Improving Terminal Performance

Mega-ships require mega-terminals

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The effect of mega-ships

In the contemporary age it is impossible to open a container shipping or operator business magazine without reading articles about the mega-ships that have entered into the business in the last few years - or the even bigger containerships of 15,000+ TEU that are on order and are set to be delivered in the coming years. Most major ports are telling us that they are ready to handle these giants but is it actually true? Yes, harbour basins and approach channels have been deepened to 17 metres and the STS crane dimensions are - in theory - sufficient in height with 50+ metres under the spreader and an outreach of 25 rows wide to operate on mega-ships.

Berth moves

Yet at the same time, what has happened with the terminals that will handle the mega-ships? Mostly not much has been changed in terminals. On average berth productivity is still at a level of 100 – 150 container berth moves per hour - even for the latest generation of semi-automated and fully-automated terminals. Crane productivity can reach 35 container moves per hour and only on rare occasions, when terminals are able to schedule a large number of STS cranes working simultaneously, they are able to achieve record productivities of 300+ berth moves per hour.

Rotations

Looking at the rotation of mega-vessels, with most of them deployed on the Asia–Europe trade route, it is obvious that two factors will make the average call size in a port increase significantly. Firstly, shipping lines want to reduce the number of ports of call. In the past 12-15 ports were scheduled in a rotation but with the bigger ships this will reduce to 8-12.

This effect itself will cause an increase of around 30-50% more containers per call. Secondly, it is the increased size of the vessels themselves that will make call sizes grow. A round-trip rotation of a 14,000 TEU vessel will produce around 35,000 container moves for all ports. With the recently delivered 18-20,000 TEU vessels this figure will go up by 40% to around 48,000, and looking to the future, with 24,000 TEU ships we could expect 60,000 container moves per round trip.

Call sizes

Call sizes of above 6,000 containers (10,000 TEU) for discharge and load will become the standard. With a berth performance of 100-150 moves per hour this would mean port calls of two days instead of the single day in the past. As a result, an additional vessel per string should be considered in order to maintain a weekly service. The cost per call will increase dramatically, not only due to the bigger vessels, but also due to a doubling of the time a ship stays in port. When designing mega-performance terminals the industry should realise that additional investments for high-productivity will give a big benefit for the shipping lines in cost reduction on mega-vessels.

Another result of the increased call sizes and reduced ports of call in the rotation is a higher transhipment volume – the 'mega-hub effect'. This might also change the overall capacity of a terminal because the total number of waterside moves will increase and enough berth space could become an issue. Higher performance on the mega-vessels could tackle this; a shorter port stay of the mega-vessel will leave more time for handling the feeder vessels.

"300 container moves per hour (CMPH) per berth should be the design target for mega-hub terminals. To achieve a berth performance of 300 the target STS productivity should be 50 CMPH, on average."

Bottlenecks in performance

Looking back over the last 20 years we can see that there are four main types of mega-terminals being constructed:

1. **Rubber tyred gantry yard cranes in combination with tractor/trailer: RTG/ITV**
   Most popular in countries with low labour costs, such as those in Asia, these types of terminals have been proven to reach high-productivity (in the range of 35+ CMPH per STS). The layout with parallel blocks to the quay is simple but effective. Stacking rules are kept efficient without conflicts between the cranes and the RTGs are flexible in operation on several blocks. However, it seems the RTG/ITV terminal has reached its limits. When operating with six or more STS cranes on one vessel, on average 8-10 manual driven TT's have to be deployed resulting in a total fleet of 60 or more TT's. This is causing a highly inefficient use of the horizontal transport with only around 50% actual driving time. The other 50% of the time the vehicle and the driver are lining up in order to have an uninterrupted STS process. The STS operation is between the legs of the STS crane and due to the tunnel effect that occurs when operating mega-ships with six or more STS cranes, all vehicles have to enter and leave the vessel operation at the front or rear side of the vessel. This is causing delays due to congestion. Although suppliers have introduced the automated RTG (A-RTG) it seems that a safe operation in a fully automated mode, including an Automated Horizontal Transport System (AHTS), is not easy to achieve because of the mix with the external trucks. From an environmental perspective, the RTG/ITV operation is moving towards E-RTGs, but TT's are still mostly diesel engines and therefore a terminal cannot be classified as "green" if it is using them. For the RTG/ITV terminal it can be concluded that the terminal can deliver a high performance with 120-180 CMPH but a stable 300 per berth level is not expected in the near future.
2. **Cantilever rail mounted gantry (RMG) yard cranes in combination with ITV**
   In general, one can say that RMG/ITV terminals can deliver the same productivity as the RTG/ITV. The advantage of the Cantilever RMG is that the crane itself can give a higher productivity of around 30 CMPH and the interchange with the ITV can be controlled in a better way. The blocks are also parallel to the quay which is very productive for transhipment moves. An Automated RMG with remote operator has been successfully introduced in, amongst others, Busan and Dubai. A disadvantage of the RMG is the same as with the RTG; there is still a huge number of horizontal transport vehicles needed, causing the same issues under the crane and a limitation in berth performance. The impact of the more expensive cranes and infrastructure is compensated by a lower number of cranes required due to the improved productivity and easier positioning.
3. **Automated RMG with perpendicular blocks**
   With the introduction of the ARMG (also called Automated Stacking Cranes or ASC's) and perpendicular blocks to the quay an important problem was solved; it became possible to split the landside operations with external trucks from the waterside operations. The first fully automated terminal in Rotterdam was designed in this manner, however at this terminal an additional move with a straddle carrier was needed between ASC and external truck, or 'Inter Terminal Transport'. With the introduction of two ASCs working on one block at CTA Hamburg in 2002 the SC operation could be deleted and the additional time for handling the external trucks directly under the ASC with the landside ASC was less influencing the waterside operation. Because of the fully-controlled waterside operations the ASC like terminals are currently reaching an STS productivity of 30-35 CMPH and berth productivities of around 150 CMPH. But can we expect that this system will reach the 300 mark? Looking at the waterside operations a few bottlenecks have been solved in the last 15 years. The introduction of the second trolley with lashing platform at CTA Hamburg made it possible to get the manual handling of twistlocks out of the main trolley cycle and to decouple the interchange with the AGV. The shift of the AGV operation to the back reach gave more flexibility to the AGV routing on the quay. These measurements have made it possible to improve the productivity from a level of 25-30 to 30–35 CMPH. The latest development is the introduction of racking systems at the ASC transfer area and Lift-AGVs to drop containers on the racks. This decoupling will decrease the fleet of AGVs but the question is if it will also give a higher waterside performance. Probably the recently opened terminals at the Rotterdam MV2 will give the answer soon. Similar ASC terminals with manned 1 over 1 Straddle Carriers are performing at a level of 35 CMPH with maximum decoupling at both ASC and STS side. The number of ASC blocks per STS is roughly calculated with 2.5 per STS, based on actual performance of existing terminals and simulation studies. In theory we can say that one ASC can deliver 20–25 CMPH and five ASCs together 100–125

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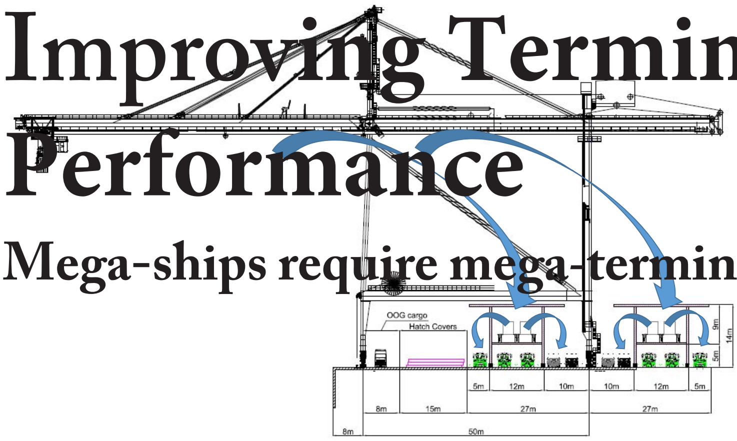


