IMPACT OF STREAM-LINED CHASSIS MOVEMENTS AND EXTENDED HOURS OF OPERATION ON TERMINAL CAPACITY AND SOURCE-SPECIFIC EMISSIONS REDUCTIONS

FINAL REPORT

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ABSTRACT

An increase in container volumes provides significant opportunities and poses challenges for ports and marine terminal operators. The Ports of Los Angeles and Long Beach and terminal operators are expanding capacity to meet the growing demands of international trade, while working together to mitigate the adverse impacts that vehicle congestion and diesel emissions associated with the expanded movement of goods have on regional and local communities. These impacts stem from the thousands of daily truck trips made to move loaded and empty containers inside and outside of the port, and to reposition truck tractors (bobtails) and empty chassis. To date most mitigation policies have focused on solving congestion problems outside of the terminal gate, targeting a reduction in the waiting and turn time of trucks as the measure of success. In concentrating on reducing total truck wait time outside of the gate, these policies fail to recognize the congestion problem inside the terminal gate brought about by inefficient truck and equipment movements, which make overall port operations less clean and efficient. Furthermore, recent studies and analyses have focused on truck queuing outside of the gates and on total turn times for trucks measured from the time they enter the terminal to the time they exit the terminal gate. When it comes to gaining an understanding of the detailed operations within a terminal, however, the impact of these mitigation policies on in-terminal congestion, intra-terminal vehicle and equipment movements, and greater terminal capacity require a specific and in-depth study.

This research assesses the potential benefits, in terms of increased terminal capacity and source-specific emissions reductions, of a unified chassis pool strategy for the Ports of Los Angeles and Long Beach. This chassis strategy, together with other recent significant efforts by the ports and terminal operators and changes in industry-wide chassis management practices,

could contribute to making port operations both more efficient and cleaner. The goal of this study is to gauge the impact of current intra- terminal truck and equipment movements on a terminal's overall performance and on the effectiveness of some current mitigation measures. This is achieved through a combination of qualitative and quantitative analysis and model simulations of terminal operations associated with the current chassis management practices of container terminals at the Ports of Los Angeles and Long Beach.

Our research finds that current chassis management practices at these ports, which do not provide for a unified chassis management plan such as a cooperative chassis pool, have a negative impact on overall container terminal performance in terms of effective capacity, system operation times, and air emissions. We suggest that effective and sensible mitigation policies should focus on emissions generated by container handling equipment inside the terminal gate in addition to the emissions created by trucks outside the terminal gates. Failing to do so works to diminish the effectiveness of policies designed to make overall port operations more "green" and efficient. Accordingly, measuring and improving performance both within a terminal as well as beyond the terminal gate should be included in efforts to measure the effectiveness of mitigation policies.

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1. RESEARCH ISSUES AND OBJECTIVES

1.1 PRESSURES ON REGIONAL GOODS MOVEMENT CAPACITY AND THE GREEN PORT POLICY

Despite the global recession, foreign trade is expected to grow in the coming years. Since the early 1990s (apart from the most recent two years) East Asian exports to the U.S. have grown some 7% annually; and U.S. trade with China alone is expected to more than double by 2020. Southern California—with its proximity to Asia's production centers, well-developed (if stressed) network of roads and railways, and large local market—has accommodated a large share of this growth in trade. In 2008, two-way trade between China and the Los Angeles County Customs District totaled $186.6 billion. While the value of imports from China was down slightly (-0.4%) in 2008, the value of goods exported to China through the L.A. Customs District increased nearly 16% over 2007 figures.

The double digit, year-on-year decline of cargo volume in FY 2009 had a dramatic impact on Southern California's ports. Volume was down 14% for the Port of Los Angeles (POLA), and 22% for the Port of Long Beach (POLB) according to World Cargo News (Jan. 2010). Nevertheless, these San Pedro Bay ports remain the nation's largest container complex: in 2009 they handled a combined 11.8 million twenty-foot equivalent units (TEU) of container volume (6.7 million TEU by the POLA and 5.1 million TEUs by the POLB). According to the latest traffic forecast released by these ports in 2009, port cargo will continue to grow, tripling 2005 volumes to reach 43.2 million TEU by 2035.

The increase in container volume has posed significant problems for ports and marine terminal operators. On the one hand, they must find ways to accommodate growth by improving the effective capacity of the terminal itself through a number of responses, including terminal expansion. On the other hand, they are facing an increasingly frustrated array of public officials and community leaders who are prepared to challenge future growth unless the impacts of goods movement on local communities are adequately addressed. This means reducing the congestion and diesel emissions caused by the truck trips made daily in to and out of the ports.

Accomplishing “green” growth requires operational changes inside the terminal gates. For example, ships are now being forced to plug into cleaner, shore-side power (as opposed to running their diesel engines for the electricity needed while docked at berth for services) as part of new lease conditions negotiated between the ports and terminal operators; and in December 2005, the California Air Resources Board (CARB) adopted regulations targeting source-specific emissions associated with mobile terminal yard tractors and other cargo handling equipment operated at the ports and intermodal rail yards in the state. These regulations are designed to encourage the use of the best available control technology to reduce emitted diesel particulate matter and oxides of nitrogen from the 4,000 yard tractors and various cargo handlers (e.g. top and side loaders) used at these facilities. In 2006, CARB approved new emission standards and testing procedures for forklifts and other off-road engine-powered equipment. In late 2008, CARB amended these engine regulations to include more stringent exhaust emissions standards. These new and evolving emissions standards will continue to have a significant impact on port operations.

Apart from the demand for cleaner and more fuel efficient vehicles and cargo handling equipment, the POLA and POLB are also coping with existing capacity constraints and the need for additional container storage space to accommodate increasing demand. The ports have reported that 3,624 new acres of container terminal space are needed to accommodate growth over the next eighteen years, given current growth levels and per acre productivity (Blust, 2005). This would represent an increase of over 35% of the current terminal area capacity. Substantial investments and improvements in both physical capacity and operational efficiencies will continue to be necessary. However, physical expansion is currently constrained by the limited supply of available land in close proximity to the ports and the escalating environmental and community concerns related to port development. All of this leaves the ports and terminal operators with the challenge of expanding terminal capacity by improving the productivity and efficiency of all aspects of terminal operations and the use of available terminal space.

The San Pedro Bay ports have responded by joining with other interested port entities to identify, propose and implement operating practices designed to improve the productivity, efficiency and total throughput of the terminals. These initiatives include (1) developing port-wide truck appointment systems; (2) extending terminal operating hours; (3) stabilizing harbor trucking businesses; (4) managing free time more efficiently; (5) managing vessel sailing and arrivals to make maximum use of existing terminal capacity; (6) developing port-wide, regional and national chassis pools, and (7) developing standard methods for measuring capacity and productivity at ports and terminals (Waterfront Coalition, 2005.) Initiatives 1 through 5 have been implemented through either mandatory or voluntary policies. The implementation of a port-wide or regional chassis pool system for Southern California has not progressed very far, despite the fact that a number of chassis pool operations have been successfully implemented in other coastal container ports and inland intermodal regions across the nation.

In the US context, chassis—like containers—have been historically owned by ocean carriers, or shipping lines. The movement of a chassis depends upon their equipment needs. A chassis pool is simply a collection of chassis that two or more shipping lines agree to share when moving their containers. The operation of chassis pools can be set up in different ways, but one common method is to have the carriers take part in a contributed pool by making available their own chassis to the pool on slow days for ‘pool credit’ and then use this credit to pay for the times when they need to borrow extra chassis from the pool on busy days (Brennan 1997). If carriers do not want to contribute any of their chassis to the fleet, they also have the option of simply paying a fee for using a chassis from the pool (Brennan 1997). Another option is to use all ‘neutral chassis’ (a.k.a. a cooperative pool) whereby a leasing company (considered the neutral third party) provides and manages all of the chassis in the chassis pool and charges a user fee for the use of each chassis. Chassis pools work best when the chassis are used locally within a region (e.g. regional pool), as this makes it easier to track the location of the chassis as well as to ensure that they will be available for the carriers’ needs (Brennan 1999).

The Ports of LA and Long Beach handle mostly imports destined for regional and national markets. For import-based operations, the capacities and performance of container yards, the circulation of vehicles and equipment within a terminal, and the transfer to landside transportation systems are particularly important factors contributing to terminal productivity (Le-Griffin and Murphy, 2006). Optimizing the landside performance of a container terminal as an overall system is challenging, and is particularly critical for ports like those in Los Angeles and Long Beach that frequently receive large vessels with capacities of 5,500-plus TEUs. These mega-vessels require a fast container handling speed to minimize the time a vessel spends at dock, and the container yard must be able to accommodate a great influx of containers over a short period of time. Meeting this demand requires marine terminal operators (MTOs) to reduce container handling time by increasing the operating speed of the terminals, i.e. the number of containers processed in a given period of time (Le-Griffin and Murphy, 2006). Also, increased container trade volumes mean that a larger number of chassis are needed for container handling operations at terminals and inland intermodal facilities. Given the existing imbalance in trade with Asia, there are increased empty movements of chassis back and forth at the ports that further complicate the operations of the container terminals. In this context, a more rational system of managing chassis operations in the Southern California region could be implemented in accordance with and in support of other development and policy initiatives aimed at making overall port operations more efficient and "green."

