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Reducing Train Turn Times with Double Cycling in New Terminal Designs

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North American rail terminals need productivity improvements to handle increasing rail volumes and improve terminal performance. This paper examines the benefits of double cycling in wide-span gantry terminals that use automated transfer management systems. The authors demonstrate that the use of double cycling rather than the currently practiced single cycling in these terminals can reduce the number of cycles required to turn a train by almost 50% in most cases and reduce train turn time by almost 40%. This change can provide significant productivity improvements in rail terminals, increasing both efficiency and competitiveness.

As the North American economy and international trade volumes significantly expanded in the 1980s, the introduction of double-stack service—beginning with the Southern Pacific Railroad in 1981 (*1*)—effectively doubled rail capacity where there were sufficient height clearances. Where there were not sufficient height clearances, the railroads often invested in infrastructure to create the necessary double-stack clearances. This increase in capacity coupled with an increase in main line average speeds (*2*), and double and triple tracking in strategic corridors, put a strain on capacity at the terminals. The Class I railroads nevertheless have continued to make rail (intermodal and carload) more competitive: from 2002 to 2007, rail productivity (rail revenue ton-miles per employee) increased by 11% (*3*).

Terminals in the late 1970s and early 1980s introduced many major innovations that allowed the industry to efficiently grow. These included the two-for-one ramp design (where loads are prestaged on one side while unloading occurs on the other side), center-row parking, chassis racks, and continuous duty-cycle overhead and side-lift cranes (*1*). However, a new wave of innovation is needed to ensure that intermodal rail shipping, which grew 4.9% annually from 2003 to 2008 (*4*), will not lag well behind trucking through the years 2020–2025 as forecast (*5–8*).

Although future rail productivity gains will be tougher to achieve, new and retrofitted intermodal terminals that transition away from wheeled operations (container on parked chassis) hold great promise. That is because of the major shortcomings of wheeled operations, foremost of which is the need for an ample chassis fleet to maximize chassis use (and the necessity of providing for their storage, stacking, tracking, and maintenance). A second shortcoming is the need to track and manage multiple truck scenarios (e.g., empty chassis drop off, container drop off and pick up, leaving empty after drop off, leaving bobtail after drop off, and chassis flips—the transfer of a container from a bad chassis). Third, wheeled operations require a fleet of yard tractors to shuttle chassis, with and without containers, to and from the ramp and remote storage area. Fourth, labor productivity suffers from the considerable amount of time drayage and yard tractor drivers spend connecting and disconnecting the chassis (also increasing equipment wear and tear). Fifth, the operation of the cranes and yard tractors must be synchronized, which is made more difficult by early- and late-arriving trains. Sixth, chassis fleets entail enormous repair costs and phantom damage claims problems. And last, high container volumes require significant real estate, especially with greater free container dwell time allowances.

Capacity constraints at rail intermodal terminals have triggered debate on the future direction of terminal designs and container handling technology. Expanding existing wheeled operations at conventional rail terminals poses difficult challenges. Many rail yards in cities such as Chicago, Illinois, were built in the 19th century, a boom time for the railroads. Usually sited on undeveloped land at the edge of urban areas, these rail yards were eventually engulfed by urban development. Most were of more squared proportions for railcar traffic, which was not ideal for a modern intermodal rail terminal. Modern terminals benefit from larger tracts and longer rail spurs so that typical 100-well-car trains do not have to be broken apart into two or three units in the yard. While general freight terminals use multiple spurs to permit the assembly of fewer railcars to form train blocks, intermodal trains serve a much more limited number of cities, often are dedicated to one destination, and benefit from longer ramps to minimize switching to build and break apart a train. Purchasing adjacent real estate to build longer ramps is often not feasible because of a lack of availability, community opposition, high cost, and the need for environmental remediation. Construction of highways over and adjacent to rail yards also limits redesign and expansion options.

As Class I railroads continue evaluating investments in infrastructure that will profitably expand capacity, there is a need to examine the feasibility of terminal designs that can expedite train and truck turn times while simultaneously reducing cost, congestion, and associated emissions of both criteria pollutants and greenhouse gases. Unfortunately, megaterminal designs can create a paradox between turning trains and turning trucks (i.e., optimizing train turn comes at the expense of truck turn or vice versa when cranes must choose between servicing the train or the trucks). The wide-span gantry (WSG) crane terminal operations that include an automated transfer management system (ATMS) have been designed to achieve this goal by focusing all terminal activity under the cranes and offering immediate container selection for both crane operators and motor carriers (*9*). To determine the feasibility of turning trains even more

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quickly, this study examines the benefits of double cycling, which is a central design element of the ATMS terminal.

