AUTOMATED CONTAINER TERMINAL PLANNING

THE FUNDAMENTALS

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What does an "automated" marine container terminal look like in 2016? Straddle carriers and RTGs can be automated but these are rarely used as the backbone for an automated terminal due to lack of density or poor performance from a rubber tyred interface compared with steel wheels running on a steel rail. Cantilever RMGs running parallel to the quay are a viable option in places with cheap labour (horizontal transport is still manual) or that have a lot of transshipment or have street trucks that frequently pull multiple trailers (and can't back into an ASC buffer effectively). Container warehouses or terminals based on overhead structures may also be a viable option for very high density situations, but for most people an automated terminal implies the use of automated stacking cranes (ASCs).

ASCs are portal frame RMGs that load from the end of the stack. After picking a container from the end, the ASC gantries with the container to or from the desired storage position in the container yard (CY). These ASC storage blocks are typically arranged perpendicular to the quay, but this is not an absolute requirement. The powerful advantage of ASCs over other terminal options is physical separation of gate and vessel traffic, which allows use of automated transport from the quay to the container yard.

THE ASC TERMINAL

The first ASC terminal was built in Rotterdam in the early 1990s and at this point there are approximately two dozen ASC terminals in the world. Container handling hardware and software makers are very familiar with them, and they generally pose little technical risk. Figure 1 shows an example automated terminal at Euromax, Rotterdam. Note the overall rectangular shape, ASCs perpendicular to the quay face, and on-terminal intermodal railyard (IY) at the rear of the terminal.

There are four options for horizontal transport in an ASC terminal: standard automated guided vehicles (AGVs), lift AGVs, manual shuttles/straddles, or automated shuttles/straddles. Table 1 summarises the key strengths and weaknesses of each and some examples of where each technology has been deployed:

MANUAL VS AUTOMATIC

In ports with large pools of trained and reliable straddle carrier drivers, manual shuttles are an appealing option as they are typically able to achieve high quay crane productivity and require less time for testing than fully automated transport options. Fully automated terminals have a generally poor record of quay crane productivity, especially at startup, due to the complexity of managing a large pool of robotic vehicles that operate in a large area of open pavement.

Human beings by contrast are quite good at driving vehicles and improvising their way through complicated situations (there is a reason that driverless cars that are effective in the real world are still some way off). This performance gap may shrink over time as hardware and software vendors gain more experience, and as firms outside the industry, such as Tesla and Google, continue to invest in robotic vehicle technology.

TERMINAL LAYOUT

Terminals that are non-rectangular in shape can see a great deal of benefit in the use of strads as opposed to shuttles or AGVs in order to maximise

Mode	ADVANTAGES	Disadvantages	Example Terminals
AGV	Cheapest per-machine cost. Proven record with battery powered machines	Coupled operation requires the most machines. History of poor quay crane productivity at project startup	Euromax, Rotterdam CTA, Hamburg
Lift AGV	Decouples the AGV/ASC interchange, which potentially increases productivity and/or reduces the required number of AGVs	More expensive than regular AGVs. AGV/Quay crane handoff is still coupled. ASC rack infrastructure required	APMT MVII, Rotterdam
Manual shuttle (or strad)	Decoupled storage on each end of the move between quay and CY. Ability to use irregular areas for extra storage. Track record of high quay crane productivity at project startup. Less testing required at startup. Can easily phase from manual strad terminals	Higher cost per machine than AGVs. Labour cost and reliability are issues not found in robotic machines. Full electric machines are only in prototype stage	Khalifa, Abu Dhabi Algeciras, Spain APMT, Virginia GCT Global, NJ CTB, Hamburg DPW, London Gateway
Automated shuttle (or strad)	Potentially high productivity and low labour cost	Unproven track record of performance. Highest capital cost per machine	TraPac, Los Angeles

