# INTERMODAL RAIL FACILITY DESIGN FOR THE NEXT CENTURY

*David Vandeveer, Vice President of Maritime Planning*
*Vickerman-Zachary-Miller*

The onset of containerized shipping in the 1960s revolutionized the worldwide maritime industry and forever changed the face of the cargo-handling facilities at the world's major ports. We are now in the midst of a second revolution led by the dramatic expansion of intermodal railcargo. In 1984 there was one dedicated double-stack intermodal train per week running from the West Coast to the inland United States. Today, 10 years later, there are much more than 200 such trains weekly, and intermodal traffic is the fastest growing cargo segment for most major U.S. railroads.

In light of this dramatic and continuing growth, intermodal rail-handling facilities must be designed for long-term effectiveness. In addition, the importance of planning and designing intermodal rail facilities cannot be overemphasized from a land-use and master planning perspective. The constraints of accommodating intermodal's large track radii and adequate numbers and lengths of access, storage, and working tracks for trains, which are often more than 1 mi long, must take on a primary significance in overall land planning and transportation systems design. This expensive infrastructure may be difficult or impossible to modify in the future. Therefore, in designing intermodal rail facilities, it is important to get it right the first time. This paper will explore the key factors and design guidelines that should be considered to ensure that intermodal rail facilities designed today will remain effective well into the next century.

There are two major types of intermodal cargo-handling facilities: maritime container facilities, commonly referred to as container yards, and intermodal rail facilities, commonly referred to as intermodal yards. Although this paper will deal with the future of the newer of the two facilities—intermodal rail—an examination of the evolution of maritime container terminals can illuminate the developments that are likely to occur at intermodal rail facilities.

Consider the history of maritime container facilities. A constant stream of physical and operational innovations has been applied to maritime container vessels, handling equipment, and facilities, with varying degrees of success. These innovations continue to resize and reconfigure the infrastructure requirements of these facilities. The same phenomenon is now occurring at intermodal rail facilities.

Much has been written about the appropriate sizing and design of third- and fourth-generation maritime container facilities. This subject, therefore, is therefore not included here. A brief review of the history of these changes, however, will shed light on the likely course of evolution for intermodal rail facilities. If history repeats itself, the phases of evolution (generations) for intermodal rail facilities will proceed in the following pattern:

- *Generation 1.* The conversion of traditional cargo-handling facilities into dedicated or partial intermodal rail facilities.
- *Generation 2.* The application of minimum requirements, learned through trial and error from the failures of inadequate configurations developed in generation 1.
- *Generation 3.* The development of terminals that are reasonably configured, sized, and well-proportioned to accommodate an appropriate volume of cargo for the life of the facility.
- *Generation 4.* The refinement of third-generation standards to allow the introduction of proven innovative features without sacrificing the basic land-use efficiencies learned in earlier generations.

The first phase of evolution involves the conversion of traditional cargo-handling facilities into dedicated or partial intermodal rail facilities. This phase is currently in progress. By paying careful attention to the lessons learned on the maritime side, it is possible to fast-forward through generations 2 through 4 for intermodal rail facilities.

For example, Vickerman-Zachary-Miller (VZM) was assigned by Union Pacific Railroad to explore an ideal terminal concept with respect to land use, track configuration, storage areas, gate facilities, administration and maintenance, and support facilities. This idealized concept incorporates advanced features which are available today and provides the flexibility to allow future innovations to be added. This approach not only provides terminals that will remain in a state-of-the art-mode well into the next century, but also provides a consistency that allows Union Pacific staff to develop and operate using consistently efficient procedures.

### Key Elements of Intermodal Rail Facilities

What are the key elements of an efficient intermodal rail facility that has the ability to remain state-of-the-art years after its initial design? Judging from the history of maritime container facilities, there are a number of basic principles that guide the design of successful, long-lasting facilities. These principles include designing the facility for the following characteristics.

*Responsiveness to Overall System*

This means understanding the macro systems picture. How does the facility—whether on-dock, near-dock, or remote—relate to the overall transportation system? If the facility designer becomes more involved with the trees than the forest, the design may incorporate features that inhibit the overall efficiency of the system. For example, a gate can be designed to concentrate on equipment damage inspection procedures; yet, from an overall systems perspective, equipment damage inspection has relatively little effect on the ultimate goal of rapid and efficient cargo movement. A more important consideration might be to plan for future needs related to intelligent transportation systems such as intelligent vehicle highway systems.

*Ability to Accommodate for Long-Term and Short-Term Expansion*

The best way to plan for long-term expansion is to establish a full build-out scenario to use as a guide for the immediate design. Not only should the overall facility footprint be located and configured to allow the eventual phased development into the full build-out scenario, but every detail of the facility should be tested against these criteria. Usually there is little or no capital cost involved in locating and aligning facility elements for this kind of expandability. Furthermore, the facility design should allow short-term expansion such as that required by annual peak periods. For example, wheeled storage areas can be designed to allow occasional stacked storage for peak periods, and gates can be designed to allow reversible inbound and outbound flows to allow variations in directional peaks.