LITERATURE REVIEW

To address growing highway congestion, several studies have evaluated the feasibility of diverting more roadway traffic to the railways (*5*, *10*, *11*). These studies identify the high cost of constructing and operating rail intermodal terminals, drayage costs, and the drayage distance from the origin–destination (O-D) pair as major impediments to the growth in rail intermodal operations. Rail intermodal operations move a significant fraction of international freight but only a very small fraction of domestic freight. The studies by Bryan et al. (*10*) and Casgar et al. (*11*) recommend diverting more domestic traffic to circus loading (ramps with bridge plates) chassis or truck–chassis for shorter intermodal O-D pairs. But this approach is not as energy efficient (compared with double-stack service) and would slow the progress of container economies of density: the greater the density along a corridor, the easier and more profitable it is to provide more frequent service. With sufficient density, many more corridors can reach returns that match the scope and scale equivalent to that of the Los Angeles, California–to–Chicago route, where intermodal operations with high-capacity, high-frequency trains are competitive with truck service. Many corridors still need to grow the volume to support double-stack service as the ongoing transition from trailer service proceeds. For example, the BNSF Railway—the largest intermodal rail carrier in the world—has gone from a 1998 traffic mix of 62% containers/38% trailers to a 2008 rate of 92% containers/8% trailers, as intermodal volume grew by 48% (*12*).

Wiegmans et al. (*13*) considered the risk per reward of a new generation of rail terminals but did not define what technology this entails; moreover, application of such data to North America is problematic because the volume of rail freight is much lower in Europe, and the analysis included shunting yards as well as railroad and transmodal rail. Terminal analysis should distinguish between capital and operating costs. The reduction of operating costs is paramount because it generates positive cash flow, generates profits for future capital investment, and (unlike capital costs) cannot be depreciated.

Double-cycling crane operations have been researched in the context of marine terminals, with a focus on developing methods to determine the benefits of double-cycling quay crane operations on container ships (*14*). That work was extended to determine the effects of double cycling in container port landside operations in an effort to increase productivity and improve vessel turnaround time (*15*). The results show up to 20% reduction in crane cycles and nearly 10% improvement on operational time. The research presented in this paper follows the methods and formulations developed by Goodchild and Daganzo (*14*) to estimate and model the benefits of double-cycling gantry cranes in the intermodal rail terminal.

BACKGROUND CONVENTIONAL TERMINAL OPERATIONS

Intermodal rail terminals consist of three interactive operations: gate, transfer, and storage. Storage has primarily been a wheeled operation, but stacking between loading ramps or in remote storage yards has grown in prevalence as freight volumes have increased.

All conventional container terminals are variants of two types: (*a*) chassis fleets–chassis storage areas with areas for parked container–chassis storage, and (*b*) stacked storage terminals that use remote storage areas and the center row to store stacked containers. Generally, small-volume terminals use wheeled operations or parked storage exclusively, and higher-volume terminals use parked storage but also stack in center rows and remote storage yards after all parking spots are taken. The following are the basic inbound and outbound operational sequences for a train turn.

Inbound Trains

Before an inbound train's arrival at a ramp, the yard tractors transport and parallel park a sufficient number of empty chassis trackside to unload all the top containers. Once the inbound train arrives, the inter-box connectors (IBCs) are unlocked by the ground personnel. Top containers from the double-stack car are then unloaded by a trackside overhead crane to the parallel-parked chassis. As the inbound train is being unloaded, yard tractor drivers usually begin picking up and delivering the chassis or inbound container to a storage area in the terminal. Yard tractor trips continue until all top containers are delivered to the designated inbound storage area. Next, railroad personnel remove the IBCs from all top castings of the bottom container sitting in the bottom cell of the double-stack car as yard tractors bring a sufficient number of empty chassis trackside from the chassis storage area to unload all the bottom containers. Bottom containers from the double-stack car are unloaded by the crane and then picked up and delivered to an inbound storage area. After the inbound train is unloaded, it becomes an outbound train.