Table 1: Horizontal Transport Options for ASC Terminals

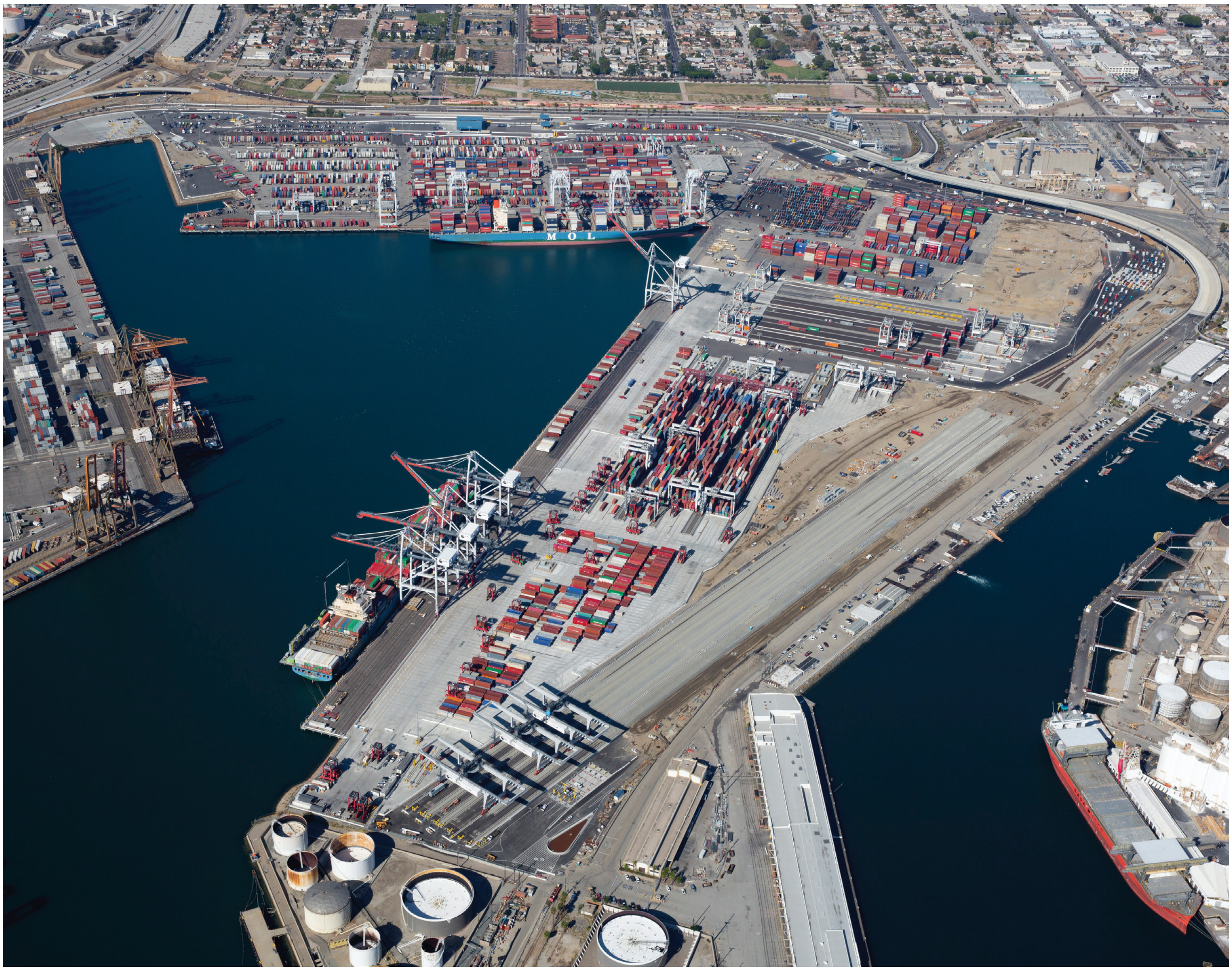

Figure 2: TraPac, Los Angeles

the storage potential of these areas. The TraPac Terminal in Los Angeles is a good example of this. The tip of the triangular terminal, shown in the foreground of Figure 2, is filled with straddle carrier storage rows. This area would be wasted in an AGV terminal because AGVs need an overhead crane to remove or place a container whereas a straddle carrier (strad) can both lift and carry a container.

KEY ELEMENTS OF ASC DESIGN

The biggest influence on terminal design is the fraction of cargo moving by transshipment or by rail. For transshipment terminals, it may be worth studying alternatives with ASC rows running parallel to the quay as opposed to perpendicular. This allows both ends of the stack to be used effectively for transshipment. Using the traditional perpendicular alignment of ASCs in a transshipment terminal can also work (it was done in Algeciras, for example) but it leaves the landside ASC crane underutilised and may generate an excessive amount of rehandling moves to properly utilise all of the terminal's container storage. Transshipment terminals may benefit from an oversized waterside block of storage served by cantilever RMGs to maximise accessibility to the most useful storage location on the terminal.