*Adaptability to Current and Future Technological Advances*

This does not necessarily require that every new technology be incorporated in the immediate facility design. It may only be necessary to provide enough space in the layout to allow future implementation of such elements as automatic equipment identification (AEI), vertical line scanning cameras, paperless gate transaction equipment, and equipment handling and storage innovations. These innovations include chassis stacking racks, pin-handling systems, yard inventory systems, and automatic guided vehicles. In some cases, it may be prudent to provide in-ground conduits for future applications, especially where it would merely involve including additional conduits in a planned installation. Other advances that should be incorporated in the design include responses to environmental mandates. For example, the storm-drain systems should be designed in accordance with the latest requirements of the National Pollutant Discharge Elimination System.

*Flexibility for Alternative Equipment-Handling and Storage Modes*

This important aspect can be incorporated in the design by analyzing alternative handling modes for a given facility and then selecting the mode with the highest priority for the basic layout, while incorporating other high-priority layouts in the facility design. These modes can be changed after several years, such as when a new operator prefers one type of equipment over another or when the mode of operation may be changed on a monthly or daily basis to accommodate variations in density of storage requirements, type and size of equipment, and mix of trailer-on-flat-car (TOFC), container-on-flat-car (COFC), and double-stack cargo volumes.

VZM's technique for ensuring this flexibility is referred to as the Modular Grid Overlay System (MGOS). This system uses a series of computer-aided design and drafting overlay drawings for each handling mode. The drawings are overlaid to identify windows of opportunity for fixed facility features. This design approach allows any of the operating modes to be easily implemented as needed. Figure 1 shows the MGOS for an inland intermodal railyard (conceptual design for Union Pacific's planned Memphis terminal). Figure 2 shows the MGOS as applied to Maersk's Port of Long Beach on-dock facility. Figure 3 shows the use of MGOS for a planning project in Russia, where rail-mounted cranes may be used in the future. In all cases, the system allows the operator to start small and phase into higher throughput conditions in the future.

*Accessibility for Both Rail and Road Movements*

Designing to accommodate this principle requires a thorough understanding of possible train and track configurations, volumes, and peaking characteristics. Again, an understanding of the macro system is essential. Although it may be necessary to provide receiving and departure, storage, repair, and runaround tracks for a given facility, it may be a wasted use of space and capital if nearby rail marshaling capability is

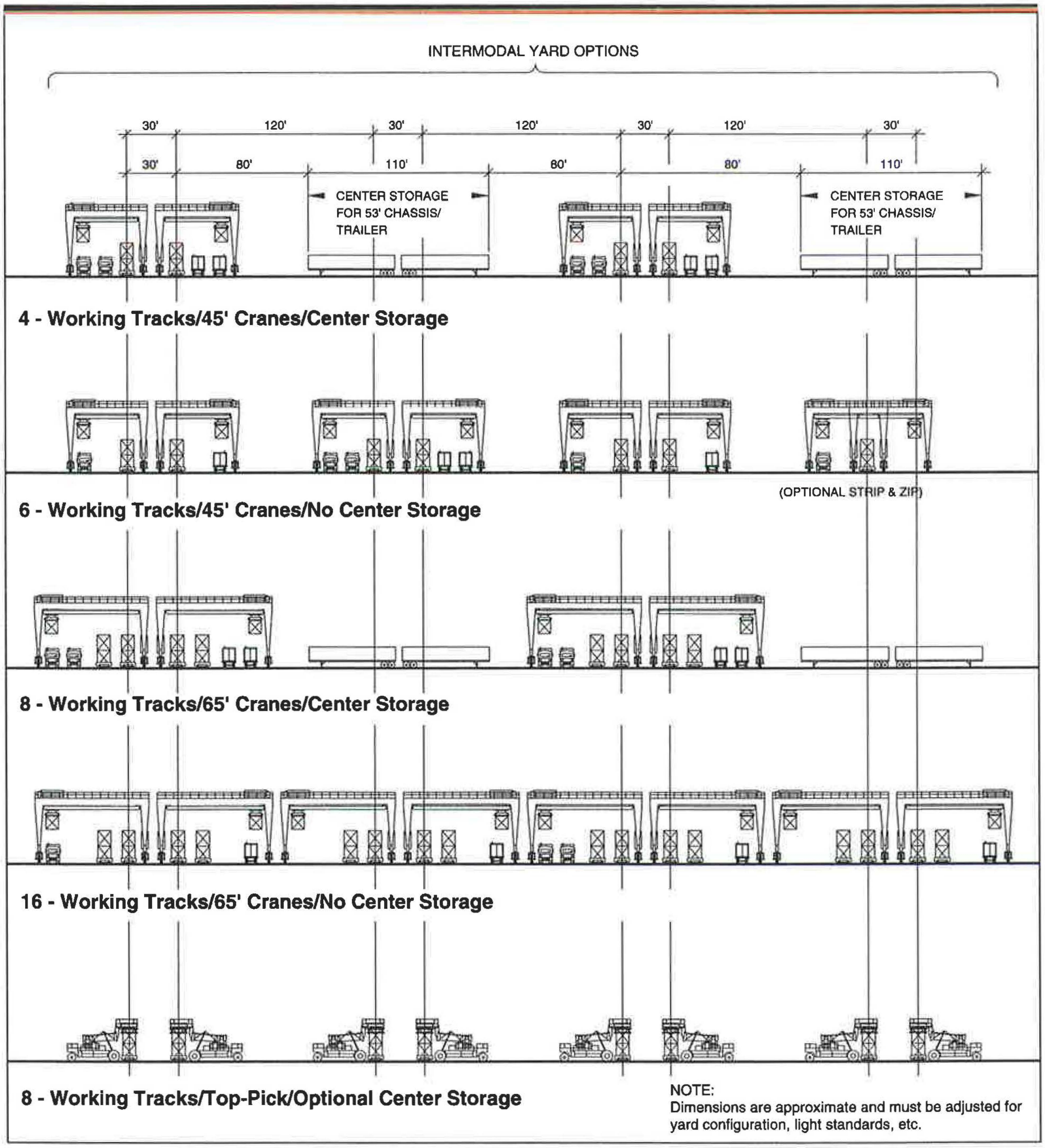


FIGURE 1 MGOS System for Union Pacific Railroad — Memphis Inland Intermodal Rail System — conceptual cross section.