Outbound Trains

Containers for the outbound train are sorted into blocks according to destination. When outbound containers are delivered by truck carriers to the terminal, the driver is given instructions on where to park the chassis–outbound container (a specific block location) in the storage area. Containers are stored in blocks with containers for the same destination. After all the chassis–outbound containers have been delivered and parallel parked trackside in blocks, the overhead crane loads them into the bottom cells on the train. Yard tractors then remove the empty chassis from trackside as railroad personnel install the IBCs in all container corner castings. The train is ready to pull once all the top containers are loaded and all IBCs are locked. Although this system has worked well for low-volume terminals, wheeled operations become increasingly more problematic as volumes increase. For a comprehensive account of conventional terminal operations, see Boidapu et al. (*16*).

WSG Stack Terminal Operations

The WSG terminal design eliminates yard tractors and stores containers under the WSG.

There are alternative WSG stack terminal designs: single and team. The single WSG operation features cranes straddling rail tracks, container stacks, and truck lanes; the team operation features one cantilever WSG feeder team straddling the truck lane and stacks, with the other cantilever loading team (higher cantilever to overlap) straddling the rail tracks, a few container storage rows, and sometimes truck lanes as well. With all storage under the cranes, both designs reduce three operations (gate, storage, and transfer) to two (gate and transfer).

There are considerable labor, traffic, and air quality benefits in eliminating yard tractors shuttling containers to and from storage, but the trade-off is additional lifts. Typically transfers involve a minimum of two lifts, with a period of storage in the stacks. Often there will be additional dig or rehandle lifts to retrieve the desired buried container for loading onto a truck chassis or railcar. However, the greater number of cranes improves the feasibility of more direct transfers (live lifts), which are rare at conventional terminals and difficult to achieve in practice without a negative impact on crane and drayage productivity. Although there are several WSG terminals in Europe, the first in North America was the 2008 opening of the BNSF Seattle International Gateway Yard featuring WSGs spanning three train tracks, four rows of containers, and two truck lanes. A second WSG terminal opened in Memphis, Tennessee, in 2010, followed by the CSX Northwest Ohio Terminal in 2011.

WSG In-Line (One-Way Traffic) ATMS Terminal Operations

An ATMS is in essence an active robotic parking stall—a minicrane—that can elevate, lower, store, and block and stage (position) containers without using an overhead crane or side-loading lift equipment so that a rail or port customer can be accommodated immediately (Figure 1). Designed to position and transfer a container between or among modes, ATMS sequences include chassis-to-ATMS-to-railcar for outbound freight, and railcar-to-ATMS-to-chassis for inbound freight. Aside from unlocking, removing, reinstalling, and locking IBCs, terminals with ATMS trackside eliminate all preparation for the accommodation of the inbound and outbound trains, permitting the immediate unloading and loading of containers when the train arrives at the terminal. Truck carriers transferring outbound containers automatically block and stage containers safely from the confines of their cab.

The ATMS would be positioned perpendicular or parallel to the tracks, depending on capacity needs. Without assistance from terminal staff, containers can be loaded or unloaded from the tractor driver's chassis to or from the ATMS. The multicell ATMS can be used to service very-high-volume ramps, with the tractors uploading containers to the ATMS bottom cell and the cranes loading the train from the ATMS top cell (Figure 2). After the crane transfers the top container, the ATMS automatically lifts the container from below. By including the ATMS trackside, the need for yard tractors is eliminated (*9*). The ATMS ensures that the crane operator never has to wait for the tractor driver and the tractor driver never has to wait for the crane. The ATMS simultaneously stores and stages containers for loading or unloading. This is critical because outbound and inbound containers need to be staged in ATMS bays adjacent to one another. This reduces empty movement distance; after an inbound container is unloaded from the train to the ATMS, the empty spreader moves just 10 ft to load the outbound container from the ATMS to the train.

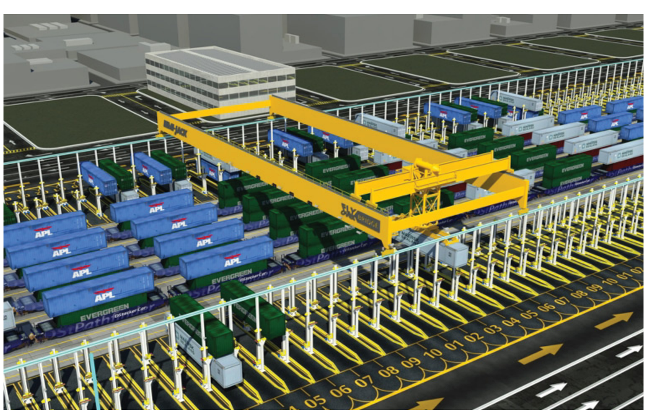

FIGURE 1 WSG in-line ATMS terminal. (Crane hovers over two-well car positions and 16 ATMS stations without traveling.)

