Ship-to-Shore productivity: can it keep up with mega-ship size increases? Part 1

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The ocean carriers' key phrase these days seems to be the cliché 'Bigger is Better.' The economics of carrying more containers on fewer ships regardless of the infrastructure consequences has kept ports on a seemingly never-ending path of 'catch up.' Port authorities and terminal operators are caught in the middle of a vise whose jaws are the growing size of ships due to alliances and mergers on one side and on the other side the need to keep container volumes increasing to pay for the requisite infrastructure changes. One thing is obvious in the ocean transportation environment, ship size will continue to drive the size of the cranes necessary to serve them. Figure 1 illustrates the evolution of container ships since their debut in the 60's.

There is even talk of ships as large as 18,000 TEU sometime in the future. Is there no end to how large a ship could be designed? Aside from physical harbour constraints another impediment that may slow down the size increases of these giants could be propulsion power. The Emma Maersk requires 109,000 brake horsepower to maintain a transit speed of 25.5 kts. Some experts believe that engine manufacturers will find it difficult to squeeze more power from present propulsion designs. Even so, there is little doubt that vessels beyond the size of the Emma Maersk will eventually materialise.

Improving turnaround time

Ship lines are seemingly in a position to 'have their cake and eat it too.' Despite the larger dimensions, almost doubled compared to 40 years ago, they're demanding fast turnaround times for their vessels since 'time is money.' From a terminal operator's perspective, there are only three ways of improving the turnaround time for a container vessel:

1. Employ more cranes, either on one side of the ship as in most conventional wharves, or work both sides of the ship such as incorporated in the Ceres Paragon 'Ship in a Slip' scheme in Amsterdam.
2. Employ tandem or multiple lift cranes such as the one shown in Figure 3.
3. Reduce or maintain the average cycle time of the typical single or twin twenty lift crane in the face of larger ships.

Figure 2. Emma Maersk.

