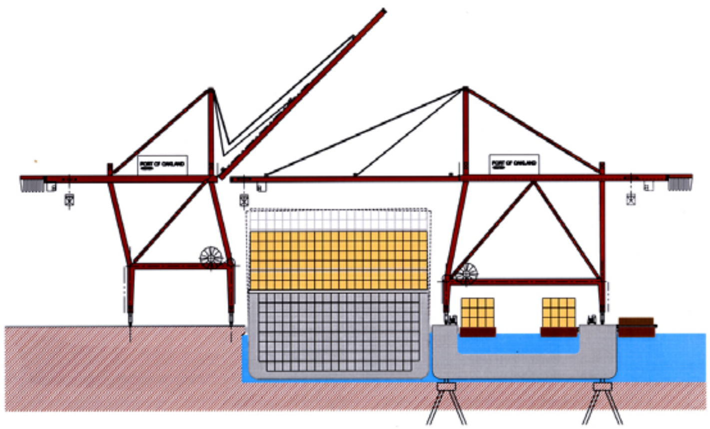


Figure 5: FloatTerm Example One

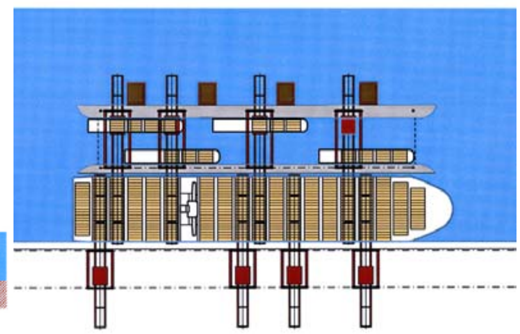


Figure 6: FloatTerm Example One

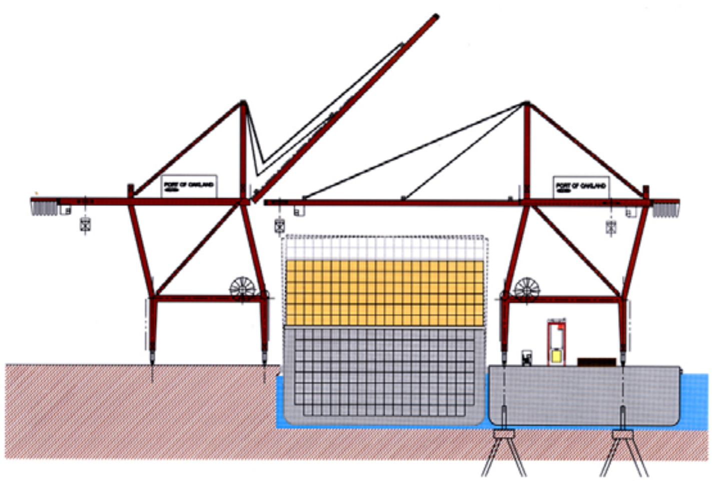


Figure 7: FloatTerm Example Two

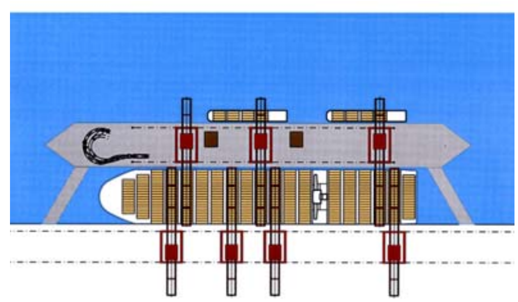


Figure 8: FloatTerm Example Two

The FloatTerm concept extends the ship-in-a-slip concept. One side of the ship is serviced from the landside quay and the opposite side is serviced by cranes operating on a vessel.

A number of schemes are workable. The vessel could have removable bridges to shore. The vessel could include barge-berthing slots. Or the vessel could work entirely within a bay, providing midstream container transfers.

The vessel could be stabilized on legs that would be extended to the bay bottom or by counterweights located in the lower chambers of the vessel. The movement of the counterweights would be automatic and depend on the trolley position and load on each crane.

The cost of the vessel is comparable to the cost of an equal length of the quay.

Linear Cranes

All the previous concepts included cranes that moved containers in curvilinear paths: the trolley travels while the load is lifted, which reduces the combined time for travel and hoisting.

Some crane concepts employ only linear paths. The hoisting and traveling are independent. For the linear concepts discussed, the hoist lifts full height to the trolley girder elevation for every cycle. This adds time to the hoist time increment. Since the trolley does not travel, load control is much better. The time added due to a longer lift will be more than made up by the time saved by better load control.