available. All sizes of rolling stock must be considered. If the storage or working tracks can accommodate an incremental number of railcars in an expected size (e.g., 305-ft double-stack cars), does the track length fall just short of accommodating an increment of train length consisting of another size of car (e.g., 89-ft flatcars)? If so, the track length should be adjusted to allow this possible condition. Similarly, the yard and gate should

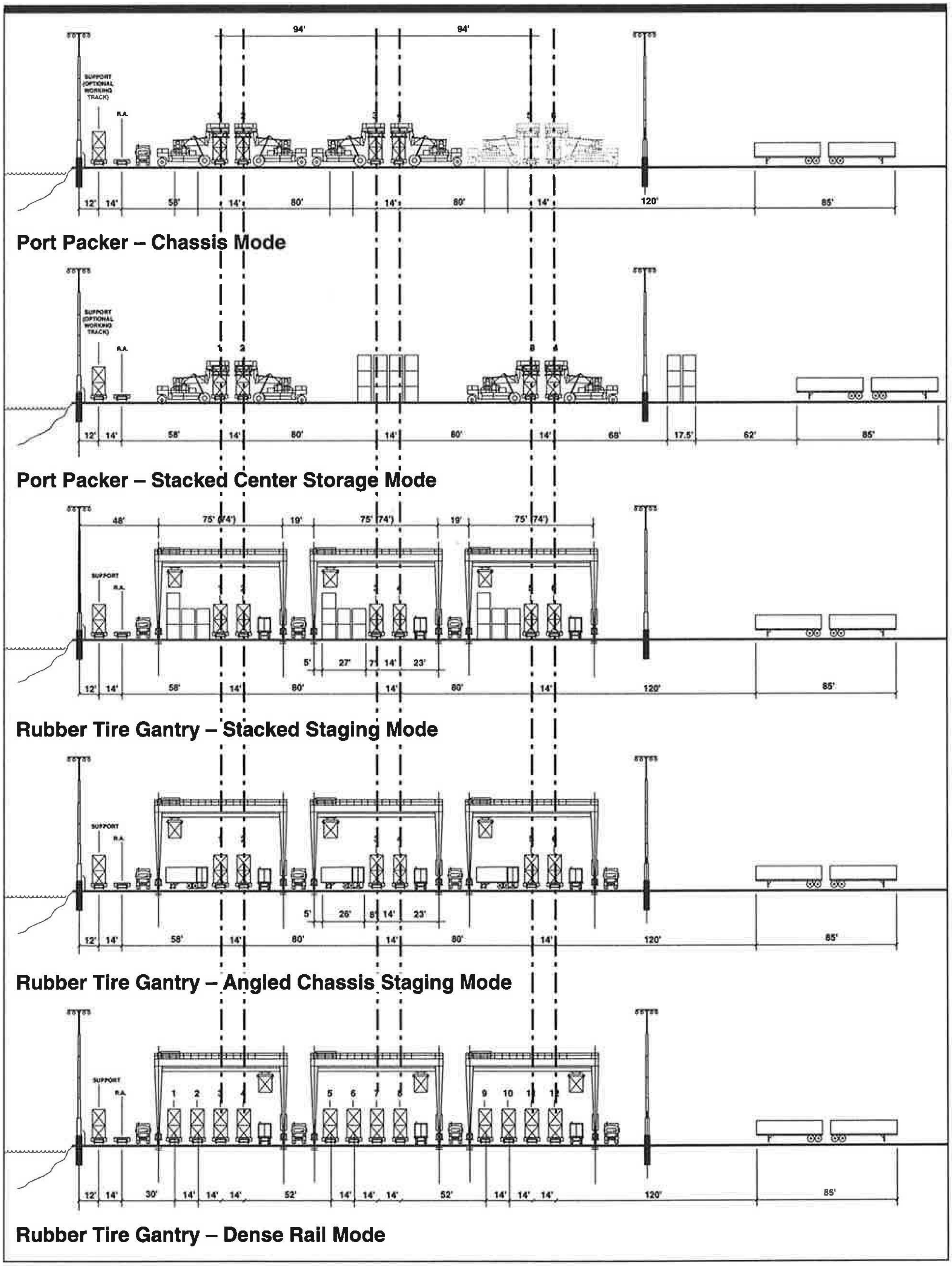


FIGURE 2 Maersk Pacific LTD — Port of Long Beach — cross section.