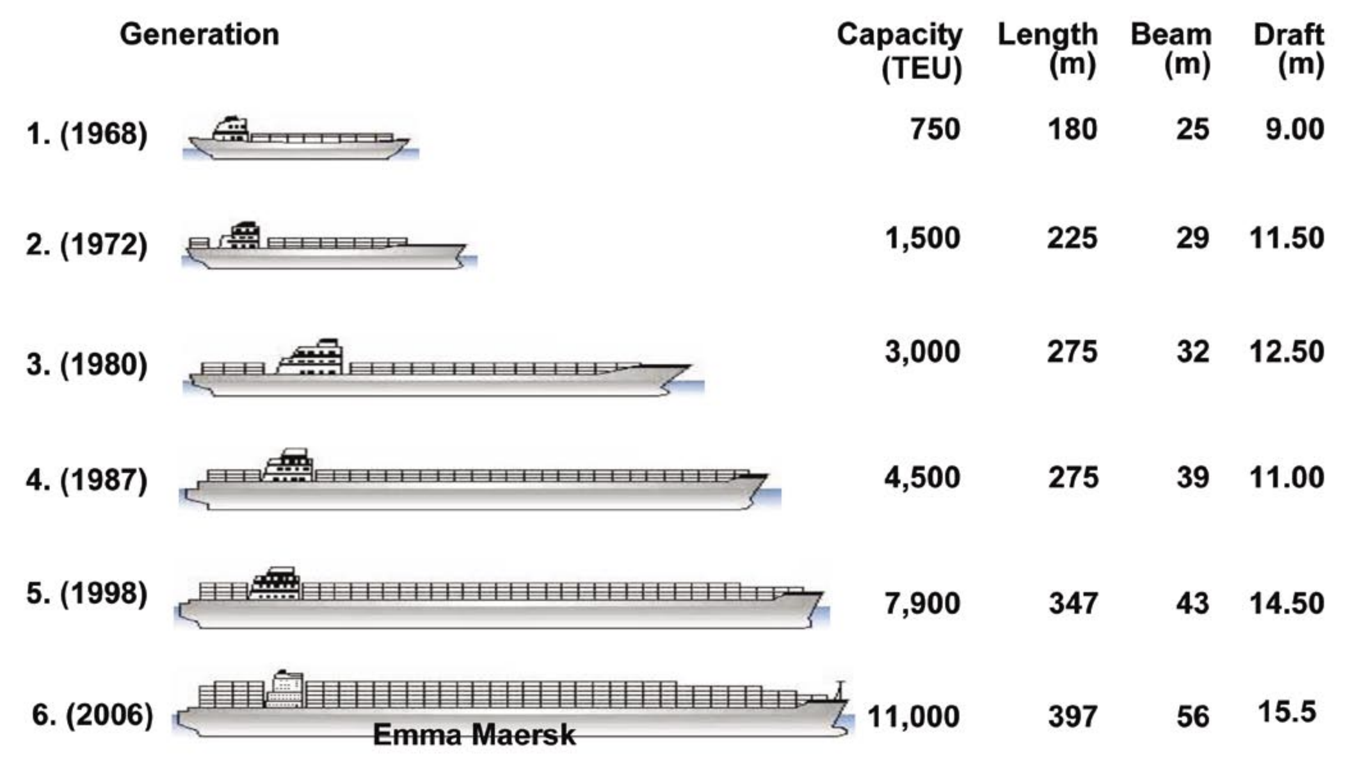

Figure 1. Evolution of container ships.


Figure 3. Jebel Ali Tandem Lift Cranes.

Each of these strategies has it drawbacks. A 'Ship in a Slip' approach requires extensive infrastructure capital cost. The tandem lift crane approach requires considerable additional capital cost and potentially higher wharf expense either to build new or modify the existing structure. Based on a capital focused analysis it would seem preferable for the typical non-hub terminal operator to employ faster single lift cranes, the workhorse of the industry, The key question is: how large and how fast. Let's look at how size and cost have increased over the years in the race to keep up with the ship size increases.

In attempting to maintain productivity, crane purchasers have demanded huge increases in accelerations and speeds to accompany the large dimensional increases and heavier loads such as when handling twin twenty foot containers. The evolution of typical crane machinery dynamics are shown in Table 1.

TABLE 1: CRANE POWER INCREASES

Crane Generation	Hoist Speed Loaded [ft/min]	Hoist HP	Trolley Speed [ft/min]	Trolley HP
1st	100	250	400	40
2nd	130	400	500	100
3rd	150	500	550	175
4th	175	650	600	200
5th	245	1,000	800	250

Larger, faster cranes have resulted in a variety of costs to the terminal operator. The costs to replace wires and sophisticated electronic components have risen markedly. Accessing remote parts of the crane for maintenance is a challenge. Wharves have to be stronger, with more concrete and steel, and with higher construction costs. Spring effects of larger cranes have resulted in phenomena such as harmonic oscillations to be considered in the design usually resulting in more steel and adding to the weight of the crane. Beyond these considerations are the detrimental effects on the operation of the crane. Longer hang lengths result in greater rope stretch, catenary effects, and longer pendulum periods, which take longer to damp. The operator is now twice as far from his work as he might have been 40 years ago, increasing parallax and depth perception effects. And he must move containers farther from the ship to dock and vice versa. Can he maintain or improve productivity despite the problems associated with the larger, faster cranes? There has been speculation in the industry that cycle times will grow and individual crane productivity will diminish with ship size. The stop gap for large hub terminals such as Jebel Ali and Yangshan Deepwater Terminal in Shanghai has been to purchase tandem lift cranes.