1.2 CURRENT MITIGATION POLICY INITIATIVES

1.2.1 IMPROVING EFFICIENCY THROUGH EXTENDED HOURS AND APPOINTMENT SYSTEMS

Off-peak operating hours are expensive due in large part to labor costs; and recent attempts to increase operating time at the Ports of LA and Long Beach have largely come about in response to the threat of legislative action. California Assembly Bill (AB) 2650 (the Lowenthal Bill) was passed in August of 2002 and encouraged off-peak operations. The bill imposed a penalty of $250 on terminal operators for each truck delayed more than 30 minutes waiting to enter a terminal gate. Terminals that operated gates 70-hours per week or offered trucks an appointment system to pickup or deliver cargo were exempt. Both options were, however, voluntary; consequently, the means of implementation differed greatly. According to Giuliano and O'Brien (2006) the legislation had limited impact. No terminal at either port extended its hours of operation because of AB 2650. Appointments to enter the terminal gate are not appointments for cargo loading and unloading on the docks, and no terminal used appointment information to set aside containers for a trucker in advance. Once inside the terminal, all drivers must wait for a container to be removed from the stacks before being loaded on to a chassis. As such, where appointment systems have been implemented, there is as of yet no record of improved terminal operating efficiency.

1.2.2 PIER PASS PROGRAM

An extended hours of operation program known as PierPass began in July 2005, and was also initially designed in response to the threat of a legislative mandate. PierPass assesses a Traffic Mitigation Fee (TMF) on certain containers moved into and out of the San Pedro Bay ports between 8 AM and 5 PM. The program is run by the terminal operators and the fees are intended to defray the costs of extended operations at the ports. The reduction in cargo volumes brought about by the global recession has resulted in a reduction in the number of off-peak gates offered by marine terminals under the program. In March 2009, terminals eliminated either one night or one weekend gate. To date, the PierPass program has shifted almost 30% of truck traffic to evenings and weekends, an increase from 10% in 2005 to almost 40% of the total port truck traffic in 2007 according to figures reported at the PierPass.org website. Clearly, PierPass has been successful in reducing the number of truck trips made during peak hours and in relieving rush hour cargo congestion along urban commercial corridors. It has shifted freight traffic to off-peak hours, but has not reduced the aggregate number of truck trips. As a result, communities along the corridor must still contend with the same - and during certain parts of the day, even more - environmental and social impacts associated with these truck trips (Le-Griffin and Moore, 2007; Giuliano and O’Brien, 2008).

1.2.3 CLEAN TRUCK PROGRAM

The San Pedro Bay Ports version of a truck licensing program grew out of the Clean Air Action Plan (CAAP) adopted by both ports in the fall of 2006. CAAP can be seen as an attempt by the ports to get ahead of state-mandated environmental mitigation. The Action Plan consolidated many of the existing measures that the two ports had previously adopted individually, including vessel speed reduction programs. The Clean Trucks Program, a component of the CAAP, progressively bans older vehicles, whose engines have not been appropriately retrofitted, from accessing the port complex. As part of this program, grants and financial incentives have been created to encourage trucking companies to accelerate the replacement of older, high-polluting vehicles with newer, cleaner trucks. Subsidies also encourage the use of alternative fuels. The use of port subsidies to replace older trucks did not originate with the CAAP: both ports were partners with the Gateway Cities Council of Governments, a coalition of 27 cities in the vicinity of the ports, in a truck replacement program targeting pre-1987 vehicles that began in 2002.

The CAAP's Clean Trucks Program had the potential to reduce air pollution from harbor trucks by nearly 80 percent as of January 1, 2010.Impacts on terminal operations have not been studied, although Goodchild and Mohan (2008) use terminal operations data supplied by three terminal operating companies to conduct a simple queuing analysis and considered the potential impacts of the program. They found that while the Clean Truck Program will modestly increase incentives to improve operational efficiency outside the terminal and reduce terminal gate processing time, gate time improvements are needed to avoid container moving delays within the terminal.

It is clear that ports and terminal operators are expanding capacity to meet the growing demands of international trade while also working together to mitigate the adverse impacts that vehicle congestion and diesel emissions associated with expanding goods movement activities have on regional and local communities. These impacts stem from the thousands of daily truck trips made to move loaded and empty containers inside and outside of the port, and to reposition truck tractors (bobtails) and empty chassis. To date most mitigation policies have focused on solving congestion problems outside of the terminal gate, targeting a reduction in the waiting and turn time of trucks as the measure of success. In concentrating on reducing total truck wait time outside of the gate, these policies fail to recognize the congestion problem found inside the terminal gate brought about by inefficient truck and equipment movements, which in turn diminish the effectiveness of policies designed to make overall port operations more “green” and efficient.

Furthermore, current studies and analyses of experiments with extended gates and appointment systems have focused on truck queuing outside of the gates and on total turn times for trucks—measured from the time they enter the terminal gate to the time they exit the terminal. When it comes to gaining an understanding of the detailed operations occurring within a terminal however, the impact of these initiatives on in-terminal congestion, intra-terminal vehicle and equipment movements, and greater terminal capacity require a more specific and in-depth study.

1.3 ISSUES OF INTRA-TERMINAL VEHICLE AND EQUIPMENT MOVEMENTS AT THE PORTS OF LOS ANGELES AND LONG BEACH

Currently, activity within a terminal is characterized by a number of movements by terminal cargo handling equipment (CHE) including yard tractors (UTRs) and road trucks. In particular, extra moves between different operational areas or facilities and the designated chassis storage areas for different shipping lines are required to drop off and pick up a specific chassis for use by a specific local or intermodal customer, and to exchange (a.k.a. swap or flip) a chassis between moves for pick up or delivery of containers for different steamship lines. Unlike most parts of the world, at US ports the chassis is not the property of the trucker or transportation company, but is rather owned or managed by the ocean carriers (Le, H.D., 2003).

An actual swap (or a flip) will generally take a matter of minutes, however, based on observations at the Ports of Los Angeles and Long Beach, the queue to accomplish a swap can be quite long and often takes 20-30 minutes.. These inefficiencies extend to intermodal operations as well. Once containers are drayed to intermodal facilities, most bare chassis need to be brought back (i.e. repositioned) to the marine terminal, mostly due to a lack of demand for reuse by local exporters (Le, H.D., 2003). In addition, dozens of acres of terminal land are currently used to store thousands of bare chassis needed for the operations of different steamship lines within a terminal. These extra chassis-related operations and movements - and required terminal area for chassis storage -are a direct result of the current chassis management practices at US ports, including those in Southern California (Le-Griffin and Murphy, 2006).

Development of a chassis pool system in the Southern California region would benefit the ports by freeing up dozens of acres now used for chassis storage to be used more productively for cargo handling. However, studies of how well this system would work to reduce terminal congestion, reduce trucker time spent inside the terminal, and reduce emissions related to intra-terminal vehicle and equipment movements have not been previously conducted.

1.4 OBJECTIVES OF THE STUDY

The key objective of this research is to assess the potential impacts of streamlining intra-terminal vehicle movements at the Ports of L.A. and Long Beach through the use of cooperative chassis pools. We assess these impacts in terms of terminal capacity and source-specific emissions associated with container chassis operations on the docks, dressing both operational practices and institutional coordination. In particular, the goal is to evaluate the impact that current intra-terminal truck and equipment movements have on a terminal's overall performance and on the effectiveness of some current mitigation policies. This is achieved through a combination of qualitative and quantitative analysis and model simulations developed for actual terminal operations associated with current chassis management practices at LA/Long Beach terminals.

The study first profiles the current intra-terminal movements of vehicles and equipment necessary to process a container transaction of different transaction types. Using a series of computer simulations developed for different operational scenarios, we capture and document the sequence of movements and time it takes to conduct the container handling process within a terminal. Impacts of the current intra-terminal vehicle and equipment movement on terminal productivity and effective capacity, as well as potential source-specific emissions, are then evaluated. Consequently, the potential benefits of a cooperative chassis pool at the Ports of Los Angeles and Long Beach are discussed, and changes in institutional practices necessary for the realization of these benefits are identified. These findings contribute to our understanding of the impact that intra-terminal operations can have on the efficiency of the overall distribution system, and build an appreciation of the dynamic and systemic nature of container terminal operations. This study suggests that effective and sensible mitigation policies should consider these factors in the measurement of mitigation effectiveness, and also adds to our knowledge of the relationship between operational efficiencies and environmental benefits.

2. RESEARCH METHODOLOGY

This research has been conducted through a combination of qualitative and quantitative analysis, which involved both the operational and managerial practices of terminals. Descriptive data and information on the current state of terminal operations and productivity in relation to existing practices for chassis management at terminals, and extended hours of gate operations at the Ports of Los Angeles and Long Beach have been gathered from a number of recently completed studies as well as extensive interviews with terminals managers and drayage companies operating in Southern California.

This view of current terminal operations is then augmented with a detailed survey of in-terminal vehicle and equipment movements associated with current chassis management at terminals at the two ports. The movements (meaning the number and sequence of moves) of vehicles and equipment within a terminal are different depending on the methods used to store containers at terminal container yards (CY) and the layout and locations of terminal facilities. Data, such as the number and sequence of vehicle movements necessary, and the time it takes to conduct the container handling process within a terminal, were captured for three pre-selected terminals. Based on this information on in-terminal operations, a series of maps of intra-terminal truck and equipment movements for key container transaction types were developed. The data analysis established a foundation for analyzing the impact of different chassis pool systems on terminal operations.