FIGURE 2 Two-high ATMS positioned under WSG crane and perpendicular to loading tracks.

DOUBLE CYCLING IN INTERMODAL RAIL TERMINALS

This paper's objective is to determine the potential to reduce train turn times for a WSG in-line ATMS terminal using double cycling to maximize productivity. The use of double cycling reduces the need to make empty returns by loading and unloading the train simultaneously. For example, after a container is removed from the train, the crane does not return to the train empty, but rather, carries a container to be loaded onto the train. Train turn time consists of three components: (*a*) changeover (refueling, maintenance, crew, and equipment); (*b*) disassembly or assembly into two or more units; and (*c*) unloading or loading by single or double cycling. Double cycling can occur in three variations:

1. From inbound to outbound for a single train,
2. Servicing two trains with inbound from one track and outbound from another, and
3. Servicing two trains with empty well cars brought to the ramp to work around a late-arriving train.

All three variations fulfill the double-cycling requirement of adjacent inbound and outbound well cars (the ATMS already has all inbound and outbound containers staged in sequence). For Variation 1, two single-cycling moves are first required to unload the top and bottom containers from the first well car. Thereafter, the synchronization of the loading and unloading phases begins, reducing traverse moves by 50% (and gantry travel by 75%, with one pass to unload or load the train compared with four passes for single cycling).

In the following sections, the number of cycles required to turn a train using double cycling is quantified and converted to an estimated time benefit for WSG terminals.

Double-Cycling Train Turn Analysis

This section examines the effects of double-cycling WSG crane operations with the ATMS terminal design. Double-cycling benefits are compared with single-cycle operations and quantified by the number of crane cycles. The methods of using the lower bound developed by Goodchild and Daganzo (*14*) are followed to determine the number of cycles. Where ω is the total number of cycles, Λ is the number of containers to be loaded, γ is the number of containers to be unloaded, and Π and Π' are defined as the loading and unloading permutations, respectively. For this paper the assumption is made that $\Pi = \Pi'$ and that all inbound and outbound trains are completely loaded and unloaded. Given this, the number of cycles can be defined as follows:

Single cycle:

$$\omega = \gamma + \Lambda \tag{1}$$

Double cycle:

$$\omega \geq \Lambda + u_{\Pi'(1)} = \gamma + l_{\Pi(1)} \tag{2}$$

This analysis assumes a 5,000-ft ramp and train and a train with 83 double-stack well cars. In the first case, all containers are assumed to be 40 ft; in the second, 30% are assumed to be 20 ft-containers (70% are 40-ft). Using Equations 1 and 2, the number of required cycles is determined and the results are compared and presented in Table 1.

In all cases, there is nearly a 50% decrease in the number of cycles required to turn around the train when using double cycling as compared with single cycling. The two-container stacks in the rail cars allow for a near optimal crane productivity with only two empty crane moves per 83 well cars when double cycling.

Train Turn Analysis Case Study

In this section, the number of estimated cycles from the previous section are used to estimate the time required to turn a train, based completely on cycle time, assuming any other factors involved in turn time remain constant and are independent of crane operations. The five different track scenarios presented here are examined. In each case, the time required is compared using both single- and double-cycle crane operations from the following:

1. Single track with 10-ft traverse length,
2. Single track with 40-ft traverse length,
3. Single track with 90-ft traverse length,
4. Two tracks with 10-ft and 25-ft traverse lengths, and
5. Two tracks with 40-ft and 55-ft traverse lengths.

Crane data are used for a typical rail-mounted gantry crane. The traverse speed has been given as a maximum value. In typical crane operations, the maximum speed is rarely reached because of safety and precision restraints. Traverse times may also vary with each lift, depending on the talent of the operator. The authors have assumed the average traverse speeds to be 70% of the maximum when traversing with an empty spreader and 30% of the maximum when loaded. In each case, the time has been estimated for one complete cycle. The use of the ATMS allows immediate load or unload when the crane operator is ready. Each cycle movement includes the traverse, hoisting, return traverse, and final hoisting activities. The hoisting distance will be constant and has been estimated at 20 ft. The gantry speed used in this analysis is 70% of the maximum speed specified by the manufacturer.