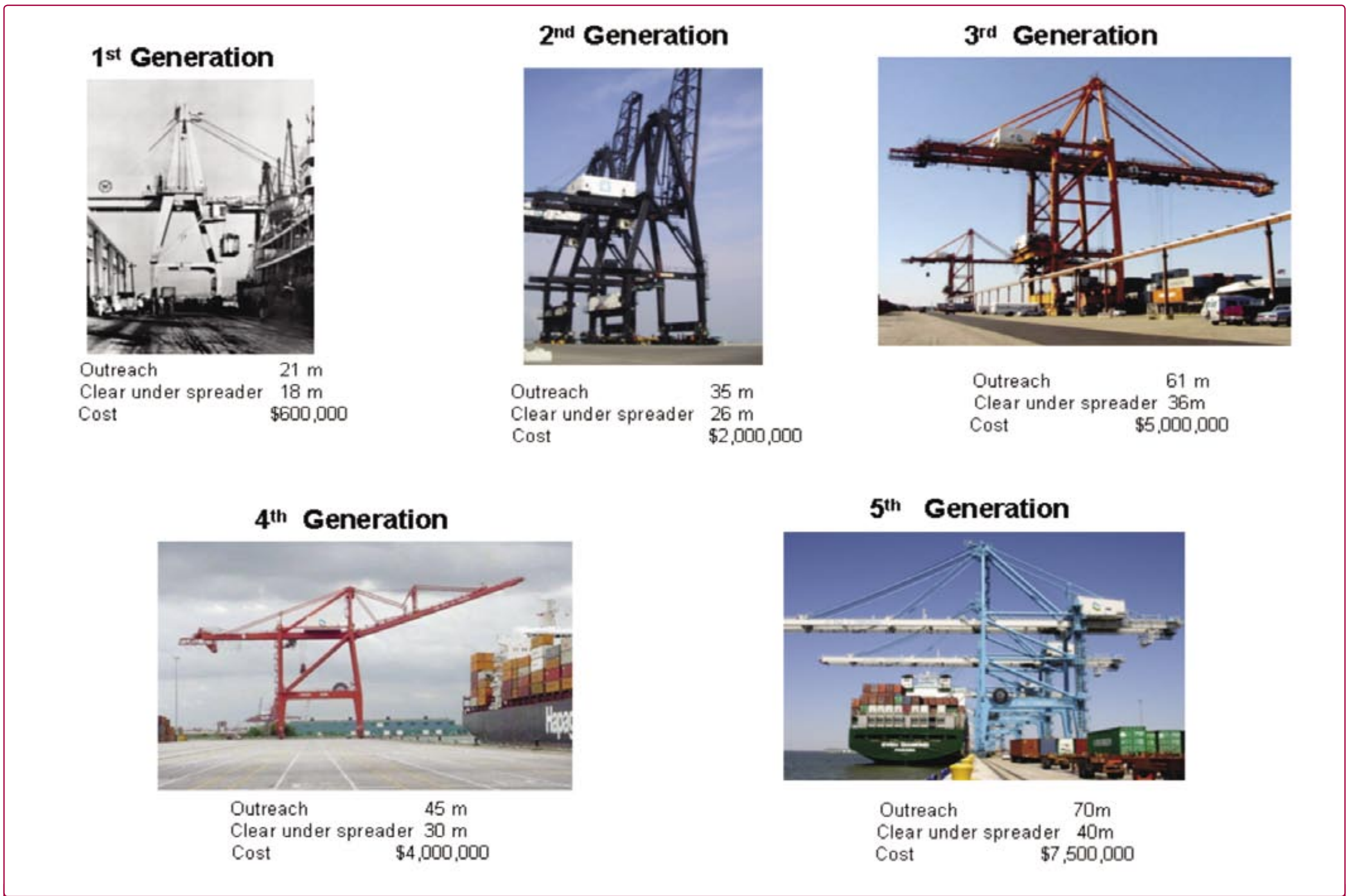

Figure 4. Crane size and cost increases.

I have attempted in other papers to point out that hypothetically, unless a terminal can average at least 30 per cent tandem forty foot lifts, the economics point to single or twin twenty lift cranes. This paper will concentrate on the single lift crane and what can be done with it to keep up productivity with increasing ship size.

The Port of Virginia was in an ideal position to study such a problem since the crane inventory consisted of machines from several generations, from the second generation Paceco A-frame cranes delivered in the seventies to the largest cranes yet delivered, the fifth generation Suez Class. The study incorporated two tools to analyse crane capability and performance, a crane simulation programme developed by Liftech Consultants of Oakland, California, and a crane monitoring program developed under the guidance of Tony Simkus, then VIT's Assistant Director of Engineering and Maintenance for Virginia International Terminals.