In order to identify the impacts of current chassis management practices at the San Pedro Bay ports on intra-terminal movements and to understand the potential impact that a cooperative chassis pool management scheme might have on terminal productivity, a simulation software was designed and developed to simulate the actual operations of intra-terminal movements of truck and equipment associated with current chassis management practices.. The distribution pattern of truck traffic throughout the hours of terminal operation and their impact on intra-terminal movements were taken into consideration in the design of the simulation software.

A series of random trials were run for the designed comparison scenarios and the results were synthesized in terms of total intra-terminal movements and transaction time for both terminal equipment (i.e. UTRs) and trucks. These results document the efficiency and effective capacity of a streamlined intra-terminal vehicle movement scheme resulting from the use of a cooperative chassis pool system. The potential for source-specific emission reductions associated with the reductions in truck and equipment movements within a terminal were then evaluated.

Once the impacts of current chassis management practices at the ports were documented, a number of in-depth interviews (see Appendix B) with key participants in international cargo movements, including representatives from shipping lines, terminal operators and port tenants, trucking companies, intermodal rail companies and transportation agencies were conducted. These interviews were designed to profile the problems and issues associated with the implementation of different chassis pool systems and help us better understand prevailing industry opinions and preferences related to the application of chassis pool systems in Southern California. These findings also underscore the need to coordinate equipment management with other terminal improvements and air quality efforts.

An analysis of the current chassis management systems at the Ports of LA and Long Beach and in other regions of the US and a discussion of intra-terminal operations and the movement of trucks and terminal equipment follows in Section 3. Our analytical approach is presented in

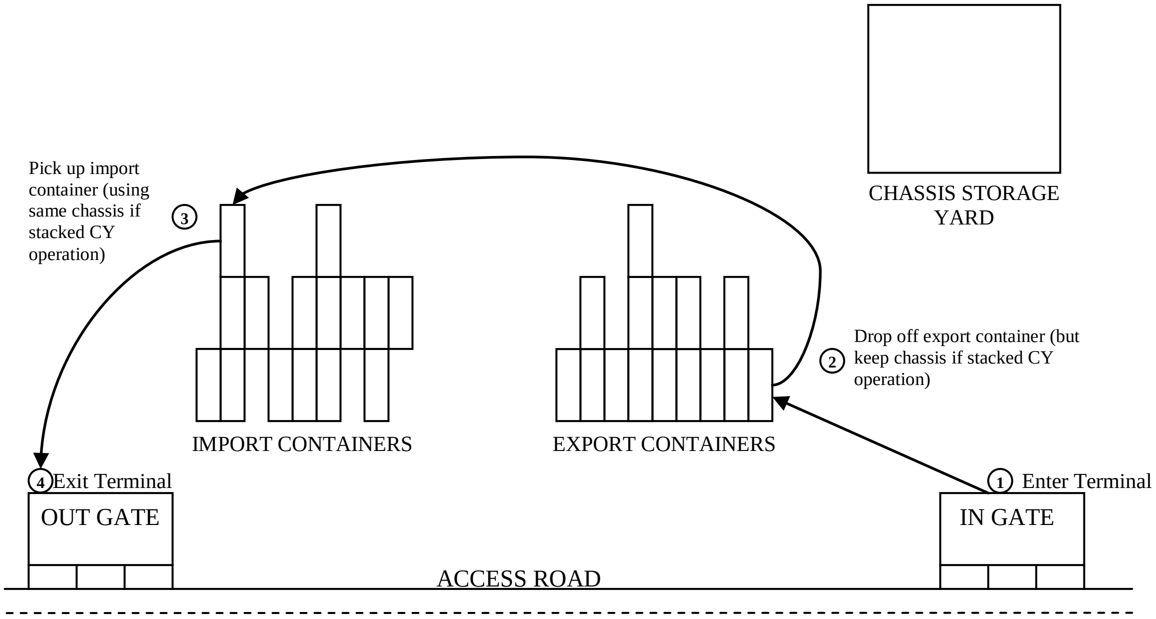
Section 4. This includes the design of our scenarios, the development of the simulation software and the input data generation process. In Section 5, results of our simulation model runs and an impact analysis of current intra-terminal operations are presented, including a preliminary discussion of the potential for source-specific emissions reductions. In Section 6, an in-depth discussion of institutional issues relating to the implementation of chassis pool models in the San Pedro Bay are provided. Finally in section 7, we present our conclusions along with recommendations for future areas of research.

3. MAPPING INTRA-TERMINAL TRUCK AND EQUIPMENT MOVEMENT AT THE PORTS OF LOS ANGELES AND LONG BEACH

While the movement of chassis within a terminal may seem inconsequential,, upon further investigation, it becomes clear that there is more to chassis use than simply hooking up to the tractor and dropping a container on it. Chassis can greatly complicate container terminal operations, or they can serve as beneficial tools, depending upon how they are managed; and terminal procedures and associated intra-terminal vehicle movements can be very different depending on whether or not chassis have to be switched after dropping off an export container and before picking up an import container. Examples of two different procedures for the same type of transaction are provided in Figure 1 for general comparison purposes, where (a) chassis switches are not required and (b) switching a chassis before picking up an import is required.

A typical sequence of truck moves to complete a job order to drop-off a loaded export and pick up an import container (a.k.a. dual transaction) can be mapped out as follows:

WITH A COMMON CHASSIS**—***Truck arrives at a terminal with a loaded export container and exits the terminal with a loaded import, no chassis switching is required*



1. A truck carrying a loaded export container arrives at a terminal in-gate. After completing in-gate procedures, the truck enters the terminal and moves toward the export container block;
2. At export block, truck driver drops off the export container. With an empty chassis, truck now then moves to an import container block;
3. At the import block, truck driver picks up an import container (using the same chassis (s)he brought in) and moves to terminal out-gate
4. After completing all out-gate procedures, truck exits the terminal.

b. ***W**ITHOUT A* ***C**OMMON* ***C**HASSIS*—*Truck arrives at a terminal with a loaded export container and exits the terminal with a loaded import, switching chassis is required*

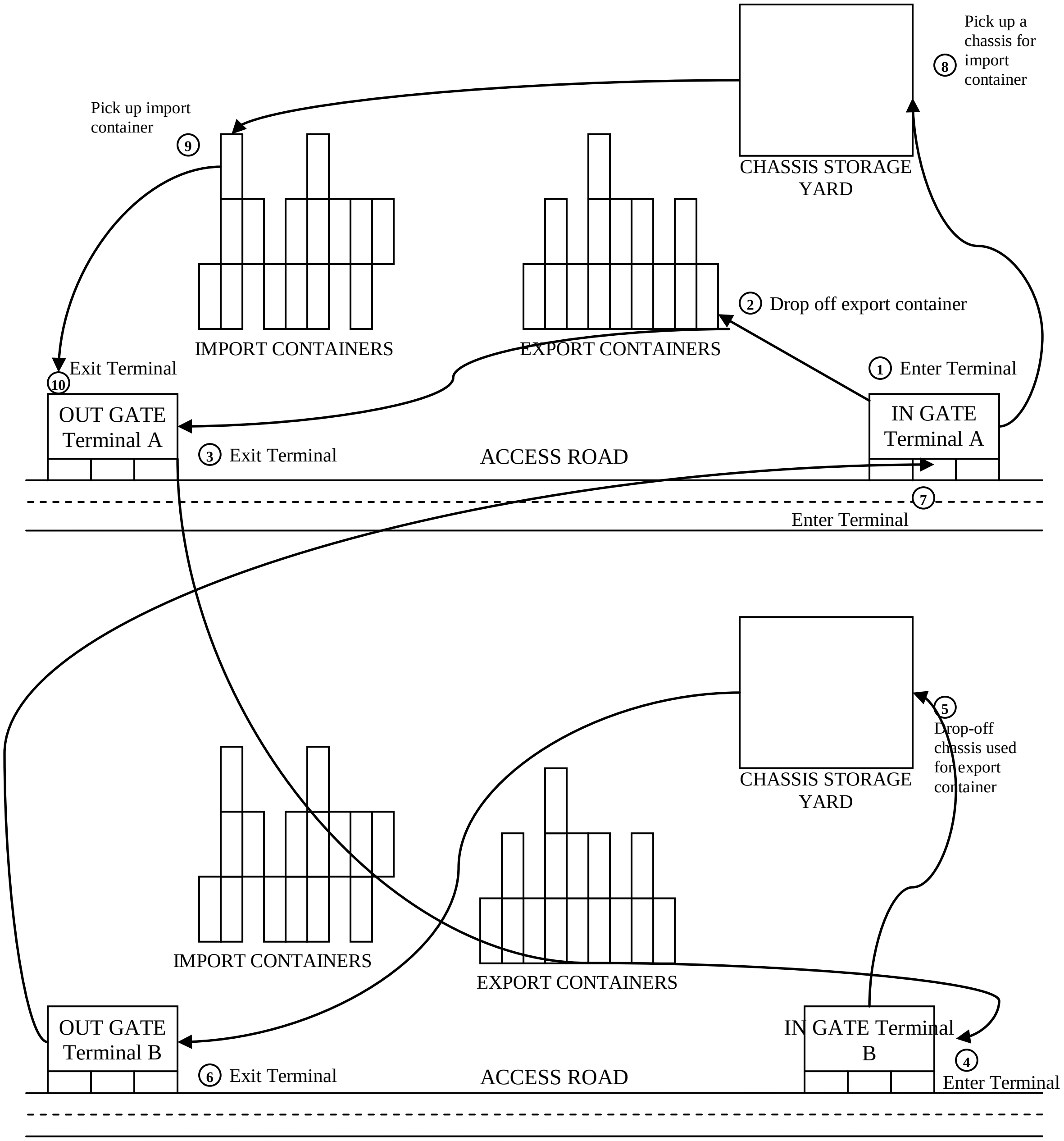


Figure 1: General Overview on Intra Terminal Container Handling Process:

W and W/O Chassis Pool

1. A truck carrying a loaded export container (e.g. for Line A) arrives at Terminal A's in-gate. After processing through the in-gate, the truck enters the terminal and moves toward the export container block;
2. At export block, truck driver drops off the export container;
3. Now, with Line A's empty chassis, trucker then exits Terminal A;
4. Trucker then proceeds to Terminal B to drops off Line A's empty chassis;
5. After completing the empty-chassis-return in-gate procedure, trucker moves toward the chassis storage area designated for Line A and drops off Line A empty chassis
6. Trucker then proceeds to Terminal B out-gate;
7. Trucker then moves back to Terminal A to pick up an import container for Line B;
8. After processing through the in-gate at Terminal A, trucker moves to designated chassis storage area of Line B for an empty chassis to pick up an import container for Line B;
9. With Line B empty chassis, trucker proceeds to import block to pick up an import container for Line B; and proceeds to Terminal A out-gate;
10. After completing all out-gate procedures, trucker exits Terminal A.

For the same job order, Figure 1(b) demonstrates a much more complicated sequence of vehicle movements than the case described in Figure 1(a) where chassis matching and switching operations are not required.

A job order is a legal contract document which states what a truck driver will need to do at a specific container terminal and when. When the truck arrives at the terminal, a series of services will be provided by the terminal operator for the trucker to allow him/her to complete a job order. For terminals, these services are referred to as transactions. There are 5 key transaction types:

Type 1: Single transaction: dropping off an export or an empty container or a chassis

Type 2: Single transaction: picking up a grounded import or an empty container

Type 3**:** Single transaction: picking up a wheeled import or an empty chassis

Type 4: Dual transaction: dropping off a grounded export and picking up a grounded import

Type 5: Dual transaction: dropping off a grounded export and picking up a wheeled import

3.1 EXISTING CHASSIS POOL MODELS

A chassis pool is simply a group of chassis that two or more shipping lines agree to share when moving their containers. The operation of chassis pools can be set up in different ways. One common method is to have different carriers contribute their own chassis to the pool on slow days for 'pool credit' and then use this credit to pay for the times when they need to borrow extra chassis from the pool on busy days (Brennan 1997). If carriers do not want to contribute any of their chassis to the fleet, they also have the option of simply paying a fee for using a chassis from the pool. (Brennan 1997). Another option is to use all 'neutral chassis' in which a leasing company - considered the 'neutral' third party - provides all of the chassis in the chassis pool.

Carrier-owned chassis are a legacy of containerization, which allowed for the development of a true intermodal system in this country. By controlling the chassis, ocean carriers had access to other portions of the U.S. domestic market. As containerization spread into Europe and Asia however, trucking companies or shippers provided the container chassis (Prince, 2006). Thus the practice of shipping lines owning the chassis is unique to the United States (Le, H.D. 2003).This American tradition of the shipping lines owning and managing the chassis fleet was maintained over the years. The model was often used by the lines as a sales or marketing advantage (Prince, 2006). Some shipping lines had better quality or larger numbers of chassis in their fleet and would claim that, as a result, they could offer more reliable service to shippers (Prince, 2006). Many terminals in the US have also had the luxury of space. Large port complexes have allowed terminal operators to utilize land for wheeled operations, i.e. the storage of containers on chassis. This allows truckers to pick-up import loads without requiring longshore labor to unload the container from a stack. This provides operational flexibility to a terminal, particularly in the evening and on weekends when labor is most expensive. Not all ports have land available for wheeled operations. The Port of Singapore for example moves more TEUs than the San Pedro Bay ports despite covering a much smaller land area: 1,050 acres compared to a combined 7,300 acres at the ports of Los Angeles and Long Beach.

Over time, this has become less of an advantage as chassis have become more uniform and the availability of chassis less of a problem due to the creation of lease-on-demand firms. Nonetheless, many shipping lines still take pride in their chassis fleet and have required a great deal of persuasion to be convinced that relinquishing control of this asset is in their best interest.

Furthermore, harbor trucking companies usually do not have enough capital to purchase or lease a large fleet of chassis, nor do they have enough space to store them (Mongelluzzo, 2000). Even if trucking companies could figure out some way to afford and store chassis fleets, this would not necessarily be a more advantageous scenario. Since many terminals use grounded (or wheeled) storage of containers, the containers would have to be switched from the terminal’s chassis on to the trucker’s chassis, which would actually increase congestion at the port terminals by adding extra steps in the container handling process (Mongelluzzo (1), 2000). Thus, the model of chassis ownership that works overseas is not very feasible in the U.S.

However, there have been examples in the U.S. where a combination of factors has contributed to the development of chassis pools. The majority of these have occurred along the east coast and at intermodal centers in places like Denver, Salt Lake City and Memphis.

Maher Terminals – Ports of New York/New Jersey

Maher Terminals created the first common-user chassis pool in the U.S. in 1995 (Brennan, 1999). The chassis pool involves shipping lines calling at Port Elizabeth in New Jersey as well as the Port of New York. It is a voluntary, cooperative pool in which each of the participating ocean carriers has a seat on the directing board (Mongelluzzo (1), 2000). The chassis pool was badly needed in the Port of New York because many carriers have vessels that call at multiple terminals (Dupin, 2001). 95% of the chassis used at the Ports of New York and New Jersey never leave the region, making it easier to track the locations of the chassis and make them available for the shipping lines (Dupin, 2001). As of 2005, there were more than 20 carriers involved in the pool of12,000 chassis (Leach (2) 2005).

Hampton Roads – Virginia Port Authority

The Virginia Port Authority's chassis pool was created in two phases. It started initially as a smaller, voluntary pool in 1997 and included only about one-fifth of the chassis used at the Ports of Norfolk, Portsmouth, and Newport News (Leach, 2005; Mongelluzzo, 2005). The second phase began in October 2004. In contrast to the Maher Terminal chassis pool - and the first phase of this chassis pool - the second phase *required* participation of all the carriers (Keever, 2005). The Virginia Port Authority was able to mandate participation since it operates all of the terminals. Within ten months of its inception, on June 1, 2005, all 25 ocean carriers that use the terminals at the Ports of Norfolk, Portsmouth, and Newport News had signed on to the Hampton Roads chassis pool (Leach (1) 2005).

Virginia Intermodal Management, LLC operates this chassis pool, which is overseen by a board of directors composed of executives from the carriers, equipment companies, and an alternate member from the Virginia Port Authority's operating company, Virginia International Terminals, Inc. (Keever 2005). The anticipated flow of chassis between the terminals and the rail is discussed every day to determine if repositioning of the chassis will be necessary (Keever, 2005).

The pool focuses on chassis safety and quality control. The overriding philosophy of the pool has been "No unsafe chassis will be made available" (Keever, 2005). Major chassis repairs have been reduced by 35% and the pool enabled the terminals to phase out 5,000 of the oldest chassis (*Interchange,* 2005). An Assistant Director of the Teamsters Union's Port Division was quoted saying that,"' A truck driver is more likely to get a roadworthy chassis more quickly in Hampton Roads [(Port of Virginia)] than anywhere else in the country'" (Leach, 2006). In addition, the port did not want the pool to be a profit center. It was agreed that it would be a break-even venture, with all of its operating costs being covered by user fees. Participants consider a utilization rate of about 78% to be successful (Keever, 2005).

There is some indication that pooled operations have a positive impact on cost. The average number of revenue trips per year is approaching 45 per chassis. Before the implementation of the chassis pool, the average usage was about 32 revenue trips per year (Mongelluzzo, 2006). The more revenue trips performed, the less the overall cost of the chassis.

South Atlantic Consolidated Chassis Pool

This is a common chassis pool for the Southeast region of the U.S. It began with an initial request filed by the Georgia Ports Authority, the South Carolina Ports Authority, and the 18 carriers of the Ocean Carrier Equipment Management Association (OCEMA) (*Shipping Digest*, 2006). The OCEMA structure provides some insurance. The pool is owned by the South Atlantic Consolidated Chassis Pool, LLC, a subsidiary of Consolidated Chassis Management, LLC (CCMLLC), and managed by Flexi-Van Leasing Inc. (Leach, 2007). The initial agreement included the Ports of Savannah and Charleston, as well as the inland intermodal hubs of Atlanta and Charlotte. It has since been expanded to include the North Carolina State Port Authority's Port of Wilmington, Florida's Port of Jacksonville, and additional inland intermodal facilities in North Carolina, South Carolina, Georgia, and Florida (Leach, 2007).