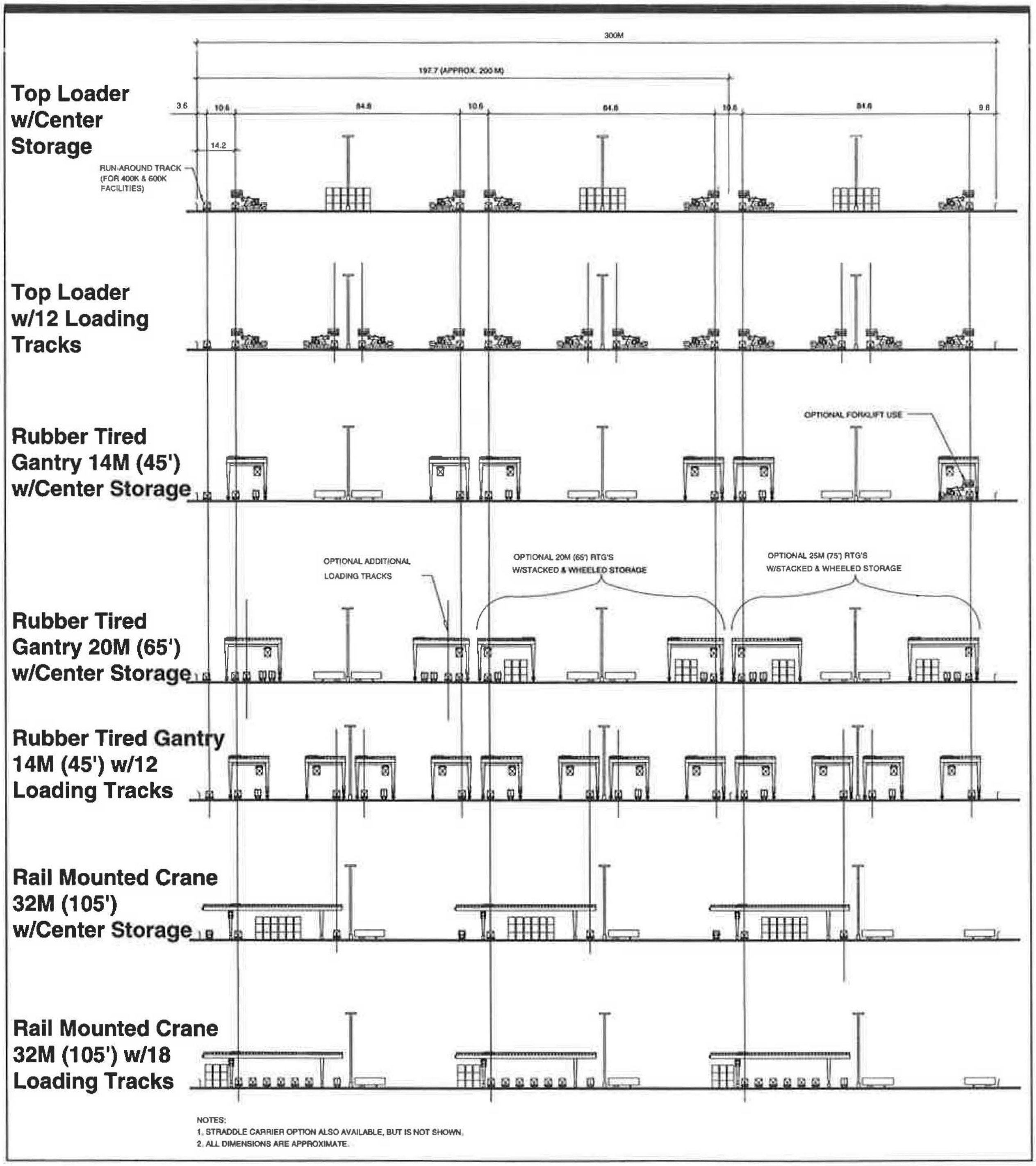


FIGURE 3 Russian railway development of intermodal transport intermodal terminal — Modular Grid Overlay System (MGOS).

be configured to accommodate a variety of container and trailer sizes. The value of understanding and designing efficient road and rail access is clear when one considers the fact that these access issues form the basis of judgment for a facility's trucking customers and for the adjacent community. Access and congestion problems are the most common basis for a customer or community perception that a facility is flawed.

*User-Friendliness for Operators and Customers*

This means that a facility should be able to be operated as simply and logically as possible. As important as it may be to incorporate technological bells and whistles, it may be even more important to provide design elements that are capable of operating effectively with any user, regardless of the user's level of familiarity and skill. Furthermore, the flexibility to provide simple operations in case of temporary computer problems must always be considered. For example, in our gate designs for several Union Pacific facilities, some or all of the lanes are designed to allow unstaffed, or remotely controlled, transactions. However, the space is provided to allow human interface with mobile data terminals, or clipboards, if necessary. In addition, the space to add future clerk booths is provided, if the operator wants to add that capability.

*Cost-Effectiveness and Space-Efficiency*

This last principle certainly is not the least. In an attempt to provide space and infrastructure that will accommodate every contingency, the designer could easily overdesign elements of the facility. Considering the possibility that an intermodal rail terminal may be approximately 6,000-ft long and that each $ft^2$ of grading, paving, and infrastructure may cost \$7 to \$8 (not including land purchase costs), each 10 ft of width could cost the owner more than \$240,000 in capital costs. Therefore, the prudent designer will attempt to balance an ideal terminal design with a pragmatic, workable design that still allows efficiency, flexibility, and expandability. Even more important, the designer should understand and balance the throughput-generating capability for each component of the facility. VZM uses a computerized throughput capacity model to do this. The model breaks a terminal into six components. The result is that all elements of a facility are balanced so that money and space are not wasted by overdesigning a given component.