Computer simulation

Simulation has been used quite effectively in evaluating and designing many aspects of the terminal operation from the wharf to the yard to the gate. Using this tool on the ship-to-shore operation, one can vary certain physical parameters such as crane and ship dimensions, spotting times (referred to as dwells), crane accelerations and speeds, bay cross sections and container locations, location of working lanes on the wharf and the horizontal and vertical location of the ship relative to the wharf. Liftech's programme is also capable of adding delays such as hatch covers and inter-box connectors (IBC's), as well as incorporating various specialty crane configurations such as the dual hoist and the elevating girder cranes. For purposes of this study I incorporated two typical bay cross sections, a 4,500 TEU Panamax vessel and a Suezmax ship viewed on the computer screen as shown in Figures 5 and 6. The Panamax size was chosen since it comprises the majority of larger vessels serviced at Virginia International Terminals. The Suezmax size was selected to analyse the productivity effects when serviced by the 5th generation crane.

In the simulation, actual measured dwell times along with measured times for hatch top covers and IBC placement and removal times were incorporated. Other delays such as mechanical downtime, waiting for equipment arrival, changing bays, or changing operators, while very important for productivity

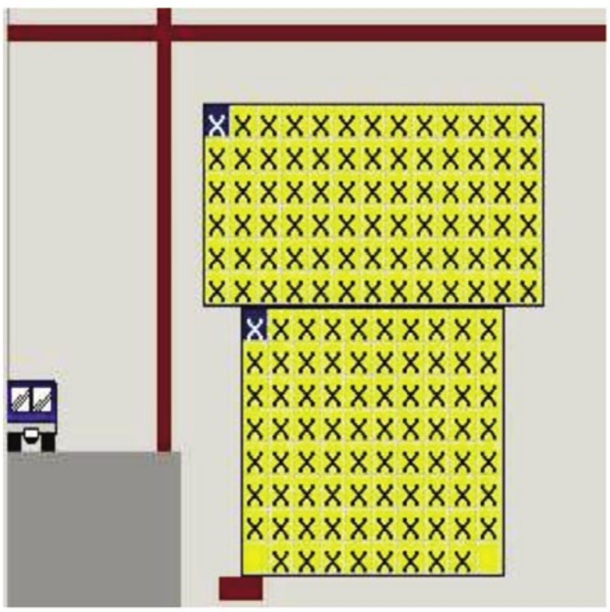

Figure 5. Panamax bay cross section.

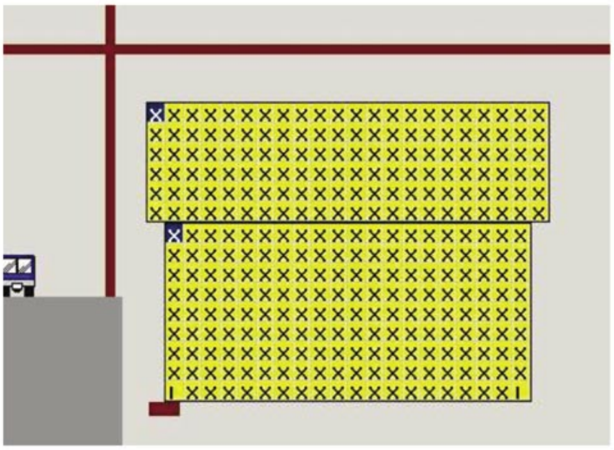

Figure 6. Suezmax Post Panamax bay cross section.

Figure 7. Handheld touch screen monitoring devices.

purposes, were not included in this study to simplify the comparison of computer data with actual measured crane cycle times. All lifts were considered single and do not include any twin twenty or double cycle handling. As discussed in a paper written by the author published in 19991, I will use the simulated productivity using cycle times, incorporating only hatch cover and IBC delays, as the theoretical maximum ship-to-shore productivity against which to compare data taken by monitors.

Production monitoring

In order to validate the computer simulation, individuals trained as Crane Monitors collected actual data. In order to reduce the tedious process of using pencils and stopwatches as well as minimising errors, handheld computers such as those shown in Figure 7 were used. The software programme initially developed, as discussed in [1], for the Newton is easily adaptable to other small handheld devices. In conjunction with the revised software, additional tools were developed to break down and more closely analyse all aspects of the ship-to-shore cycle. In the most recent study, over 15,000 records were collected with the handheld devices encompassing 2nd, 3rd, 4th and 5th generation cranes in VIT's inventory. The only crane operations recorded were for those employing a straddle carrier transport operation. As I mentioned in the previous paragraph for purposes of this study and to compare the theoretical handling rate (or cycle time) determined through simulation against that recorded empirically, the actual recorded data was purified to include only single load or discharge cycles (which included the empty spreader portion of the cycle) with any associated IBC and hatch cover delays.