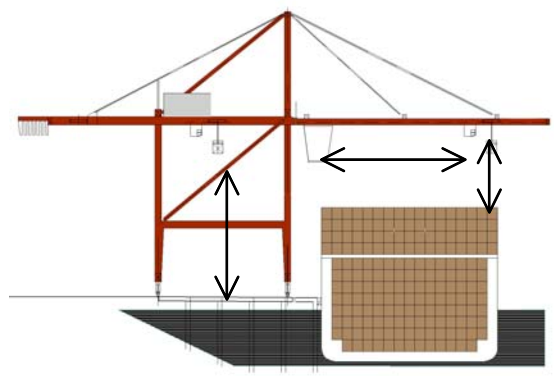


Figure 9: Linear Crane

Various linear crane concepts have been studied since the 1960's. Some of the possible linear crane concepts are presented. All will have cycle times, i.e. periods, less that any of the curvilinear concepts. And all cost more than a curvilinear crane.

All the concepts are interesting. Detailed studies will be needed to fully understand the ramifications of each on the quay, the initial and operating costs, and the productivity of each concept.

The period of each concept will need to be determined by estimating the incremental times of each operation and simulation of all the operations. The period will probably be in the range of 60 to 45 seconds, or 60 to 80 lifts per hour.

Paceco Supertainer©

The Supertainer includes three linear paths: hoisting from the ship, shuttling along the runway, and hoisting to the quay. The crane can perform double cycle operations, but this will increase the cycle period to unacceptable levels, since the ship hoist will need to

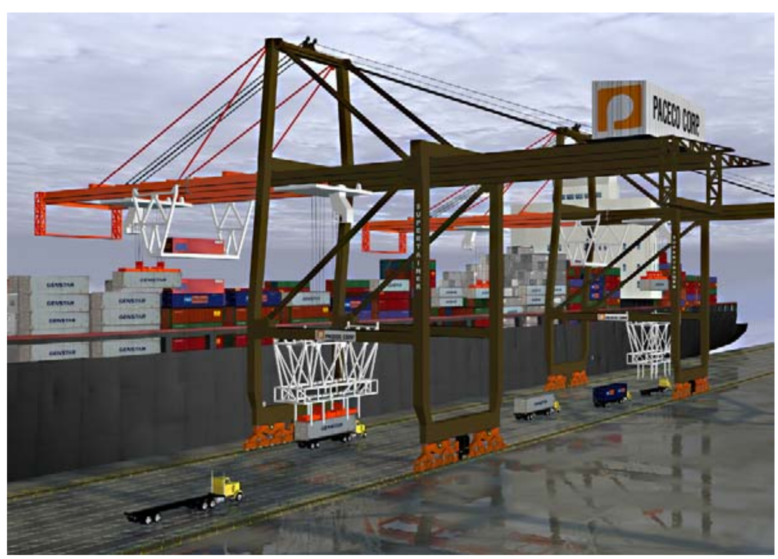


Figure 10: Paceco Supertainer®

wait for the shore hoist to set and pick a container and the shuttle to travel. The Supertainer is suitable to handle unidirectional operations. The period will be the longest of three operations: hoisting over the ship, shuttle traveling, or hoisting over the quay.

The ship hoist time will be the time required to find the container on deck or to find the hold guides, to find the container, hoist the container, verify that the runway is clear, move the shuttle under the ship hoist, set the container on the hoist, and move the container from under the spreader to allow the spreader to lower and the cycle to repeat.

The Supertainer shuttle is wide enough to handle the maximum length container, 16.1 m (53 ft), so it will be relatively wide and heavy. The usually desirable boom width of 9.1 m (30 ft) will be exceeded, and the crane will not be able to approach the ship's house as closely as a conventional crane. The crane will also weigh significantly more than a conventional crane and will overload most existing quays.

The Supertainer may be suitable for some new installations where the quay strength may be increased by design at a nominal cost and where the crane does not need to make a close approach to the ship's house.

CreaTech Technotainer©

The CreaTech concept is essentially a conveyor system. The container is picked by the ship hoist, raised to the full height position, and the spreader load is transferred from the head block to a special runway. The spreader travels along the runway to a shore hoist that picks and lowers the spreader and the load to the quay. The spreader is retracted to the 20-foot configuration and is carried to the ship hoist on a third runway. The retracted spreader allows the boom width to be about 9.5 m. This allows the crane to approach the ship's house and keeps the crane weight down.