Most traditional "fully automated" terminals like Euromax or CTA Hamburg use a completely manual tractor move to transfer a container

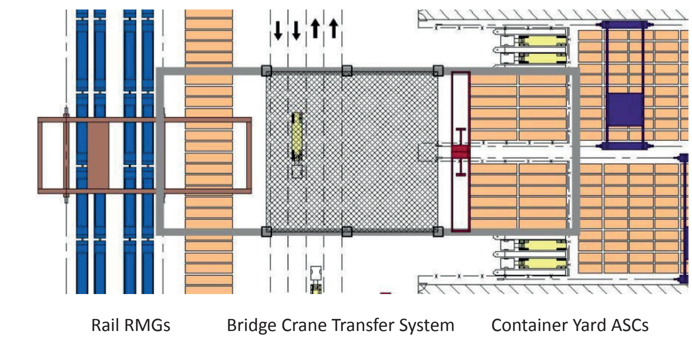

Figure 3: Bridge Crane IY Connector Concept

from the ASCs to the on-terminal intermodal railyard (IY). This may be fine for terminals with 10% of cargo moving via rail, but some terminals on the West Coast of North America move over 50% of vessel cargo via rail, and may be more motivated to explore options to allow automated vehicles to move containers between the CY and IY.

Physical separation of manned and automated equipment is one of the fundamental principles of automated terminal design, so terminals that want to connect the CY and IY with robots have two options:

1. Restrict gate trucks to a limited area of the terminal and allow at-grade access for robots in the remainder. This is the strategy employed by TraPac in Los Angeles. The tip of the triangle in the foreground of Figure 2 is an area for robots only
2. Use a bridge crane to lift containers over street trucks and connect the CY and IY

Option 2 has yet to be used in an example terminal but was described in detail in an article in the July, 2010 edition of Cargo Systems Magazine. An example plan and section view of this option is shown in Figure 3. It offers the advantages of allowing gate trucks full access to all of the AGV stacks, and will have a much lower operating cost than use of AGVs or automated shuttles.

Although much seems to be settled in 2016 for automated terminal design, there are still opportunities for innovation and improvement. Differences in terminal shape, cargo mix, labour cost and productivity, and other considerations will continue to push terminal development in different directions as more terminals around the world make the leap to automated operations.

ABOUT THE AUTHOR

Mark Sisson leads AECOM's marine analysis group. He is responsible for business development, project execution, and oversight of research and development of AECOM's simulation models. Mr Sisson has over 20 years' experience managing and executing a wide range of marine and rail terminal planning, simulation, and analysis projects. Typical projects involve supervision of field data collection, model development, and presentation of analysis results. Sisson received his BS in Civil Engineering at California State Polytechnic University and his MS in Civil Engineering from Northwestern University and is a registered professional engineer in the state of California, USA.

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2016 UPDATE

CAN THE SOFTWARE KEEP UP WITH THE HARDWARE?

One trend to watch in automation is the performance of new terminals soon after opening, and over time. This is difficult to do of course because KPIs such as quay crane moves per hour are rarely made public. That notwithstanding, there has been plenty of anecdotal evidence that new automated terminals such as Rotterdam World Gateway (RWG) have opened to relatively modest levels of productivity.

RWG is surely one the most expensive terminals ever built, with a site based on ocean fill and 100% brand new equipment featuring very sophisticated technology such as tandem 40 quay cranes and lift AGVs. It seems that, despite significant pre go-live testing, this terminal opened with levels of quay crane productivity that are perhaps only 50% or less compared to its theoretical maximum. CTA Hamburg experienced a similar situation when it opened in 2002 and it seems that the ensuing decade has not made automated terminal openings any smoother. Labour is clearly not the main culprit here as these terminals use very little of it (quay crane driving and IBC handling still required labour however even in a "fully automated" terminal).

The biggest challenge for productivity in automated terminals seems to be management of a pool of free ranging, rubber tired vehicles. The terminal TOS must constantly be determining the "best" vehicle out of perhaps 30 or more to assign to each container move, as well as the best position to put each container in the yard. It may well be that the quest for perfection in these work task assignments is actually counterproductive because the situation is so dynamic that it generates constant churn in the TOS and delay in making assignments instead of action that is prompt and good enough.

Despite perhaps being a disappointment to industrial engineers in its early days, CTA generated productivity that was good enough for its shipping line customers to rapidly fill the first phase with business and expand the terminal, and to inspire many more automated terminals. The level of investment is so high, and so fixed, that failure is not an option for new automated terminals. In poker terms, once a decision is made to automate, the terminal ownership is "all-in" and must do whatever it takes to get adequate terminal performance. It seems prudent to set productivity expectations low, and technical support levels high, in the initial months and even years of fully automated terminal business cases.

Much like John Henry beat the steam drill, ASC terminals with manual shuttles or straddle carriers moving boxes between the quayside and the ASC waterside buffers appear to be beating the terminals that rely on robots for transportation, at least in terms of quay crane productivity. It will be interesting to see if and when the improvements in sensors, driving software algorithms, and collective management experience allows the robots to produce productivity on par with human drivers.