Figure 8. 4th generation cranes working a Panamax vessel.

TABLE 2: SIMULATION WITH SAME DWELLS

	4th Gen	5th Gen
Trolley Speed [ft/min]	500	800
Hoist Speed Loaded [ft/min]	170	245
Height (dock to spreader) [ft]	105	120
Dwells [sec]	8-15	8-15
Handling Rate [cont/hr]	36.6	42.6

Crane size effects when working Panamax vessels

To assess the theory of productivity degradation with increasing crane size, I first used simulation of a 4th generation versus that of a 5th generation crane working a full discharge and load of the largest bay of a Panamax ship similar to that shown in Figure 8.

The first simulation used the same spotting dwells for both cranes with the appropriate speeds, accelerations, and crane dimensions listed in the table below. It's obvious that if the operator were at no disadvantage by being positioned in the larger crane that the theoretical productivity would far exceed that of the older, smaller crane merely because the crane was faster.

However, in reality the operator is subject to some degradation because of the longer spreader hang length which results in a longer swing period and also because of visual parallax effects. I attempted to quantify what these effects would be to revise the simulation. Knowing that the pendulum period of a swinging load is proportional to the square root of the hang length, the difference in swing period can be calculated. For the two cranes illustrated above it is approximately a second and a half. If one observes an operator in production a typical damp time is about one period.

This is not hard and fast since some of the tricks of the trade involve minor intentional collisions with other containers to stop the sway. One might qualify this assessment by claiming that anti-sway systems can eliminate any operator damping, yet even the best anti-sway systems are not perfect at eliminating load swing. Additionally, operators at VIT and many other terminals prefer not to use installed electronic anti-way. For purposes of this study I estimated that sway damp and parallax effects would amount to about one period damping time plus an arbitrary 1 second for parallax, an estimated total of 2.5 seconds on each end of the cycle. The dwell parameters were thus reduced for the 4th generation crane, the simulation rerun, and the following results obtained:

TABLE 3: SIMULATION WITH MODIFIED DWELLS

	4th Gen	5th Gen
Dwells [sec]	5.5 - 12.5	8 - 15
Handling Rate [cont/hr]	39.3	42.6

Assuming that my estimates were in the ballpark and the simulation sufficiently accurate for the parameters used, the analysis demonstrates that the dynamics of the more modern crane overcome any disadvantages that a dimensionally larger crane would impose on the operator.

End of part 1. Part 2 of this article will evaluate the actual data, discuss operators' perceptions and apply the simulation data to 5th generation cranes working 11,000 TEU vessels. This will be followed by a short conclusion.

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1. Port Technology International Limited, 10th Edition, 1999, 'The Dual Hoist Crane's Influence on Productivity,' C. Davis Rudolf III.

ABOUT THE AUTHOR

C. Davis Rudolf III is a Professional Engineer and Principal of TechPort Consultants, LLC. He holds an MS in both Mechanical Engineering and Financial Management, from the U.S. Naval Post Graduate School. Mr Rudolf's career at VIT spans 20 years, three as Assistant Director of Engineering and Maintenance and 16 years as Director of Engineering and Maintenance. He is the developer and holder of patents on the following: Elevating Trolley Girder Crane, High Speed Trolley Stabilizer System, Automatic Robotics System.

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Ship-to-shore productivity: can it keep up with mega-ship size increases? Part 2

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Part 1 of this article was originally published in edition 34 of Port Technology International and is available for download at www.porttechnology.org under journal archives.

Part 1 introduced us to the challenge of improving ship unloading turnaround time and focused on single lift cranes and what can be done with them to keep up productivity as ship sizes continue to increase. A study was carried out at the Port of Virginia incorporating two tools to analyse crane compatibility and performance, a crane simulation programme and a crane monitoring programme. Part 2 now continues with the evaluation of the actual data from the study.