As with all conveyor systems, this concept takes the shuttle travel time out of the equation. The period is limited by the longer of the ship hoist cycle time or the shore hoist cycle time. Since the unloaded spreader retracts before it returns to the ship hoist, the width of the boom is not excessive.

The crane weight will be about 25 percent more than a conventional crane, so many existing quays will be able to support the load. The main disadvantage of this concept is the increased complication of the spreader. The spreader will includes some complex features: wheels and the associated mechanisms to allow the spreader to become a shuttle, the spreader will be towed when it is in the shuttle mode.

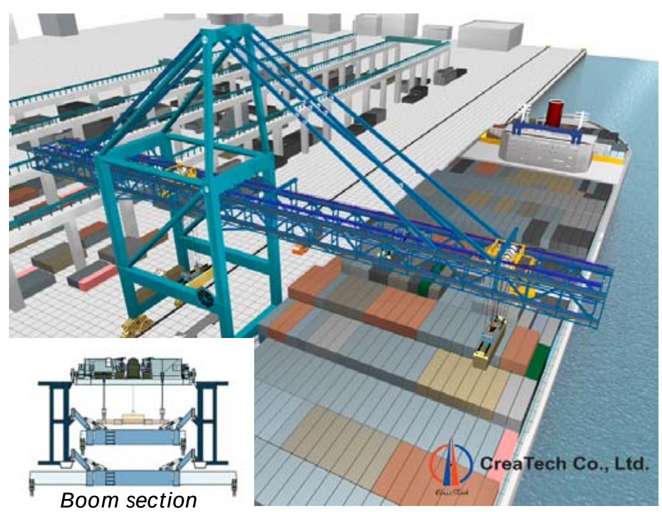


Figure 11: CreaTech Technotainer

As with the Supertainer, the period will be the greater of the time needed to pick and hoist from the ship, transfer the load to runway, move the load out of the way, pick the next spreader and return to the next container—or—the time needed for the shore hoist to pick the spreader, lower to the quay, set the load, release the headblock, and return the spreader to the runway.

Delft University Carrier Crane©

This rather massive crane includes a conveyor system. The container is picked from the ship, set on a shuttle car, transferred to a shore hoist, and lowered to the quay.

The figure shows two ship hoists. Two hoist could be used for all the other linear concepts, as well.

Since the system is a conveyor system, the shuttle movement does not effect the period. As with Supertainer and the Technotainer, the period will be the greater of the times required for the ship hoist, or hoists, to cycle or the times required for the shore hoist, or hoists, to cycle.

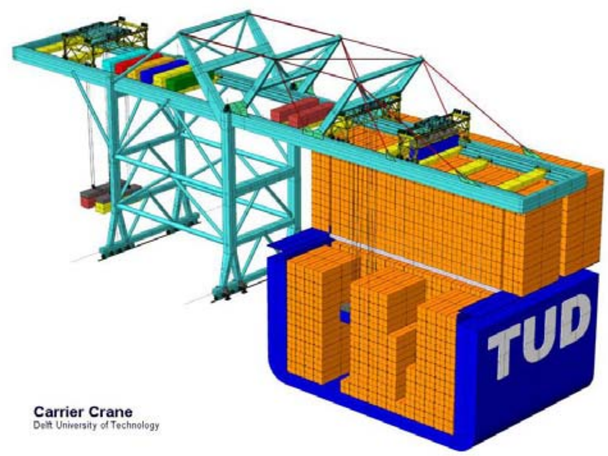


Figure 12: Delft University Carrier Crane©

The shuttles will be wide and heavy. The overall crane weight will be 30 to 50 percent greater than the weight of a conventional crane and require high capacity quay. The initial and operating cost will be at least as much higher in proportion to the weight.

Liftech SuperCrane©

Like the Technotainer, the SuperCrane includes a conveyor system. The load is lifted from the ship by a rotating trolley, rotated 90 degrees, and set on two lightweight motorized shuttle cars. The shuttle cars carry the load to the shore hoist, which picks the load and sets it on the quay. The shuttle cars are returned to the ship hoist on an overhead rail. Elevators raise and lower the shuttle at the landside and waterside ends of the runway.