Double cycling has a significant impact on gantry time; Table 2 shows a large decrease in gantry time when double cycling is compared with single cycling. With single cycling, the crane must travel the length of the track four times (two times during unloading and two during loading). With double cycling, the loading and unloading phases are completed with one gantry down the length of the ramp. However, the cycle times increase because of slower traverse speeds when moving with a container (compared with 50% empty-spreader moves with single cycling). The results in Table 2 demonstrate that the reduction in gantry time and empty traverse moves exceeds the increase in cycle time, resulting in significantly reduced turn times with double cycling.

It was noted in the previous section that the benefits of double cycling produced nearly a 50% decrease in the number of cycles required to turn a train when compared with single cycling. Figure 3 shows the percent decrease in the estimated train turn time to be 38%–40%.

Although double cycling reduces the number of cycles, the time of each cycle is increased because the hoist and traverse speeds are reduced when a spreader carries a full container. With double cycling, the crane spreader is full for a larger percentage of the cycle. Because traverse speeds vary, the authors introduce a range of ±20% to the traverse speed to understand the impact on cycle time reductions. The results are shown with the error bars in Figure 3.

The benefit of double cycling improved as the number of containers was increased. When considering Figure 3, the percent benefit seems to inversely correlate with the traverse length. However, Figure 3 includes gantry travel time, which increases with traverse length. When the turn time is considered only as a function of the number of containers and gantry travel is excluded, the positive correlation is again seen between the benefit of double cycling and the number of containers.

The traverse length has a large effect on the crane cycle time; a longer traverse will result in a longer cycle time. Double cycling reduces the number of cycles by nearly 50%, a factor that becomes

TABLE 1 Train Turn Analysis

	166 40-ft Containers per Track			216 Containers per Track (30% 20-ft)		
	Single Track In- and Outbound Service	Two Tracks In- and Outbound Service	Two Tracks with Empty Outbound	Single Track In- and Outbound Service	Two Tracks In- and Outbound Service	Two Tracks with Empty Outbound
Single cycles	332	664	664	432	864	864
Double cycles	168	334	332	218	434	432
% decrease	49.4	49.7	50	49.5	49.8	50

TABLE 2 Double-Cycling Case Study Results

Track Setup	Single Cycle No. of Cycles	Single Cycle Cycle Time[a] (s)	Single Cycle Gantry Time (min)	Single Cycle Projected Turn Time (min)	Double Cycle No. of Cycles	Double Cycle Cycle Time[a] (s)	Double Cycle Gantry Time (min)	Double Cycle Projected Turn Time (min)	Percent Decrease
Single track, 10-ft traverse	432	41.4	60.5	359	218	54.9	15.1	215	40.1
Single track, 40-ft traverse	432	55.7	60.5	462	218	73.2	15.1	281	39.1
Single track, 90-ft traverse	432	79.7	60.5	634	218	103.7	15.1	391	38.2
Two tracks, 10- & 25-ft traverse	864	90	60.5	709	434	118.9	15.1	447	37.0
Two tracks, 40- & 55-ft traverse	864	118.6	60.5	914	434	155.5	15.1	580	36.5

[a]Cycle times are calculated from manufacturer specifications and estimated movement lengths. The crane speeds were derived from the following crane specifications: Hoisting speed: 30 m/min loaded and 60 m/min with empty spreader, trolley traverse speed up to 150 m/min, and gantry travel speed up to 240 m/min.

more important as the cycle time is increased with the traverse length. Because the gantry time remains constant for a given terminal (the length of the ramp), the relative impact of gantry time is less significant as the total train turn time is increased, either by increasing the number of cycles or traverse length.

WSG Terminal Benefits

A major goal of an in-line terminal is the seamless transfer of containers to reduce intermodal train turn times. Current train turn times are typically between 10 and 14 h. It is clear from the results in the previous two sections that double cycling with an ATMS can contribute to this goal while achieving lower crane maintenance costs (less wear and tear from 50% fewer moves). Considering the broader terminal benefits of a WSG terminal with an ATMS trackside, it can be seen that by unloading and loading trains faster, more loading tracks are available more of the time and fewer trains have to wait outside the terminal at sidings, providing the terminal operator greater flexibility to keep trains on schedule.