CCM, LLC was formed in 2005 to develop and own chassis pools. It currently has over 100,000 chassis under management at pools in Denver and Salt Lake City, Tampa, and Memphis and Nashville, in addition to the South Atlantic Pool.

Maersk Pool

The most recent example of a U.S.-based chassis pool, and one that may have the greatest impact on equipment management in other parts of the country is the one run by the ocean carrier Maersk. It is known as ChassisLink and is run as a division of Maersk Equipment Services. Maersk has a 90,000-unit chassis fleet, the largest of any carrier in the U.S. Maersk has a reputation for well-maintained equipment which may be one reason why it has resisted sharing its chassis with other shipping lines in the past. The company is currently a non-contributing member of the port-wide pool at Hampton Roads, so its decision to experiment with chassis pools now is notable. The stated goal is to prevent truckers from wasting time and fuel on unnecessary trips. The pool currently includes Maersk chassis but is open to other shipping lines and railroads that agree to lease terms.

ChassisLink was announced in June of 2009 and launched in August 2009. The first phase of the program involved 5,000 chassis for New York and New Jersey at APM, Port Newark, and at local rail ramps, with expansion to follow nationwide. Maersk charges a daily fee of $11. In return the Program allows truckers to use a Maersk chassis any way they want and make as many trips they want until it is returned. Maersk continues to provide free chassis for use in store-door deliveries to customer warehouses. The daily fee applies only to chassis used in moves in which trucking is handled separately from ocean rates. The lease agreement does not include maintenance and repair since that would involve changes to labor agreements.

In early 2012, Maersk sold its chassis linking subsidiary altogether reflecting an increasing trend to phase out chassis operations and turn them over to chassis pools operated by CCMA.

In the wake of the Maersk decision, other ocean carriers have followed suit, implementing changes to their equipment management procedures that involve either chassis pools or in some cases chassis divestiture. OOCL phased out chassis operations beginning in the Midwest and at inland locations in the East and Midwest and ultimately phasing out chassis operations at the Port of New York and New Jersey in April 2012. The implications are great. As of mid 2011, there were approximately 670,000 chassis in North America registered with the Intermodal Association of North America’s Global Intermodal Equipment Registry, 80% of which were domestically owned, and 70% ocean carrier provided. Since each chassis costs roughly $8,000 with total costs to the industry in the range of $2 billion each year, changes in equipment management procedures could result in more efficient use of chassis while providing savings to ocean carriers and shifting additional costs to truckers. A timeline of recent changes in chassis management is included in Appendix A.

3.2 EXISTING CHASSIS POOLS AT THE SAN PEDRO BAY PORTS

The large majority of chassis pools, both carrier-operated and neutral (or gray) chassis pools, are located on the east coast of the U.S where there is a concentration of chassis and where drays between marine and rail terminals are relatively short Smaller pools do exist at the Ports of Los Angeles and Long Beach, but there is no single port-wide chassis pool where a chassis can be used by all shipping lines and their customers at the ports. Chassis pools in the Southern California context are generally categorized as one of two common types: a Terminal-wide Pool—which is owned and operated by a terminal operator; and a Contributed Pool or Alliance-only Pool—in which members of a shipping alliance contribute their own chassis to the pool according to their cargo volume. The latter is often managed by a terminal operator or its subsidiary and provides service across different terminals that are called at by alliance members in the same port.

At the San Pedro Bay ports, terminal-wide pools are operated by Maersk, which has its own chassis pool that shares chassis between the Pier 400/APM Terminal and the Horizon Line Terminal (*Interchange* 2006). There are also terminal pools at the International Transportation Service (ITS) terminal involving chassis operated by CSAV, K Line, Hamburg Sud and Polynesia Lines; the LA Basin/Pier J Pool (LABP) which includes COSCO, China Shipping, Hanjin Yangming, and CMA CGM. Containers owned by Zim can be interchanged with LA

Basin pool chassis.   LABP chassis can also be used to deliver and pull Evergreen loads and empties. Evergreen pays a fee ($50) for a shared chassis.

The West Basin Chassis Pool at the West Basin Container Terminal involves equipment owned by China Shipping, Yang Ming, COSCO and Hanjin. There is also a terminal pool at SSA Pier C (Matson terminal).

Contributed or Alliance-only Pools include The New World Alliance (TNWA) chassis pool, which only serves a few of the shipping lines calling at container terminals at the Port of Los Angeles: APL Terminals, MOL, and Hyundai Merchant Marine. Figure 2 demonstrates how the TNWA Contributed or Alliance-only chassis pool is structured.

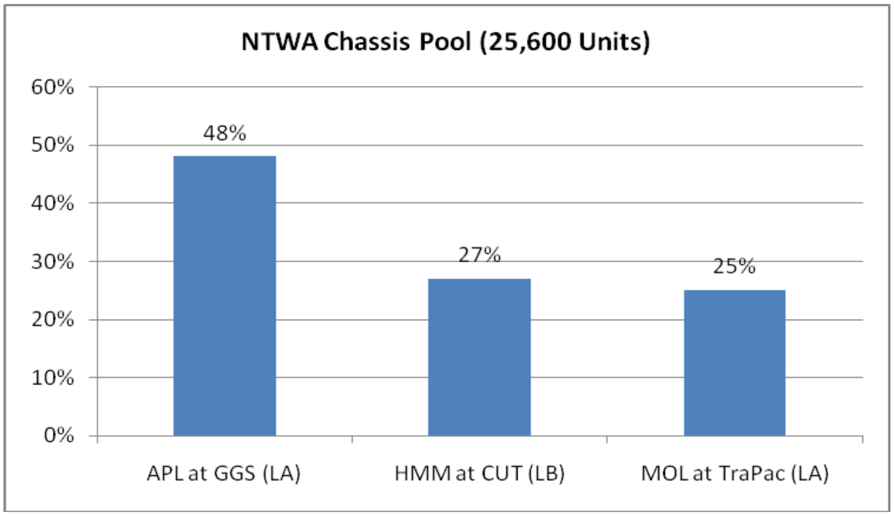


Figure 2: Structure of the New World Alliance Chassis Pool at POLA/POLB

According to our field survey and an interview with the manager of the *NWA Chassis Pool*, , 48% of the 25,600 chassis in the pool are contributed by APL operating out of the Global Gateway South (Pier 300, Port of LA), 27% by HMM of California United Terminal (CUT, Port of Long Beach) and about 25% are from MOL from the Trapac terminal at the Port of Los Angeles.

Table 1: Existing Chassis Pools at the Ports of Los Angeles and Long Beach

TERMINAL POOLS	CONTRIBUTED/ALLIANCE POOLS
ITS: CSV, K-Line, CSAV, Hamburg Sud and Polynesia	**TNWA:** APL Terminals, MOL, and Hyundai Merchant Marine
APM/Maersk: Maersk and Horizon	**Grand Alliance:** Hapag Lloyd, OOCL, and NYK Lines
LA Basin (Pier J): China Shipping, COSCO, Hanjin, Yangming, CMA-CGM Neutral Users: Wan Hai, Pacific International, Zim	**West Coast:** SSA, MSC, CMA, Hapag, Zim
SSA Pier C: Matson	
West Basin: China Shipping, Yang Ming, COSCO and Hanjin	

The Mediterranean Shipping Company (MSC) and SSA Marine Terminals (a subsidiary of CMA CGM) share intermodal chassis in a pool known as the West Coast Chassis Pool (WCCP*)*, which is managed by SSA Marine at the Port of Long Beach (Mongelluzzo 2006, Interchange 2006) and also includes chassis owned by Zim and Hapag. The Grand Alliance Chassis Pool's (GACP) shipping line members are Hapag Lloyd, OOCL, and NYK Lines (Interchange 2006).

3.3 CURRENT PRACTICE OF HANDLING A "FOREIGN CHASSIS" AT SOUTHERN CALIFORNIA TERMINALS

In the absence of a port-wide chassis pool, especially under the co-existence of various types of chassis management and operation systems at the San Pedro Bay ports, more than 30% of all terminal container transactions (of all types) remain associated with non-member chassis of some sort (Authors Interview). According to interviews with terminal yard managers at the Ports of LA and Long Beach, each year, hundreds of thousands of dollars have been spent on locating, consolidating and storing chassis that do not belong to alliance members and therefore were not supposed to be left behind by the trucker on the terminal premises.

Under the current practice, all container transactions related to non-member chassis (a.k.a. foreign chassis) must follow a different handling procedure within the terminal. All transactions involving a ‘foreign-chassis” are handled at a designated area called the “Flip Line.” Truck drivers who arrive at a terminal with a foreign chassis must stop at the flip line for all transactions. This practice is not a simple change of operation; in fact it complicates the movement of chassis-related equipment, such as yard tractors, within a terminal as detailed in subsequent sections.

In addition to the typical five transaction types discussed in section 3, the introduction of a “flip-line for all foreign chassis” procedures creates three additional types of terminal transactions, bringing the total container transaction types handled at a container terminal to eight. While transaction types 6, 7, and 8 involve the same job orders as transaction types 1, 4, and 5, respectively, due to their association with foreign chassis, transaction types 6, 7, and 8 are required to follow different operational procedures.