## SPECIFIC DESIGN RECOMMENDATIONS

To incorporate these general principles into specific recommended design features, it is useful to consider each of the six facility components. In each component, key design features are noted that should be considered to ensure that the terminal will remain effective over the long term.

### Train-Staging Activities

Access tracks with radii of at least 600 ft should be carefully planned to ensure that expected train lengths can be accommodated. The ability to make up full trains (e.g., twenty-eight 305-ft cars) and to break down segments with a minimum number of breaks should be considered. These activities affect the design of the lead tracks (multiple leads should be considered where possible), the receiving and departure tracks, storage tracks, and runaround tracks. Where possible, the storage and runaround tracks should be designed to be used as working tracks in peak periods. Repair and other support tracks also should be incorporated in the design with flexible uses in mind. Typically, storage tracks should match the length and number of working tracks. However, this requirement may not be necessary if train storage can be accommodated by nearby facilities or by the working tracks themselves.

### Train Stripping and Loading

This activity represents the heart of intermodal rail facility operations. A number of equipment options have been proven, each with pros and cons. These include the following:

- Rubber-tired gantry cranes (RTGCs) over single tracks;
- RTGCs over multiple tracks (45-, 65-, and 75-ft widths are common);
- Top picks (packers);
- Straddle carriers; and
- Rail-mounted cranes.

Examples of these equipment options are shown on Figures 1, 2, and 3. Future loading modes may include the following:

- Automatic guided vehicles;
- Direct ship crane to intermodal track conveyance systems;
- Fixed infrastructure conveyance systems; and
- Multiple container block loading such as for the FastShip system described later.

Because each mode has its own pros and cons, it is essential that flexibility for future equipment changes and day-to-day interchangeability of equipment be incorporated in the design. Flexibility to accommodate various loading operations such as trackside prestaging, live loading by customer or terminal hostler, dual cycling, and train-to-train transfers also must be considered. Figures 1, 2, and 3 give examples of flexible layouts. *By incorporating the maximum amount of flexibility and expandability in the terminal, the designer helps ensure that the facility will remain efficient and user-friendly long into the future.*

**Trackside-to-Storage Transfer**

If train stripping and loading represents the heart of the operation, trackside-to-storage transfer represents the main arteries and veins. It is the designer's job to provide appropriate sizes and configurations of aisles to provide adequate circulation.

Proper design of this element involves more than just providing enough space. Again, a great degree of flexibility is required to allow various mixes of traffic, including the following:

- In-terminal hostler traffic (yard tractor and yard chassis "bomb cart");
- Both live load and prestage modes;
- Customer live load; and
- Direct loading equipment to track circulation (such as straddle carrier loading).

In addition, the design must be conducive to a counterclockwise traffic flow that meshes with the normal right-hand traffic at the gate and minimizes blind-side turning by truck drivers. Clockwise flow should be encouraged in left-hand–drive countries. The counterclockwise requirement is complicated by the need to account for random variations in the direction of containers and trailers as placed on the train, which may require trucks to make figure-eight turns or loading equipment spreaders to rotate. In addition, other traffic flow elements must be considered, including the following:

- Accurate and controlled inventory;
- Hostler (ramper) equipment control;
- Train-moving alarm; and
- Truck crossing control at train breaks.

This last item may best be served by signals mounted flush with the ground to avoid signal poles interfering with the loading and transfer equipment clearance requirements.

**Storage Yard**

In planning an efficiently sized intermodal rail facility, the placement and configuration of the trailer, chassis and container storage are critical. Because working tracks are thousands of ft in length, an overly generous storage configuration can cost millions of dollars in land and development costs. On the other hand an underdesigned storage area can limit the throughput capability, flexibility, and long-range viability of the facility. The major items to be considered in the planning and design of an effective storage layout follow:

- Site location and configuration;
- Type and quantity of equipment to be stored;
- Type of storage (center versus remote);
- Type of trainloading equipment;
- Prestaging and live loading considerations;
- Diagonal parking and mixed parking considerations;
- Chassis storage and vertical stacking considerations;
- Expected storage dwell time; and
- Flexibility and expandability.

A variety of types and sizes of equipment may be handled within a given intermodal facility. Typically, containers appear in lengths of 20, 40, 45, 48, and 53 ft and in 8- to 9-ft 6-in. (high-cube) heights. Larger sizes probably will be part of the future picture. Containers may be loaded on flatcars or on double-stack train cars. At inland facilities, trailers often make up a large part of the throughput volume. Trailers may be 28, 40, 45, 48, 53, or 57 ft in length and typically are loaded on flatcars. In addition, a variety of chassis sizes may be stored on site. Given the assortment of equipment and the variety of wheeled and stacked storage possibilities, it is essential that intermodal rail storage areas be designed for flexibility.

The amount of storage spaces needed varies for each condition. However, a reasonable rule of thumb is to allow a ratio of storage slots to static train slots of about 3:1. The dwell time in an intermodal yard typically is only about a day. If one train were to be turned around on each track per day, you would need a 2:1 storage-to-train-slot ratio (for unloading plus loading). However, it is not uncommon to expect two trains to be turned per day, which requires a 4:1 ratio. Fluctuations in anticipated dwell times, train turns per day, and use of off-site storage concepts will affect the actual number of storage slots required.