CMPH. In order to support a STS performance of 35 CMPH there seems to be an inefficient use of the ASC , even taking into consideration a peak load at landside of 10 CMPH per block. Actual figures of ASC terminals with 2 ASCs on one block show that the ASC system is spending 40-50% of its moves on housekeeping even during peak demand. In principle, with perpendicular ASC blocks complicated stacking algorithms and priority conflicts cannot be avoided. Adding more blocks is physically impossible because a 10-wide block has a module width of around 36 metres. A mega-vessel with a six STS operation will require at least 6 x 2.5 = 15 blocks x 36 metres = 540 metres, being much more than the length of the vessel itself. Based on the above, it is hard to believe that the current design of perpendicular ASC-blocks can support stable berth productivities of above 200 CMPH in an efficient way even if the horizontal transport and STS are capable to deliver this performance.

4. **Full straddle carrier operation**
   In some Northwestern European ports such as Antwerp and Bremerhaven, a full SC operation is still popular. It is a simple but effective way of operating with only one type of equipment serving landside, yard and waterside. The disadvantage is the amount of space that is needed for the yard area to reach high throughput volumes. For handling mega-vessels it can be expected that a full SC operation will cause congestion under the STS crane and in combination with that will be a limited stack perfomance. Therefore a performance of 300 CMPH will be difficult to reach.

How to solve bottlenecks

Designing a new generation terminal requires the courage to think at higher performance levels with new concepts that will be used for the next 30 years. At present, the technology is available, but it is a matter of finding the best mix of existing and proven concepts. The starting point in the design should always be maximising the waterside performance and STS productivity.

a. **The STS crane**
   One of the effects of increased vessel sizes is the distribution around average crane cycle times has increased. There is a huge difference in the cycle time of picking up a box at the first row on deck and at the lowest position at the last row in the last hatch. Terminal performance can be improved by predicting cycle times and actively reacting to this. Particularly, remotely operated STS's might be more predictable, because most of the cycle is in automatic mode. Another effect that will make productivity differ from crane to crane is the use of twin lift and tandem lift. Twin lift (2 x 20') is more or less a fully accepted mode of crane operation and tandem lift has developed to a mature level with proven high performance. Mega-vessels with big call sizes will be able to use tandem lifting for 80% of the 40' boxes and this will have a big impact on the overall berth performance. Mega vessels with big quantities of containers being discharged and loaded on the same bay provide an ideal situation for dual cycling and this by itself can increase productivity by more than 50%. In order to fully utilise the STS production capabilities on a mega-ship, the handling of semi-automated twist locks (SATL) should be done outside of the main trolley cycle of the STS. A few methods have been developed to achieve this. The most successful one, a twist lock handling platform with second trolley system was successfully introduced at CTA Hamburg and afterwards copied at other AGV terminals. This system not only separates the twist lock handling from the main cycle but it also shortens the main trolley cycle and decouples the handshake with the horizontal transport Even without big changes to the STS crane design, it is possible to reach average productivities of 45–50 CMPH when using multi-lifting, dual cycling and decoupling of the twist lock handling. This way a berth productivity of 300 CMPH is achievable without deploying new technologies.

b. **The process to support the STS operation**
   Around 1998 at the first fully automated terminal in Rotterdam (ECT) and Sea-Land worked closely in what were then called Performance Improvement Teams (PITs) to improve productivity from 25 to 30 CMPH. "Why is the hook hanging?" was the simple question to start the discussion. This simple question should be the starting point to design the process to support the STS today too. The table shows that the ITV (Internal Terminal Vehicle) demand by the crane can vary from 30-70 vehicles per hour. Calculating in averages per crane has become pointless and the process to support the STS should have the flexibility to cope with a huge variation in demand. One of the current bottlenecks at the existing terminals is that horizontal transport is arriving too late and causing congestion under the STS. In order to avoid the direct handshake between main trolley and horizontal transport, the introduction of decoupling and buffering should be considered, especially when using tandem lifting. For the decoupling and buffering on the STS itself, the lashing platforms with support tables (for twist lock handling) and second trolleys were mentioned earlier in the article. The only disadvantage of this solution is that it will require an additional investment for each STS of around US$2.5 million. Buffering on quay level can be created by using straddle carriers, placing the containers on the pavement under the portal or in the back reach, or with buffering of the vehicles themselves.