Intermodal operations center around the train schedule that connects the throughput of the yard to the network, and the faster and more reliably trains can be turned, the greater the capacity of the terminal. The ATMS WSG terminals reduce operating costs compared with conventional terminals by eliminating

- Chassis for wheeled storage, yard tractors, and drivers;
- Repair, maintenance, parts, service, and inventory costs for chassis and yard tractors;
- Staff buffer to service daily peak hours as well as low productivity man hours during off-peak hours; and
- Searchers trying to locate misparked containers.

The elimination of yard tractors, chassis fleets, and reductions in terminal staff will result in significant operating cost savings. For example, the annual operating cost for each yard tractor ($64,000 for a new yard tractor) operating 2,000 h is estimated at $32,000 (*17*). Adding a labor cost of $90,000 ($45/h), results in a $122,000 operating cost per yard tractor, or $9,150,000 annually for a fleet of 75 yard tractors. Significant operating cost savings will come from the elimination of the chassis fleet as well (maintenance and repair of chassis and chassis stackers, inspections, storage costs, and insurance).

In conjunction with other innovations, train turn times can be reduced further. Converting the benefit of immediate selection into actual train turn time savings is difficult to quantify. To understand some of the other train turn time savings, movement and event reductions should be considered; eliminating yard tractors from shuttling chassis to and from storage areas will eliminate an additional 432 movements and events (216-container train × 2), and replacing IBCs with side-box connectors will eliminate another 1,728 (864 × 2) movements and events. Table 3 summarizes all the operations involved in turning the 216-container train for a conventional wheeled terminal operation compared with the most efficient modern terminal (in-line WSG ATMS terminal using side-box connectors). Aside from a reduction in movements and events and the actual time to perform these movements and events, there also will be the elimination of coordination delays with cranes.

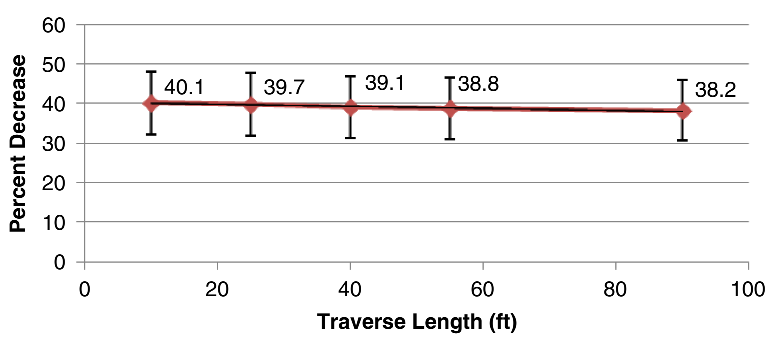

FIGURE 3 Percent decrease of estimated train turn time as function of traverse length in double cycling (number of containers is fixed at 216).

TABLE 3 Train Turning Operation Frequency in Conventional and ATMS Terminals

	Movements and Events (conventional)	Movements and Events (ATMS)
Unloading Phases		
Empty chassis from the storage area connected and driven trackside, disconnected and parked for loading	133	
IBCs disconnected, top container released	864	864
Spreader traverses empty to pick up top containers of double-stack car	133	[a]
Empty spreader lowered 10 ft to engage container	133	133
Engages corner castings, lifts container from double-stack car	133	133
Spreader traverses with container 25 ft	133	133
Spreader lowers container to chassis 17 ft	133	133
Gantry moves to next car to unload containers	83	83[3]
All loaded trackside chassis delivered to storage for local pickup	133	
All IBCs are removed from bottom containers	864	
Empty chassis from the storage area connected and driven trackside, disconnected and parked for loading	83	
Spreader traverses empty to pick up bottom container	83	[a]
Spreader lowered 10 ft to engage container	83	83
Spreader engages corner castings, lifts container	83	83
Spreader traverses with container 25 ft	83	83
Spreader lowers container to chassis 8 ft	83	83
Gantry moves to next car to unload containers	83	2[b]
All trackside containers–chassis delivered to storage for local pickup	83	
Loading Phases		
Outbound chassis–container connected at the storage area, driven trackside, disconnected for train loading	133	
Spreader traverses empty to pick up container from chassis	133	[a]
Spreader lowered to engage container from chassis	133	133
Spreader engages corner castings, lifts container	133	133
Spreader traverses with container 25 ft	133	133
Spreader lowers container to double-stack car 10 ft	133	133
Gantry moves to next car for loading containers	83	2[b]
IBCs inserted in bottom containers	864	
Spreader traverses empty to pick up container from chassis	83	[a]
Spreader lowered to engage container on chassis	83	83
Spreader engages corner castings, lifts container 17 ft	83	83
Spreader traverses with container 25 ft	83	83
Spreader lowers container to sit atop bottom container	83	83
Gantry moves to next car for loading containers	83	[a]
IBCs secure top to bottom containers	864	864
All empty chassis trackside driven to storage, disconnected and parked[b]	83	
Total	6,596	3,624