Because trailers cannot be stacked, short dwell times, and the expectation of quick pickup times by intermodal customers, wheeled storage is more common than stacked storage at intermodal railyards. There are two main types of wheeled storage: center storage, which provides a back-to-back row of trailer-chassis parking between two parallel working tracks; and remote storage, which provides multiple rows of storage in a remote location within the terminal.

If enough space is available, center storage has several advantages. Stored units with the same train destination may be blocked in groups, allowing less chance for confusion in the unloading and loading process. Also, the proximity of storage units to the working tracks results in an overall reduction in travel distance for the yard hostlers during unloading and loading. Center storage is efficient and conducive to quick train turnaround times. For a double-stack train facility using 90-degree stalls that are 10- or 11-ft wide, five storage units would be needed for each 55 ft of track length. This is a storage-slot-to-train-slot ratio of 2.5:1. For a single stack (TOFC or COFC) operation, the ratio would be 5:1. The average center storage ratio, therefore, is about 3.8:1.

On the other hand site geometry or other factors may require that some or all of the storage be in a remote location, and the facility may still work at a high-level of efficiency. Also, if dwell times are long and unit selectivity is not an issue (for example, in storing empties), a more dense grounded-stacked storage method may be appropriate. The option to allow various arrangements of wheeled and stacked storage to be implemented and adjusted as needed over the life of the facility can be an essential element of the long-term success and throughput capability of the terminal.

**Storage-to-Gate Transfer**

The transfer of a container to the customer at an intermodal yard should not disrupt other operations in the yard. To facilitate efficient storage-to-gate transfer, intermodal yards should include the following:

- Accurate storage slot placement and inventory control;
- A dedicated customer pickup area near the gate, if space and logistics allow;
- Gate bypass lanes for bobtails that allow quick access to the terminal; and
- The ability for customer trackside live loading when appropriate.

Computer systems designed to manage terminal inventory operations will maximize throughput and reduce costs. Computer inventory systems are often customized to the terminal and manage the following: pregate functions, gate-in and gate-out functions, yard planning and inventory control systems, equipment inventory and location control, container storage billing data and time-accounting tracking functions, equipment maintenance and repair status, shipping and billing documentation, AEI, and decision-support systems. Inventory control systems are currently being used by Conrail, Southern Pacific, and others to track containers to specific storage and parking lots within their yards. Future inventory systems will allow operators to be slot- and row-specific in the storage of containers. Using the Global Positioning System and AEI transponder tags on the containers themselves, terminal inventory managers will be able to locate containers on facilities to within 5 feet. Intelligent vehicle highway systems will allow terminal operations to be coordinated with global transportation strategies. Such innovations will continue to gain acceptability and reliability in the future.

**Gate Processing**

The gate of an intermodal facility has the potential to be the weak link in the chain of operation. Proper and consistent gate procedures must be controlled to manage inventory as well as damage control. The most important element that should be considered when designing intermodal gates is to provide expansion room for additional lanes and gate features as throughput increases. As containers entering the facility queue onto city streets, traffic citations issued to truck drivers and blocked city streets create an unfavorable public opinion of the facility. In addition, queuing of trucks leaving the facility can interrupt yard operations and create unsafe intermodal operations.

Gate procedures can be improved through reengineering the processes of an intermodal yard, based on the needs of the client, shipper, and yard operator. Most intermodal yards require the transfer of bill of lading information and driver's identification and inspect the container and chassis for damages. Procedural changes that improve process times and reduce inbound and outbound queue lengths include the following:

- Inbound empty and bare chassis lanes;
- Bobtail (road tractor) lanes requiring only precheck;
- High, wide and heavy lanes that may bypass check-in area;
- Spots for trouble parking; and
- Minimized inspection procedures that statistically monitor damages by inspecting less than 5 percent of in-gate moves.

The following technological improvements can reduce process times and reduce inbound and outbound queue lengths:

- Video ID cameras;
- Precheck area printers;
- Speaker pedestals;
- Swipe ID cards for drivers;
- AEI; and
- Electronic data interchange (EDI).