Single 40ft Lifts	18.10%	Total Crane Hours	210	Crane Breakdowns, Operator Breaks, Waiting Shuttles, Bins, O/H Frames, Damaged Boxes Etc	
Twin 20 Lifts (Single Spreader)	25%	Lost Time (Hrs)	60		
Tandem 40ft lifts	53.30%				
Quad 20ft Lifts	2.30%	Overall Average	35.71		
Others	1.30%				

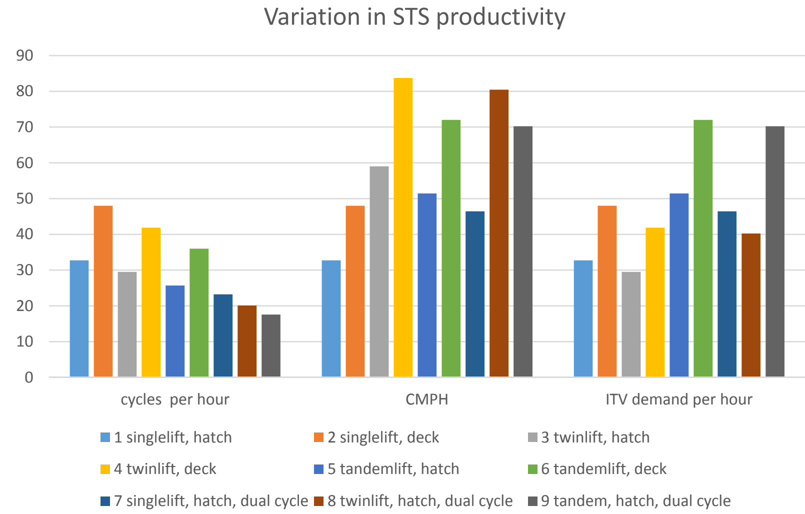
QC	Move	Time	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
2	Discharge																	
	Loadback																	
3	Discharge			10	11													
	Loadback				13	13												
4	Discharge			16	39	22	42	45	38	39	2					6	31	30
	Loadback										12	27	26	24	28	10		
5	Discharge			28	43	38	51	40	40	40	15	40						
	Loadback																	
6	Discharge			10	31	36	41	36	36	12	41	42	30	40	18			
	Loadback														3	27	24	22
7	Discharge										9	32	25	20	23	34	34	37
	Loadback			32	26	23	16	27	22	27	12							
8	Discharge								2	32	43	29	13	16	34	16		
	Loadback		6	22	20	20	21	29	13							6	22	26

QC	Move	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
2	Discharge							16																	
	Loadback								18	17	35	2													
3	Discharge			12	18	23	22	16	12																
	Loadback								7	24	31	18	21	7	24	26	22	29	23						
4	Discharge	26	34	28	16	46	43	17	40	35	35	3											5		
	Loadback											20	34	30	15	36	34	17	22	18	32	20	20	19	21
5	Discharge		4	24	24	40	36	15	14	29	30														
	Loadback											26	36	24	22	28	30	24	26	20	21	19	24	22	20
6	Discharge	4	35	26	26	40	12					16	43	40	38	30									
	Loadback	12					2	15	26	25	30	2				2	24	20	18	18	16	21	28	25	13
7	Discharge	3	28	4											19	33	1								
	Loadback			17	6												16	14							
8	Discharge									18	36	34	25							18	12				
	Loadback	20	24	21	18	22	23	12	21`	5			3	32	29	17	21	25	26	2	12	22	16	20	26

QC	Move	0	1	2	3	4	
2	Discharge						16
	Loadback						72
3	Discharge						124
	Loadback						258
4	Discharge						638
	Loadback	30	40	46	48		629
5	Discharge			10	6		567
	Loadback	24	36	18	4		424
6	Discharge						683
	Loadback	25	24	19	29	20	490
7	Discharge						302
	Loadback						238
8	Discharge						328
	Loadback	7					588

Discharge	2658
Loadback	2699
Total Moves	5357

Buffering of vehicles in a waiting queue can be done by using dedicated lanes per crane but with 8 STS cranes on a vessel this will require a rail span up to 50 metres.



