Automation and electrification are the twin goals of advanced container terminals worldwide. They are driven by the desire for reduced costs and reduced environmental impacts of operations, as well as financial pressure for higher utilization of expensive capital assets gained by moving toward 24/7 operations.

Automated stacking cranes (ASCs), which are now the industry standard for new terminals and have been the backbone for automated terminal operations for over 20 years, already meet both goals. Given that container yards (CY) themselves are already highly optimized, one of the more interesting questions facing port planners in 2017 is how to expand these desirable operating characteristics beyond the container yard.

**PLANNER TARGETS**
The first target is the on-terminal intermodal railyard. TraPac in the Port of Los Angeles became the first terminal to automate moves to an on-terminal railyard. The gate traffic there is limited to only part of the terminal, giving autostrads free reign at the narrow end of the terminal as shown in the foreground of Figure 1. This allows autostrads to move between the wharf, the triangular strad buffer, and the railyard without crossing any street truck traffic.

For rectangular terminals with the railyard at the landside of the terminal parallel to the quay, limiting the gate trucks to a subset of the ASC stacks in order to facilitate rail automation may not be desirable. In this case, overhead bridge cranes may be used to connect CY and IY on terminal, allowing gate trucks to travel underneath. This solution could replace the use of manual tractors and terminal chassis used to move containers to on-terminal railyards at terminals such as Euromax in Rotterdam, Netherlands.

Looking one step farther out from the CY takes us to external but adjacent – or nearly adjacent – railyards or warehouse districts, or other terminals in a transhipment hub such as Jebel Ali that operates four large but distinct terminals within one port complex. These off terminal destinations may be the recipients of tens or hundreds of thousands of container moves per year that travel via external trucks that are manually operated and diesel powered, with all of the resulting costs and emissions. What can be done to improve upon this status quo?

**THE GRID SYSTEM**
These external moves may instead be performed by bridge cranes for short distance moves, or AGVs or even automated trucks for longer distance moves. Overhead bridge cranes are easy to automate, have very low operating costs, and have the advantage of built in buffer storage at either end. They can be independent, or integrated into an entire terminal such as BEC’s GRID concept of overhead two dimensional structures to provide higher capacity.

**EXPANDING TERMINAL AUTOMATION BEYOND THE CONTAINER YARD**

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Figure 2 shows an example of the GRID system. The network of overhead beams allows the same spreaders to cover the gate, container yard, and rail yard without interfering with street trucks or trains.

Once the distance traveled exceeds a few hundred meters, a stand-alone bridge crane is limited to fairly low volume due to limited spreaders on one set of rails. A GRID system allows spreaders to change rails for effective two-way spreader travel and allows for much higher capacity. As the distance to the destination continues to climb, the capital cost for the construction of overhead systems may become prohibitive, however. In this case, standard but physically separated roadways can be used for automated vehicles; either AGVs, or automated trucks.

GAME CHANGERS
Given that large corporations ranging from Daimler, Amazon, Google, Uber, and Tesla are investing a great deal of money in the automation of cars and trucks, technically feasible automated street trucks seem likely to be a reality within just a few years. The issues surrounding safety and political difficulty of mixing robotic heavy trucks with standard auto traffic will be likely be more difficult to overcome than the technical issues with driving the truck itself. This problem can be eliminated through the use of dedicated roadways near the port area. Similar roadways are used in Rotterdam for trailer trains, so there is precedent for these in intra-port moves via physically separate roadways.

Both street trucks and AGVs can run on electric power. Electric AGVs currently are in use in both Hamburg and Long Beach. Figure 3 shows an example of one of the LBCT machines.

Tesla expects to announce an electric over the road truck sometime in 2017 (presumably also with a high level of automation capability). If battery range for electric vehicles is not sufficient, the road could be equipped with inductive charging or overhead catenaries, such as those being developed by Siemens, to boost range. The use of stations to allow the swapping of batteries is also an option. This is the technique used by LBCT to ensure continuous AGV power is available.

If space is available, these dedicated roadways for electric automated vehicles could extend a considerable distance from the marine terminal. Depending on the availability of right-of-way and constriction costs, dedicated roadways could be a practical solution to allow automated electric vehicles to reach high volume cargo destinations within perhaps 10–20 km from a marine terminal.
The most dramatic option to move cargo to more distant destinations at much higher speeds is Hyperloop, a new technology based on magnetic levitation within an enclosed tube with low ambient pressure to minimize air friction. Hyperloop is also automated and powered by electricity. Figure 4 shows a conceptual rendering of a Hyperloop terminal.

Hyperloop freight systems could theoretically achieve speeds of 1000kph in a vacuum tube, but with real limitations from bends in the track, operating speeds in the range of 200-300kph are more realistic. This is still much, much faster than other options and can link ports with distant, cheap warehouse land within minutes of travel. Most warehouses in Southern California, for example, are approximately 100km inland from the ports. At present, this requires a lengthy truck trip through congested roadways, creating both pollution and yet more congestion for each drayage move. Hyperloop would make these inland destinations much more convenient, and therefore more valuable, and remove trucks from congested roadways. Because the duration of Hyperloop trip is not just short but also highly predictable, containers can be delivered to a marine terminal in a just in time basis, radically reducing dwell time and related land requirements.

Regardless of the system used, any expansion in automation will pose both challenges and opportunities in terminal design. The safe and secure handoff of the container at each point in the journey will need to be ensured and documented. Planning for equipment breakdowns and maintenance must also be taken into account. Bridge crane or GRID systems, and also Hyperloop tubes, can be topped with arrays of solar panels to generate clean electric power on site.

The pressure from cargo owners and port area neighbors for low cost, low emissions transport that allows for predictable supply chains will only continue to increase over time. It will be very interesting to see how and where new technologies are used to advance the state of the art for automated cargo movement beyond the container yard.

**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. Mark 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, US.

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