The shuttle cars run the short direction of the container and are

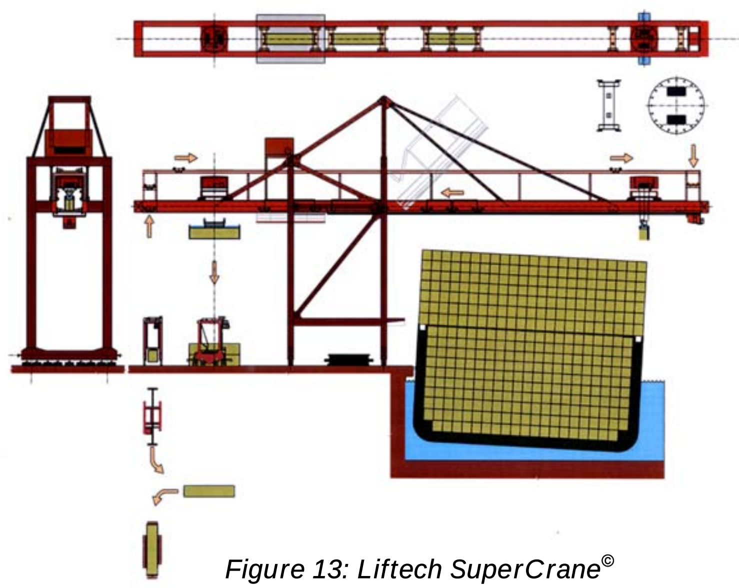


Figure 13: Liftech SuperCrane©

therefore light. One shuttle is at each end of the container, useable for containers of any length. IBC's may be removed at the runway level so no workers will need to be on the quay.

The landside hoist that also rotates can set the container on the quay at any angle to crane runway. The container could be set perpendicular to the crane runway, at an angle, or as is usually done now, in the direction of the runway.

The circular shore and ship hoist houses allow the overall dimensions to be small. This trolley would not work well with machinery trolley cranes, since the swinging hoist ropes would not lay properly in the groves.

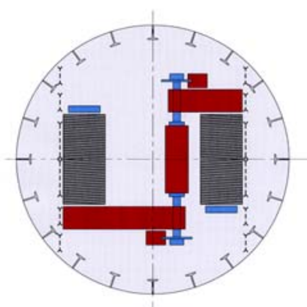


Figure 14: Rotating Machinery Trolley

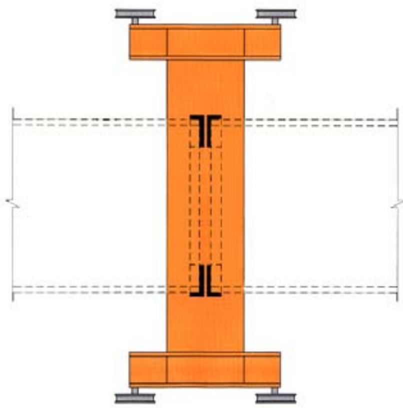


Figure 15: Shuttle

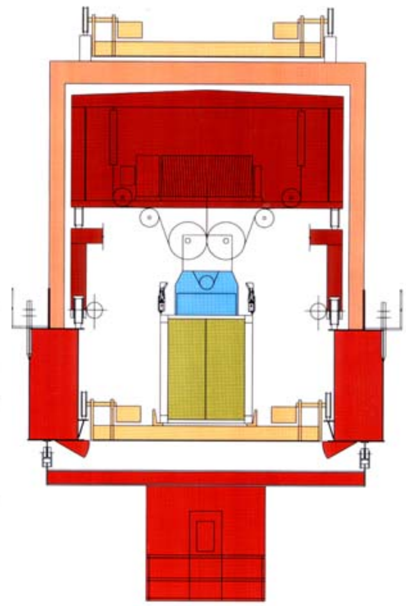


Figure 16: Boom Section

Conclusions

The discussion is my opinion; others' opinions may be different. All the concepts have some merit. Only time will tell which is best for individual cases.

Considerable further study will be needed before the expensive undertaking of some new concept is started.

As Peter Drucker[1] has stated, the proper execution of any new venture requires three ingredients: a technical study, an experienced person's opinion, and enough capital to attempt the venture. Modern computer tools can help with a reliable technical study, experienced operators can make intelligent evaluations, so the remaining issue is risking the capital on some new ideas. Someone will take the risk and someone will reap the reward. It's been done before.

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[1] Peter Drucker, *The Essential Drucker: In One Volume the Best of Sixty Years of Peter Drucker's Essential Writings on Management* (New York: HarperBusiness, 2001).