Quay Crane (QC) Booster

In order to create maximum flexibility a solution should be created that can offer decoupling, buffering, twist lock handling separation and the possibility to use it when needed. Next to that the solution should be capable of introducing automated horizontal transport at existing terminals and to work in combination with SC or ITV/AGV. With this in mind the QC Booster (QCB) was designed

The QC Booster can be described as a mobile twist lock handling platform with its own lifting system to place the container on a vehicle or on the pavement.

The performance improvement that can be expected when using the QCB with the deletion of the time required to position the container on the vehicle(s), the time to handle the twist locks and in case of tandem lifting, the time to shift the head block to the maximum width. All this together can result in 25% higher productivity.

In case the terminal with the 50 metre rail span STS would like to introduce automated horizontal transport, here the vessel planners have the flexibility to use the QCB under the portal or in the back reach, or both. Using it for both would make it possible to introduce a decoupled dual cycle tandem lift operation.

The QCB is an example of how a technical solution can create more flexibility in the vessel operation process and the QCB design gives a good answer on how to cope with an increased variation in STS productivity in a manned or unmanned operation.

Introducing horizontal transport automation would still require a need to split the manned and unmanned areas. Maybe in the future with new technologies that are currently being developed in the automotive industry it will be possible to mix the two, but with the risks associated with handling huge and heavy 30-ton containers, it could take a while before this technology is at a fail safe level.

c. Flexibility of the horizontal transport

Flexibility of the Horizontal Transport System (HTS) on the quay between yard and STS cranes will be an essential factor in designing the mega-performance terminals. The key success factor of a HTS would be that it can handle the huge variation in demand for vehicles by the STS cranes and can also support the high-peak demands without congestion problems. An important factor is the difference in loading or discharging sequences. STS cranes that are discharging have a relatively simple demand for empty vehicles, every vehicle will do and the only target is to follow the productivity of the STS. Loading on the other hand is until now a more complicated process, for almost all containers the sequence of loading is important and containers should only be placed at the locations according the approved stow-plan. With this mind it is preferred that the HTS should allow some kind of buffering of containers at the STS

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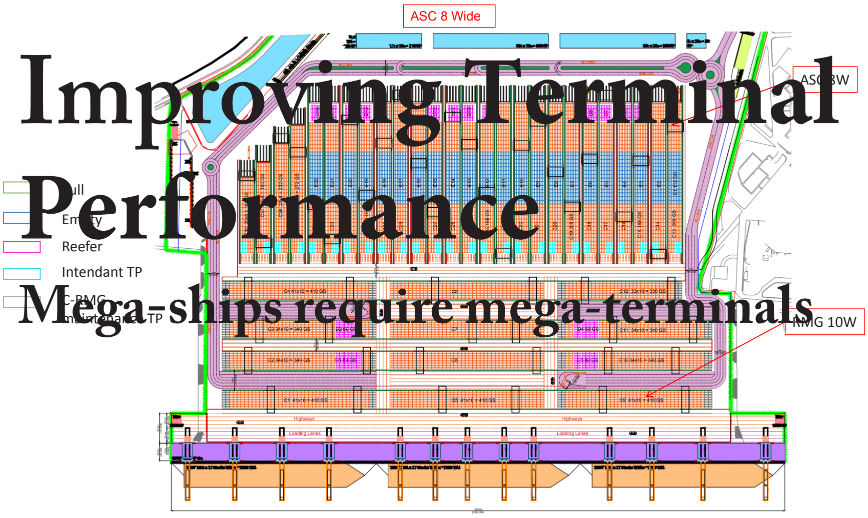