Evaluation of actual data

The next challenge was to record and evaluate real operational data under varying conditions to see if the simulation results could be supported. The simulation used a homogeneous bay plan, something rarely found in common practice at multi-user terminals such as Virginia International Terminals (VIT) operates. Also, a variety of delays to the operation are encountered and operator proficiency varies. However, if a sufficiently large sample of data is taken and, as I mentioned previously, this data could be broken down to exclude certain delays, a reasonable comparison of the simulated versus actual measured cycle time could be made.

Over the course of nine months this data was recorded on the Newton handheld touch screen computer, then downloaded into a Microsoft Excel file for further analysis. Only the delays for IBCs and hatch covers, along with the single container loads and discharges, were considered in order to closely compare this data with the simulation analysis. A histogram of cycle time frequencies is presented in Figure 1. The actual data shows a difference in the mode or most common cycle time equal to the equivalent of 4.0 containers per hour. This correlates very nicely with a difference of 3.2 containers per hour for the computer simulation for the Panamax vessels, supporting the results which indicate that, at least for the 5th generation crane, we have not reached the point of diminishing returns for operator productivity.

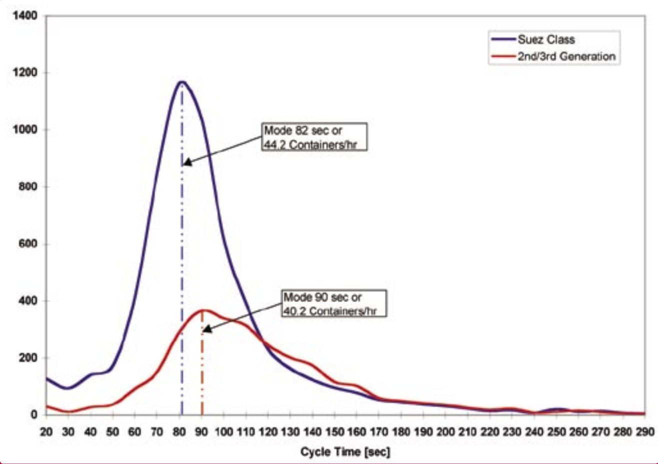

Figure 1. Histogram of cycle times of actual data.

Figure 2. Jebel Ali Tandem Lift Cranes.

Operator perceptions

Conclusions can be reached by taking data and doing simulations, but feedback from operators who spend many waking hours at the crane controls is critical to the equation. I interviewed several of VIT's most proficient operators querying them on the differences they've seen in their own productivity as the evolution of crane size and speed has progressed. The opinion was unanimous: that although the cab was farther from the spreader, and the wires longer from trolley to spreader, the faster speeds and system responsiveness made up for any parallax or sway period differences. Responsiveness of controls seemed to be a major factor in their favorable opinion. From an engineer's perspective, this faster response is a combination of increased accelerations and the ability of modern solid state PLCs to scan the programme permissives faster, resulting in quicker drive commands to the motors. The operators felt that they would not be concerned about further size and speed increases beyond the 5th generation machine. They also commented that anti-sway systems designed to reduce the damping time in the spotting maneuvers were only marginally effective at reducing cycle time and that there was no substitute for experience and the 'feel' of the crane.

What can we expect for 11,000 TEU vessels?

Since we have validated the simulation data, we can now use the simulation programme with the 5th generation crane working the vessel cross section shown in Figure 2, using the same dimensional data and dwells as used for the Suez Class crane in the Panamax example above.

The handling rate results shown in Table 1 indicate a reduction of almost three containers per hour as we might expect due to longer travel paths of the spreader.