[a]No empty traversing and lower gantry number reflect double cycling for wide-span ATMS; one gantry pass (83) for loading and unloading versus 4 ($83 \times 4 = 216$) for a conventional operation.
[b]The number of movements assumes that the conventional terminal parks chassis; if chassis are stacked or racked, 432 movements and events would be added.

Modern WSG crane-equipped terminals, with cranes capable of lifting a double stack, could provide "thruport" services in an inland port city such as Chicago or Memphis. A thruport is the equivalent of an airport for freight, in which multiple Class I railroads can dock and exchange freight, eliminating the current practice of trucks shuttling freight from one railroad's terminal to another railroad's terminal (*18*). Of the 13.98 million 20-ft equivalents that entered Chicago by rail in 2006 (*19*), anywhere from 30% to 50% is estimated to be interchange traffic (direct transfer from one train to another); the statistic is not tracked and is difficult to estimate because independent brokers generate the majority of rail intermodal sales. Building intermodal mega terminals with thruport services will be necessary for rail intermodal operations to efficiently evolve into a hub-and-spoke transportation network from the largely point-to-point model of today so that reliable and frequent intermodal service can be offered to an increasing number of O-D pairs. It also would help intermodal networks better meet the needs of supply chain networks that were designed without taking intermodal operations into account (*3*).

Table 3 summarizes all the operations involved in turning the 216-container train for a conventional wheeled terminal operation compared with the most efficient modern terminal.

Immediate selection and double cycling that limits gantry travel gives terminal operators the ability to determine the train turn time desired and then equip the ramp with that number of cranes. Aside from the WSG ATMS terminal achieving a much faster train turn time for any given number of cranes, turn times can be further improved by adding cranes. But, adding cranes to the conventional terminal operation usually does not result in an appreciable improvement because of the greater congestion created and the difficulty in keeping operations synchronized as more equipment and labor is directed at turning the train.

In theory, a team WSG terminal could match the train turn time of the WSG ATMS terminal, but in reality this is unlikely for several reasons. Containers would need to be stacked so that train loading would not require additional rehandling and outbound stacked containers could be located as easily by the crane operator as the fixed positions of the ATMS. In addition, it would be difficult to replicate the ability of the ATMS to automatically communicate container identity to the gate, crane operator, shippers, consignees, dray firm, and driver the moment the container is set in the ATMS. Further, the additional rehandling lifts required because of stacking up to five containers high would necessitate more than twice as many cranes per ramp to achieve a similar train turn time.

CONCLUSION

The analysis shows that train turn times can be significantly improved with the use of double cycling in advanced terminals. Not only will this result in improved intermodal supply chain performance but also fuel savings, congestion mitigation, and air quality improvements.

Train turnaround time savings usually come in small increments or are too unreliable to allow train operators to adjust schedules to reflect these improvements. Once the terminal dwell time is reduced in a major way, reliably and predictably with double cycling, the dwell-time reduction can be captured, especially with 24–7 operations and improved routing protocols. This is critical because, for any given terminal, the faster trains are unloaded and loaded, the greater the capacity not only for the intermodal facility but the freight network as well. Likewise, the faster trains move in and out of terminals, the greater the number of trains that can be moved and the faster they can be moved. Because loading and unloading time at the origin and destination consumes a far greater share of the intermodal transit time as distance is shorter, reducing train turn time in concert with the efficiencies of double stack for the line-haul is the most effective means of achieving truck competitive service for shorter distances.

The results presented in this paper point to several future research initiatives. Future work will examine the impacts of emissions and energy and fuel consumption resulting from the use of double-cycling WSG cranes as well as the larger network impacts (for example, number of trains and the sensitivity of WSG cranes to train delays).

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