Type 6: Single transaction; dropping off an export <u>*involving a foreign chassis*</u>,

Type7: Dual transaction; dropping off a grounded export <u>*involving a foreign chassis*</u> and picking up a grounded import,

***Type8*:** Dual transaction: dropping off a grounded export <u>*involving a foreign chassis*</u> and picking up a wheeled import.

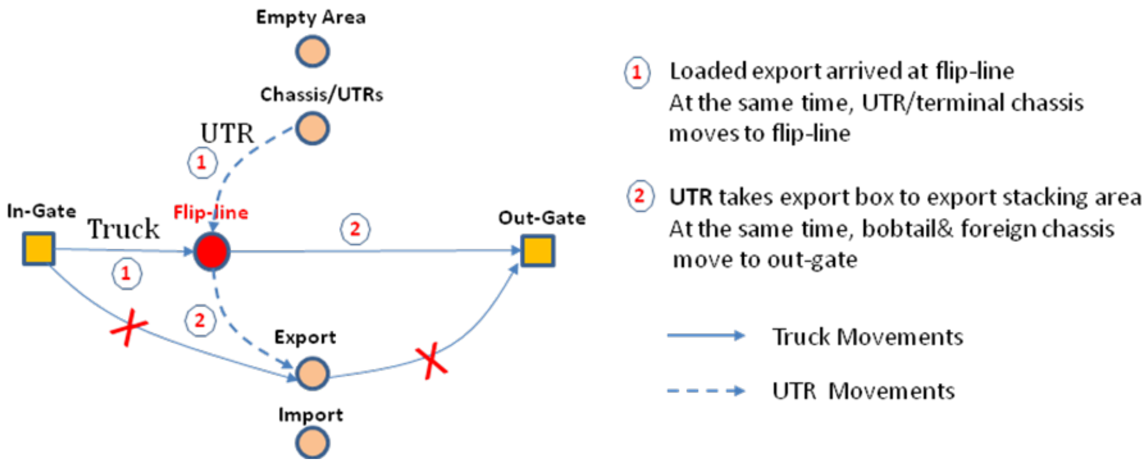


Figure 3: Intra-terminal Truck/Equipment Movements Involving a Foreign Chassis at POLA/POLB

Figure 3 presents an example of movements of trucks and chassis-related equipment (i.e. yard tractor or UTR in this case) within a terminal for a single Type 6 transaction, which involves a foreign chassis.

As depicted in Figure 3, a truck brings an export to a terminal for a single drop-off transaction. Because the truck arrives at the terminal with a chassis that does not belong to any members of the pool at the terminal, the truck proceeds to the flip line area (movement ① made by truck) instead of proceeding directly to the export area. At the same time a yard tractor or a UTR also receives a work order to proceed to the flip line to receive the export box (movement ① made by UTR). After the export container is flipped from the foreign chassis to a terminal chasis brought in by the UTR, the truck with the foreign chassis proceeds to the out-gate (movement ② made by truck), while the UTR takes the export container to the export drop-off area (movement ② made by UTR), with the UTR either returning to the chassis station or proceeding to the next job order from there.

The use of a flip line to handle a container transaction involving a foreign chassisrequires additional service facility locations and creates extra truck and UTR movements in order to complete the job order. As shown in Figure 3, for the typical single-drop-off export container transaction, the Type 6 transaction requires at least 4 movements between 5 service locations—an in-gate complex, a chassis/UTR station, a flip line facility, an export area, and an out-gate complex - instead of only 2 movements between 3 service locations (an in-gate, an out-gate complex and an export area) for the Type 1 transaction involving a pooled chassis. Depending on the type of transaction, the number of extra movements and total movement distance and time required to complete a job order that involves a foreign chassis vary significantly. Details of these extra movements and time for each type of transaction (types 1-8) will be examined closely in the subsequent sections.

4. SIMULATION MODEL OF CURRENT INTRA-TERMINAL TRUCK AND EQUIPMENT MOVEMENTS

Examples discussed in section 3.2 clearly demonstrate that the introduction of a flip line to handle container transactions involving foreign chassis, in the absence of a common chassis pool, further complicates the operational and container handing processes at the ports.

As observed during our field surveys conducted at selected terminals at the Ports of Los Angeles and Long Beach, the current chassis management practices increase the number of activities required to complete a container handling process involving a foreign chassis, both in physical and operational terms. Physical aspects include additional facility and space required at several locations to store the chassis of different users, and more equipment including chassis and UTRs required to move containers between locations within the terminal. Operational items include the number of movements (from one location to another) by trucks and UTRs and the time (measured in minutes) they take to complete a container transaction. We also observed that there are large variations among terminals in terms of daily volume (i.e. number of transactions per day) and the share (i.e. percent) of transactions that involve foreign chassis. Within a terminal these also vary over a period of time.

This leads to an important research question: how would a port-wide chassis pool system improve the current operational productivity and efficiency of the San Pedro Bay ports? In other words, how inefficient are the current chassis management and operational practices in comparison with operations absent "foreign chassis" and wherein all container transactions would involve only common user chassis? We will investigate this in the subsequent sections.

4.1 DESIGNING SCENARIO FOR THE SIMULATION OF INTRA-TERMINAL OPERATIONS—A COMPARISON ANALYSIS

In order to analyze the impact of current chassis management and operational practices at the Ports of Los Angeles and Long Beach, we first designed a comparison scenario for typical terminal operations in which all eight major transactions types as discussed earlier in Section 3.3 are included, and storage configuration is a mix of wheeled and stacked operations as shown in Figure 4. Terminal operations for this scenario were then simulated using a series of assumptions on operational characteristics, and the simulation results were synthesized and compared.

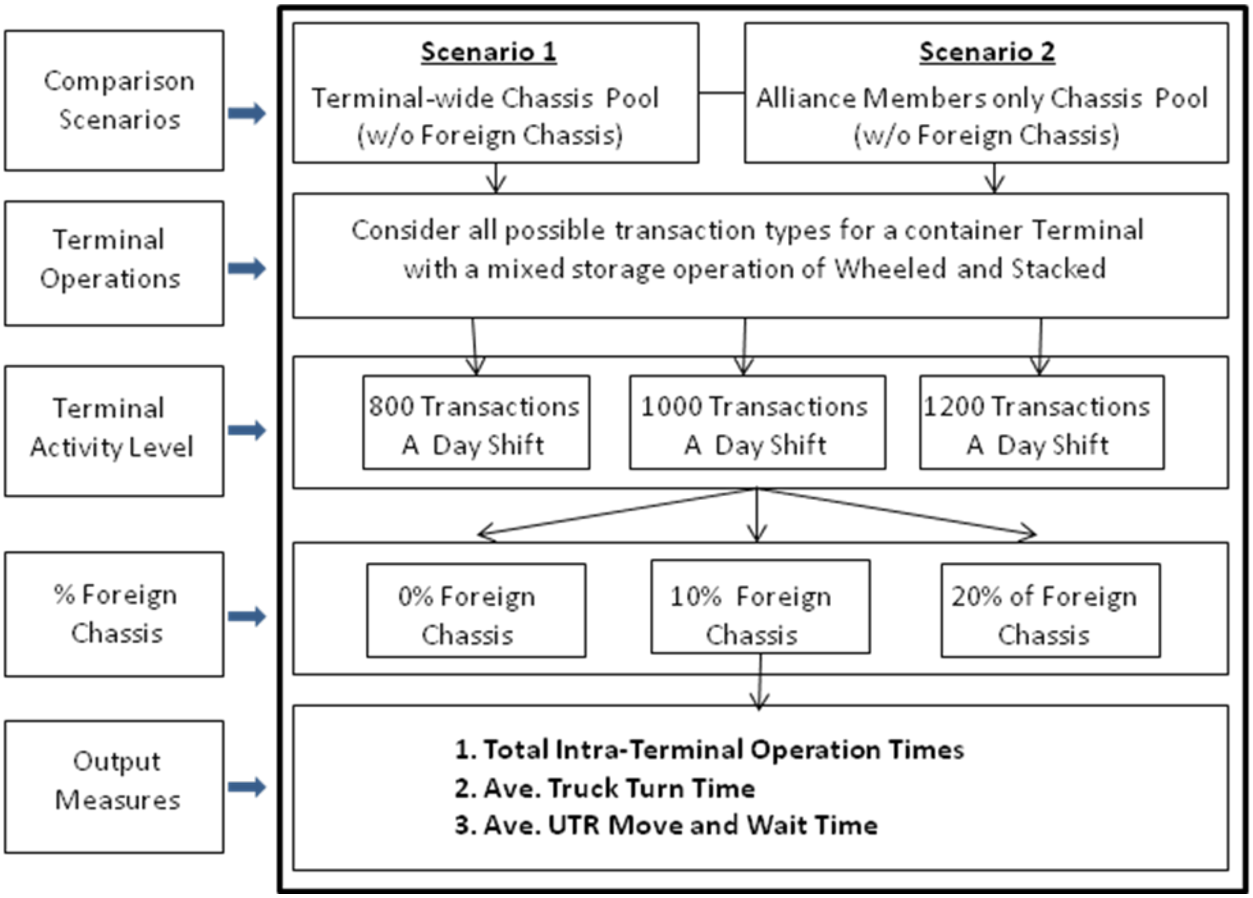


Figure 4: Simulation Scenario for the Impact Analysis of a Chassis Pool System

Scenario 1: terminal operation associated with a port-wide chassis pool (i.e. 0% foreign chassis),

Scenario 2: terminal operation associated with alliance member only chassis pool (which involves foreign chassis and is the current situation at POLA/POLB)

Three levels of terminal ***activity*** of 800, 1000, and 1200 transactions per day shift are chosen in our simulation. Based on our survey of annual container volume by terminals at the San Pedro Bay ports, we believe that this range of terminal throughput fairly represents the level of activity of Los Angeles and Long Beach container terminals. Similarly, a ten percent (10%) and twenty percent (20%) share of total transactions that involve foreign chassis are used for the Scenario 2 simulation to allow us to verify the impact of “foreign chassis” management practices on terminal operations in terms of:

a. Total intra-terminal network movement time (by both trucks and UTRs),

b. Average truck turn time (in minutes), measured from entering in-gate to exiting out-gate

c. Total system wait time (in minutes, made by truck and UTR), and

d. Total distance movement of truck and UTR within a terminal (in vehicle-miles).