crane side, this will make it possible that the arrival of the containers is not 100% sequence dependent. The buffering could be with the containers still on the vehicle or with the containers placed on the pavement. Currently existing terminals are already faced with congestion at waterside operations, higher productivity will aggravate the issue and the challenge will be to design a HTS with a simple routing principle that will avoid congestion and allow buffering. Recently a new design was introduced that gives access under the back reach of the STS without hindering the operation of the adjacent cranes even if they are working in a "shoulder-to-shoulder" configuration. This lay-out makes it possible for containers to arrive earlier than needed according to their sequence as long as a spot for the container first in sequence stays open.

e. **Mixed yard handling concepts**
As mentioned earlier in the paper, the stacking rules for parallel RTG and RMG yard blocks are less complicated compared with the stacking algorithms for perpendicular ASC blocks. However, both systems have their pros and cons and it could be a good alternative to utilise the advantages of each system in its best way, especially when designing a semi-or fully-automated terminal process. Furthermore, for the yard it would be a good approach to start the design by considering the flows at the terminal (import, export, transhipment) and create separate rules for these flows. This principle is used in the terminal design as shown in sketch. The export and transhipment flows are handled via the parallel cantilever RMG blocks and this will guarantee a high performance because of the good pre-stacking of the load containers and the short travelling distances. The import flow is handled by the ASC blocks and is not disturbing the load process in the separate RMG cranes.

f. **Yard performance**
The productivity of the yard highly depends on yard planning. Good yard planning creates shorter driving distances for the HTS and minimises the number of unproductive handlings. For the waterside, high-performance is required when a ship is being handled, but for the yard it is different. The situation for the yard changes every time, with big fluctuations in the landside and waterside demand. All terminals have their daily peaks in truck visits and some terminals have a limited opening time of the truck gate. In principle, different yard planning scenarios should be available in order to anticipate the actual situation. Although it sounds very logical, we still see that it is not commonly scheduled in a way that the time between peaks should be used to optimise the position of containers for the next expected high-productivity. New stack designs based on proven technology like the NGICT concept from Frans Koch, CEO Koch Consultancy Group, in which the Overheight Bridge Cranes can pass each other are promising developments and could be the answer on how to create maximum flexibility in the yard in order to deal with continuous changing circumstances.

You can read Frans Koch's paper here

Summary

Mega vessels require a mega terminal performance of 250-300 container moves per hour, twice the current terminal performances. All existing terminal designs are limited in performance for various reasons and only a new approach in terminal design will result in mega terminal performances. There is no need for new technologies or additional automation; all ingredients from a techincal or system perspective are available on the market.

The design of terminals should be focussed on the big variation in required peak performances and on a yard system that is capable of handling continuously changing scenarios in the container flows. Tandem-lifting has become a mature mode of STS operation that will be used more and more in the future with up to 80% of all 40' lifts in tandem. The Horizontal Transport System should be designed for optimized support of multiple containers per STS cycle and a huge variation in STS productivity (30 – 80 CMPH) .

The "QC Booster" is an example of a flexible way to support, at existing terminals, the STS cranes that are critical to the overall berth times.

About the author

In 1992 Joost joined Europe Container Terminals (ECT) to work as a Project Leader on the civil construction of automated container terminals and other projects within ECT. In 1997 he switched to the function of Operations Manager at the Delta SeaLand Terminal in Rotterdam, the first fully automated container terminal in the world. By the end of 2001 Joost became a key member of the Euromax Terminal project team as Project Manager Operations. In 2009, he joined ADPC to design and build the first semi-automated terminal in the Middle East. In 2013 he started Solid Port Solutions.

About the organisation

Solid Port Solutions is an independent group of port consultants with extensive and high-level technical and project management experience in the ports, transport and marine industries. The company is based in the UAE with most of the members European. Their expertise is based on practical experience and knowledge gained over 25 years in a wide range of countries, and many of the group members specialize in manual, semi-automated or fully automated container terminal operation and development.