TABLE 1: HANDLING RATE RESULTS

	Simulated Productivity
Panamax Bay	42.6 [cont/hr]
11,000 TEU Bay	**39.8** [cont/hr]

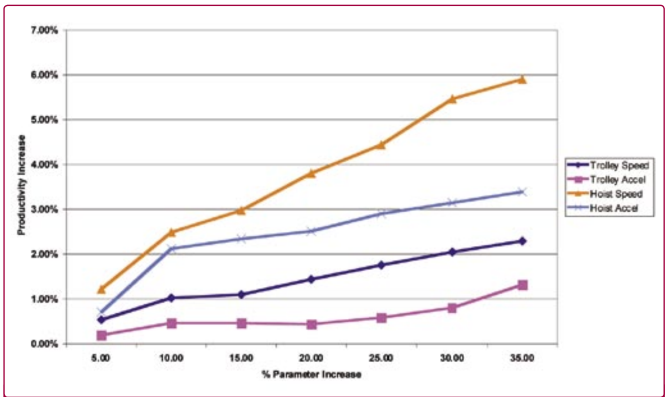

Figure 3. Simulated marginal productivity increase for speed and acceleration increases.

Assuming that increasing accelerations and speeds on this crane even further would not materially affect operator productivity, for future crane purchases we probably would want to increase the dynamics of the machine to have at least as high a handling rate as that for a Panamax vessel. But then, which of the accelerations and speeds should be adjusted? Hoist? Trolley? Both? How much? Again, simulation comes in handy. By changing the dynamic parameters in the simulation programme by constant percentages we can see the relative effects of each.

It's obvious from this comparison shown in Figure 3 that hoist increases give us 'more bang for the buck.' Based on this analysis and adjusting the parameters incrementally, I arrived at a set of parameters that would yield the same cycle time or handling rate on the 11,000 TEU bay as that experienced over the Panamax vessel. Since the trolley acceleration affects the handling rate the least yet has the most effect on operator comfort, I made no change in its value. A comparison is shown in Table 2.

Performing an energy analysis of the crane incorporating the revised dynamics reveals the following shown in Table 3.

TABLE 3. REVISED POWER REQUIREMENTS TO MAINTAIN PANAMAX PRODUCTIVITY

	Hoist	Trolley
ZPMC HP's as Designed	1,000	250
Revised HP's	1,200	325

Based on this study, I recommended that in VIT's next procurement of 5th generation cranes, motor powers be increased accordingly. These parameters were included almost exactly in that procurement. The cranes delivered in 2004 and recent operational data have proved that the theoretical prediction was very accurate.

TABLE 2: REVISED SPEEDS AND ACCELERATION TO MAINTAIN PANAMAX PRODUCTIVITY

	Actual 5th Gen Parameters	Proposed Parameters
Hoist Acceleration [ft/sec^2]	2.20	2.64 (+20%)
Hoist Speed (loaded) [ft/min]	245	294 (+20%)
Trolley Acceleration [ft/sec^2]	3.0	3.0
Trolley Speed [ft/min]	800	900 (+12.5%)
Simulated Handling Rate [cph] on 11,000 TEU Ship	39.8	42.5

Conclusion

The combination of computer simulation, operator experience and intuition and analysis of actual data shows conclusively that, at least for the size of crane which is needed to service vessels up to and including 11,000 TEU, boosting crane power along with the associated lift height and outreach does not necessarily reduce ship-to-shore cycle time. One must keep in mind that the numbers I have used for this paper may not necessarily resemble those for other terminals.

Of utmost importance is the fact that regardless of how much crane cycle time is improved, either through the use of faster cranes or tandem lift configurations, the yard system must be capable of feeding the crane or handling the discharge. If it can't, all bets are off whether a fast crane or multiple lifts are employed. Also, crane variations such as machinery-on-trolley, as opposed to the ones analysed here that use a rope-tow crane design, can make a significant difference in power requirements.

The conclusions reached herein also assume a standard A-frame design whose boom cannot be raised and lowered. The author still feels, as stated in [1], in the single lift arena an elevating trolley girder design has many advantages over the fixed design. Hub terminal operators also are using the tandem lift crane to distinct advantage. Computer simulation supports these theories. One thing is for sure: we will be continually challenged by ocean transport lines and the competition with other ports to keep their business.

REFERENCES

[1] Port Technology International Limited, 10th Edition, 1999, 'The Dual Hoist Crane's Influence on Productivity,' C. Davis Rudolf III.

ABOUT THE AUTHOR

C. Davis Rudolf III is a Professional Engineer and Principal of TechPort Consultants, LLC. He holds an MS in both Mechanical Engineering and Financial Management, from the US Naval Post Graduate School.

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