4.2. SIMULATION MODEL AND SOFTWARE DESIGN

In order to compare the two chassis pool strategies (port-wide chassis pool versus current chassis pool practice at the local ports), we wrote a traffic simulator that allows trucks and equipment to travel within a designated terminal network to capture traffic movement during terminal operations. In this section, we discuss some detailed assumptions and the development of this simulator.

4.2.1 INTRA-TERMINAL OPERATION NETWORK MODELING

As demonstrated in Figure 5, in order to model the simulation of the intra-terminal chassis-related movements of vehicles (i.e. trucks) and equipment (i.e. UTR) we used an in-terminal operation network containing six ***nodes (i)****; i= 1, 2, 3,…6* and multiple ***links (j)***; *j=1, 2, 3, …N* on which eight different types of container transactions **activities (k);** *k=1,2, 3, …8* can be performed**.** For this specific network, nodes are defined as the relative locations of facilities such as (1) In-gate; (2) Out-gate; (3) Export area; (4) Import area; (5) Chassis storage yard; and (6)

Flip-line area. Links are defined as the movement of trucks and UTRs between these nodes and are determined by the type of container transaction applied.

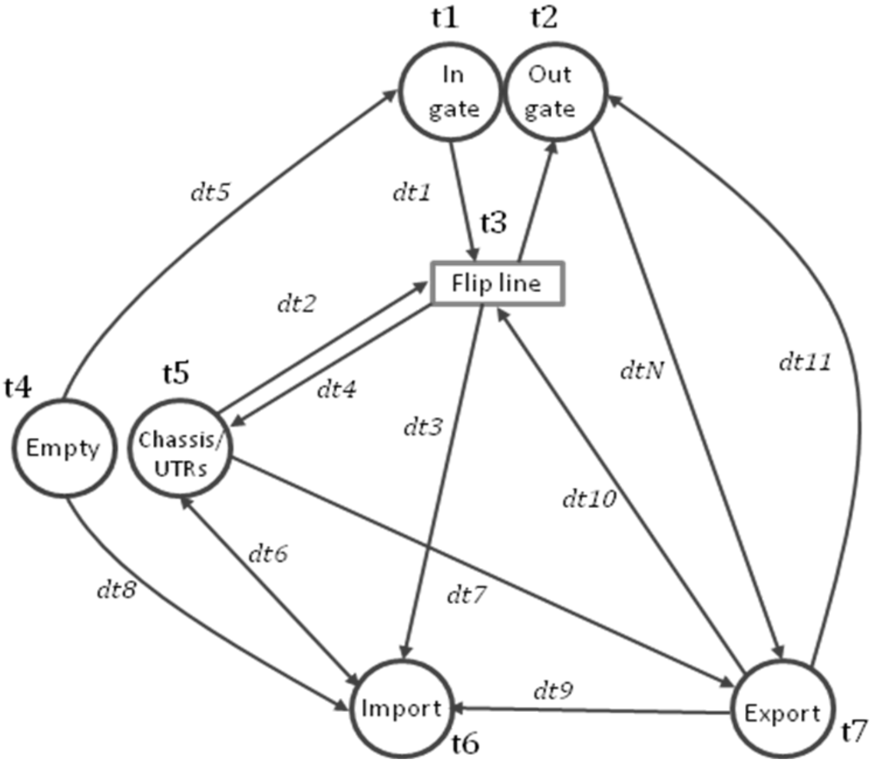


Figure 5: Model of Intra-Terminal Operating Network

The simulation of intra-terminal operations in this network is based on the following information and assumptions on terminal operational characteristics.

For a node:

1. Minimum time it takes to perform a service at node, excluding wait time
2. Maximum capacity of each node (services that can be handled in a given period of time)

For a link:

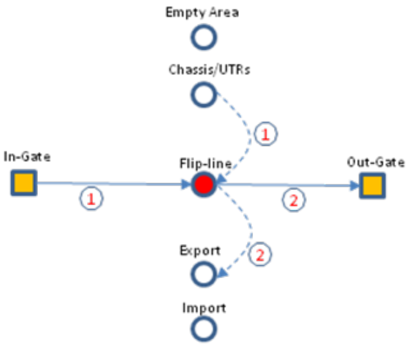
1. Relative distance between nodes

(2) Time spent at link.

As for activity:

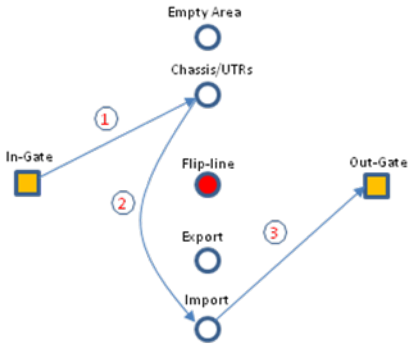
We mapped intra-terminal truck and UTR movements associated with each type of container transaction as a result of several field surveys at the Ports of L.A. and Long Beach. Although we observed some variations, the following procedures are the most generalized movements necessary to complete a container transaction of each type.

Type 1: Single Drop-Off Export with Foreign Chassis



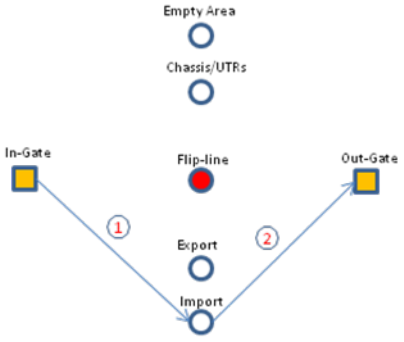
1. Loaded export arrived at flip-line
   At the same time, UTR/terminal chassis moves to flip-line
2. UTR takes export box to export stacking area
   At the same time, bobtail/foreign chassis move to out-gate

Type 2: Single Pick-Up Grounded Import, Bobtail in



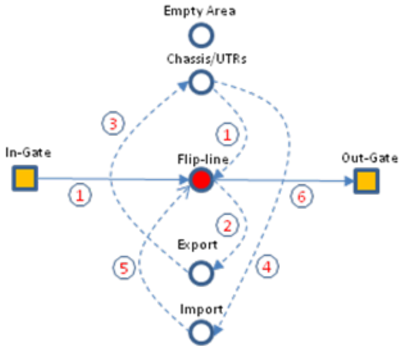
1. Bobtail moves to chassis storage area
2. Bobtail/chassis moves to import storage area
3. Loaded import moves to out-gate

Type 3: Single Pick-Up Wheeled Import, Bobtail in



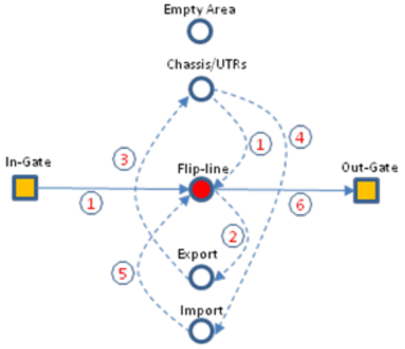
1. Bobtail moves to wheeled import storage area
2. Loaded import moves to out-gate

Type 4: Double, Export Drop-off, Pickup Grounded Import with Foreign Chassis



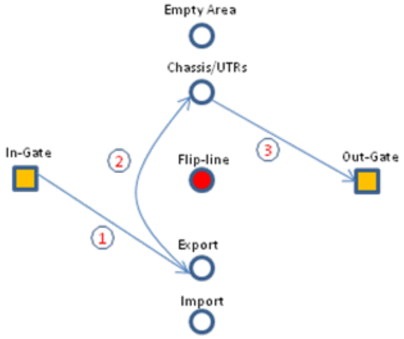
1. Loaded export moves to flip-line
   at the same time, UTR/terminal chassis moves to flip-line
2. UTR takes loaded export to export storage area
3. UTR returns foreign chassis to chassis storage area
4. UTR picks new chassis and moves to grounded import area
5. UTR takes loaded import to flip-line
6. Truck/loaded import moves to out-gate

Type 5: Double, Export Drop-off, Pick Up Wheeled Import Pickup with Foreign Chassis