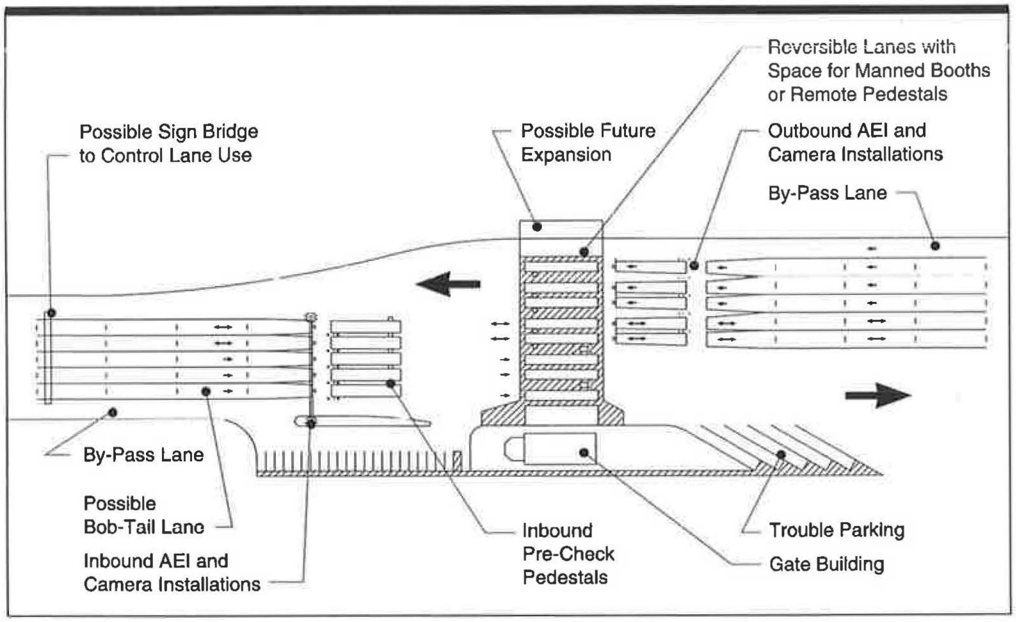


FIGURE 4 State-of-the-art intermodal rail facility gate.

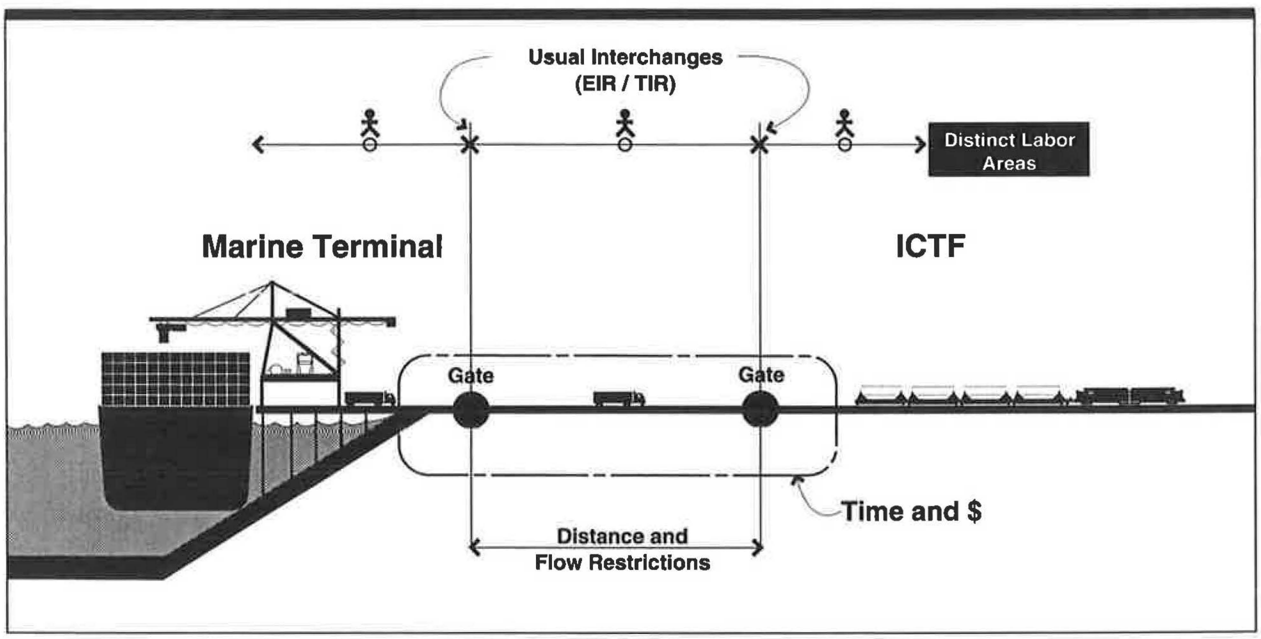


FIGURE 5 The intermodal interface, "the way it is."

The optimal gate process involves a driver pulling into a precheck lane and beginning the voiceless, paperless transaction of check in by swiping his or her computerized ID card and having his or her chassis and container read by AEI antennae mounted in the lane. The EDI equipment records the arrival time of the driver and processes the necessary bill of lading information. The inventory is updated, and the driver is told to proceed to a specific row and spot on the yard to park. The driver is able to bypass the inspection lane because of randomized, statistically balanced inspection procedures that keep accurate records of damages by

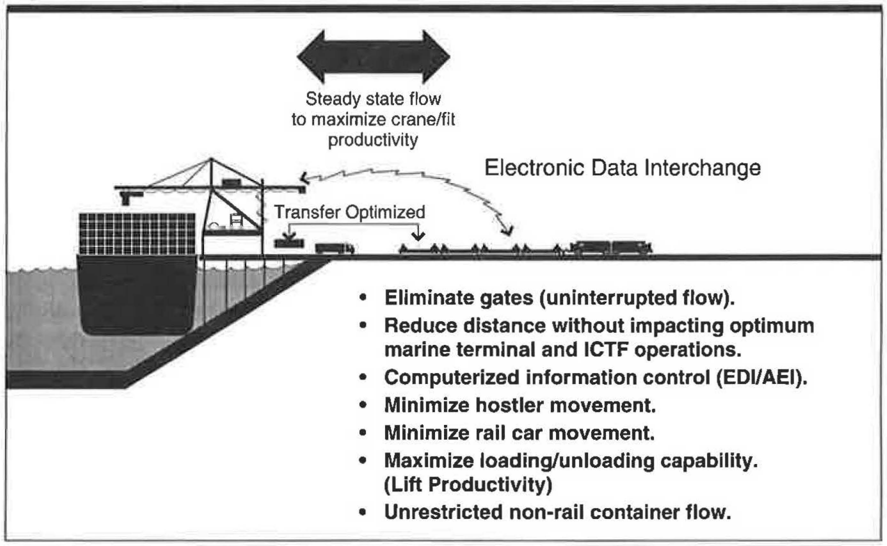


FIGURE 6 The intermodal interface, "the way it could be."

inspecting less than 5 percent of all in-gate moves. The actual processing time of an inbound truck is less than 1 minute. A typical intermodal gate arrangement for a state-of-the-art rail facility is shown on Figure 4.

### Support Functions

In addition to the basic trackage, circulation, and storage areas that make up the bulk of the typical intermodal rail facility, a number of support functions, including the following, can be incorporated into the design:

- Administrationbuilding/operationscontrolsystems;
- Maintenance, repair, and fueling facilities;
- Hazardous materials control and containment;
- Refrigerated cargo support and monitoring infrastructure;
- Site lighting, security, public address, signals, etc.;
- Permanent or portable compressed-air facilities;
- Control tower (or future tower) considerations; and
- Railroad automatic vehicle identification.

The same principles of expandability and flexibility that are essential to the design of the overall facility should be applied to the design for each of these items. For example, the gate area probably will incorporate an administration building. Because this building easily could be located in a way that precludes future gate lane expansion, it is important to plan this area to grow into the long-term, full build-out scenario as described under design principles. Even if an item is not included in the initial design, space and conduit can be planned into the design to allow future implementation.

## POSSIBLE FUTURE INNOVATIONS

On-dock intermodal rail facilities may actually reduce the land area needed at maritime container terminals. Instead of building and expanding new facilities, VZM, through computer simulation, proved that existing on-dock facility layouts can dramatically increase throughput through improved operations without expanding port property. Applying the "just-in-time" inventory practice of minimal storage and fast transfer of cargo between modes, the study examined the effects of simultaneous load and discharge (SL&D) as an operational efficiency. It is possible to start loading import containers on the train as soon as they come off the ship, as long as the ship and train begin operations at the same time. If the rate of unloading the ship is matched by the SL&D of the train, transferring ship inventory to the train could be accomplished with no build up in the intermodal storage yard of import containers from the ship. The conclusions of the study were as follows:

- The SL&D concept results in a significant land savings over conventional intermodal operating systems (potentially 8:1).
- The system contributes to efficiencies in crane use and equipment requirements.
- The system is compatible with other emerging technologies in the industry, such as EDI and AEI, and

enhances the efficiencies of such enhancements as hatchless ships and dual-hoist cranes.

- The system contributes to environmental protection in that it reduces or eliminates the need for landfill or reclamation of tidelands and wetlands and reduces highway congestion in urban areas near major port facilities.

The FastShip concept is another innovative system that may affect future intermodal layouts. Focusing on high-value, time-sensitive cargo, FastShip Atlantic is now working with the Delaware River Port Authority to develop its FastShip concept. Attempting to become the Federal Express of containerized cargo, the FastShip concept will cut the time of the transatlantic shipment of containers by more than 80 percent. Working with VZM engineers, FastShip developed a loading and unloading system that depends on the "live-load" container concept. All cargoes are loaded and unloaded parallel to the vessel's centerline through Airlift Container Systems (Alicons). The Alicons are capable of lifting a double-stack, high-cube unit off the vessel deck or the dock through the use of high-pressure air. When linked together, a multiple-unit Alicons import train will be moved off the vessel. The FastShip terminal will have significantly reduced dwell time, to almost zero, moving all import containers off the terminal site within 12 hours of arrival.

The bottom line of all technical intermodal innovations is to facilitate the rapid and efficient flow of cargo. The importance of the overall system is paramount. Figures 5 and 6 compare the values of specific terminal design elements that can greatly improve cargo flow on a systems level.

## CONCLUSION

In summary, designing an intermodal terminal for the 21st century requires a combination of vision and practicality. The designer must leave room for future technologies and expandability, while providing the flexibility for a variety of conventional operations. The history of maritime container facility design has taught us that simple and pragmatic, yet creative, principles of design will lead to long-term effectiveness. These planning and design principles include an unfaltering commitment to the following:

- Overall systems context;
- Flexibility, expandability, and adaptability;
- Accessibility for rail and road traffic;
- User-friendliness; and
- Cost and space efficiency.

The planning and design process also can be simple, but may take the following extra steps:

1. Develop a long-range concept and a series of alternatives by priority.
2. Design the facility for immediate requirements.
3. Test the design of the overall facility and each element of the facility for adaptability to the long-range concept and to top-priority alternative operating modes.
4. Adjust the design to provide space and an easily installed infrastructure that will not preclude future enhancements.
5. Provide space and infrastructure for future contingencies.

The adjustments and extra design care needed to complete these steps usually are minor compared with the redesign for major future renovations that might be required. Moreover, to apply these options at the planning and design level results in a minuscule cost compared with the cost of future land acquisition and retrofitting that may face the operator of a facility that was not designed for long-term effectiveness.