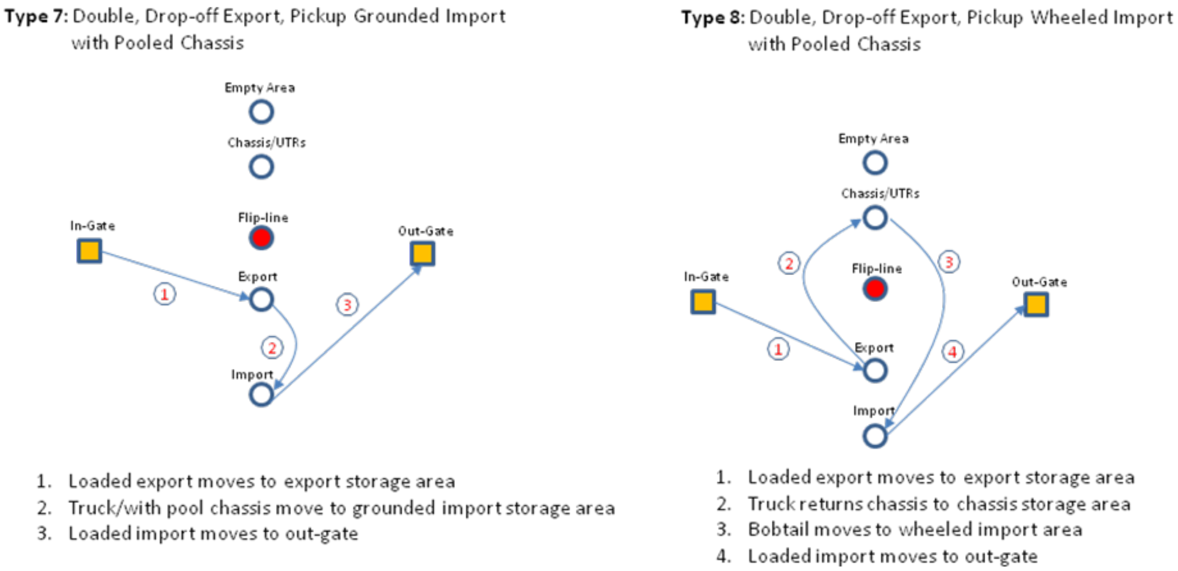


1. Loaded export moves to flip-line
   at the same time, UTR/terminal chassis moves to flip-line
2. UTR takes loaded export/chassis to export storage area
3. UTR return (export) chassis back to chassis station
4. UTR only moves to wheeled import area
5. UTR takes loaded import moves to flip line
6. Truck receives loaded import & moves to out-gate

Type 6: Single Export Drop-off with Pooled Chassis



1. Loaded export moves to export storage area
2. Truck returns chassis to chassis area
3. Bobtail moves to out-gate



Type 7: Double, Drop-off Export, Pickup Grounded Import with Pooled Chassis

1. Loaded export moves to export storage area
2. Truck/with pool chassis move to grounded import storage area
3. Loaded import moves to out-gate

Type 8: Double, Drop-off Export, Pickup Wheeled Import with Pooled Chassis

1. Loaded export moves to export storage area
2. Truck returns chassis to chassis storage area
3. Bobtail moves to wheeled import area
4. Loaded import moves to out-gate

Figure 6: Mapping of Intra-terminal Operations by Type of Transaction

4.2.2 INPUT DATA FOR SIMULATION AND SOFTWARE DESIGN

Simulation software is designed in which time is normalized as a time unit. For example, if the truck starts at time 95, spends 2 time units at a link, then 3 time units at a point, then the truck will leave the point at time unit 95+2+3 = 100. Data inputs include:

Export Data

- Total of export boxes in the simulation period
- Proportion of grounded/wheeled export containers
- Proportion (%) of types of transaction activities

Import Data

- Total of import boxes in the simulation period
- Proportion of grounded/wheeled import boxes

Other Data

- Number of available unit time per work period

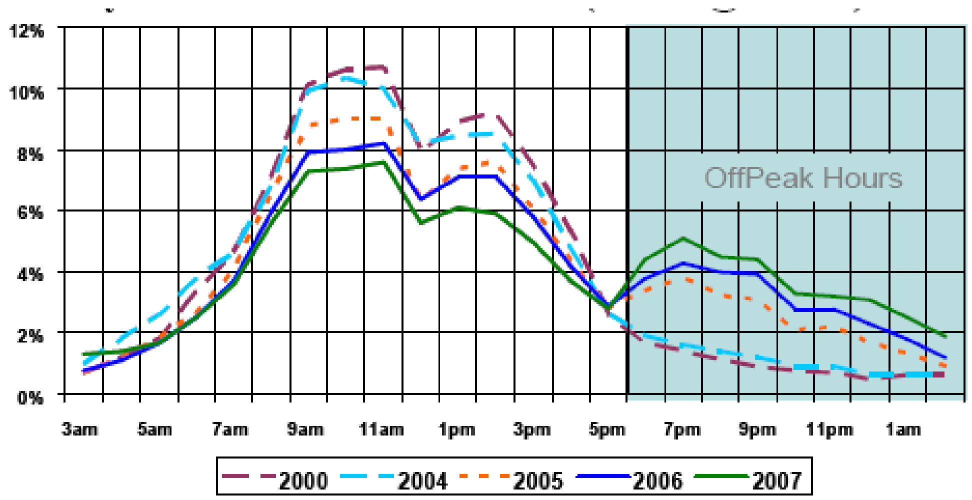
- Distribution of truck arrivals over a work period
- Time spent at each Point (minutes)
- Time spent at each Link (minutes)

4.2.3 MODEL ASSUMPTIONS FOR INPUT DATA GENERATION

Without loss of generalization and expandability of the simulation model, there are a number of assumptions on terminal operational characteristics that have been made to generate input data for the simulation of terminal operations. We acknowledge the large variation among terminals in this regard and these operational characteristics continue to change over time—there is no one model fit for all. We feel confident however that these assumptions are representative for the San Pedro Bay ports based on our field surveys and interviews with port and terminal officials. Specifically, in our simulation model, we assume:

- A balanced in-bound (import) out-bound (export) volume operation as exports include empty container repositions
- For yard operations, we assume 70% of import container volume handled at a terminal is stored on-chassis and 30% is grounded, while 100% of export containers are grounded.
- Shares (%) of different type of transactions during the 9-hour (540-minute) simulation period are determined according to the above assumptions and the sample data obtained from Giuliano and O'Brien (2006).
- Maximum operational capacity (maximum number of services the facilities are capable of providing during the simulation period) of each facility (i.e. node) is determined based on the number and productivity of equipment used at each of these locations as observed during field surveys, and

- Poisson distribution function is used to simulate the arriving pattern of trucks at the terminal.



Source: PierPass.org

Figure 7: **Hourly Share of Truck Traffic on I-710**

Our research also revealed that, even after the implementation of PierPass in July 2005 (i.e. extended gate operation hours), the arrival pattern of trucks at a terminal,, i.e., the distribution of trucks over the time period (measured in hours) of terminal operations, follows the same pattern—the Poisson distribution function—although the actual number of trucks did spread out to take advantage of the PierPass period (from 6:00PM to 3:00AM), as demonstrated in Figure 7.

4.2.4 INPUT DATA GENERATION AND SIMULATIONS OF INTRA-TERMINAL OPERATION—RANDOM TRIALS

Simulation software was developed using Microsoft Visual C++ to simulate the movements of trucks and equipment (i.e. UTRs and chassis) of an intra-terminal network and its operational characteristics as described in Sections 3.1 and 3.2 respectively. Using this software, a series of truck arrival data was first randomly generated for each trial and the operation of this intra-terminal network was then simulated to reveal the actual movements of all trucks and equipment during the entire operation period of nine hours (540 minutes), from 7:00am to 4:00 pm. Truck arrival data includes the arrival time and the interval between two consecutive trucks arriving at the terminal gate based on the Poisson distribution. Truck arrival is calculated for each one-hour period (or 60 minutes), with the number of trucks weighted according to the actual congestion factor observed in Figure 7. Also, the type of transaction associated with each arrival is randomly generated using assumptions on the ratio of transaction by types (% of total) taken from the survey sample data obtained by Giuliano and O'Brien study in 2006.

Three (3) random trials were run for each of the three simulation scenarios of 800 trucks, 1000 trucks, and 1200 trucks arriving during the 9-hour work period. Each of these simulation scenarios was run separately for three cases of zero percent (0%), ten percent (10%) and twenty percent (20%) of total transactions that involve foreign chassis. Results of the three random trials of each simulation scenario were summarized, and the average values are shown in the following sections.

5. IMPACT ANALYSIS OF CURRENT INTRA-TERMINAL OPERATIONS—SIMULATION RESULTS

5.1 IMPACT OF CURRENT CHASSIS PRACTICES ON TOTAL INTRA-TERMINAL NETWORK MOVEMENT TIME

Total intra-terminal network movement time is the total time it takes for a terminal to complete all of its transactions during the simulation period, including the movements of all trucks and UTRs necessary in the designated network shown in Figure 5. For the purposes of comparison, total intra-terminal network movement time for the case of zero percent foreign chassis (0%) is set equal to 1 in order to drive the relative changes in network movement time as the share of transactions that involve foreign chassis increases. Figure 8 summarizes the results of our simulation for different terminal activities: 800, 1000, and 1200 transactions; and different levels of foreign chassis involvement: zero (0%), ten (10%), and twenty (20%).

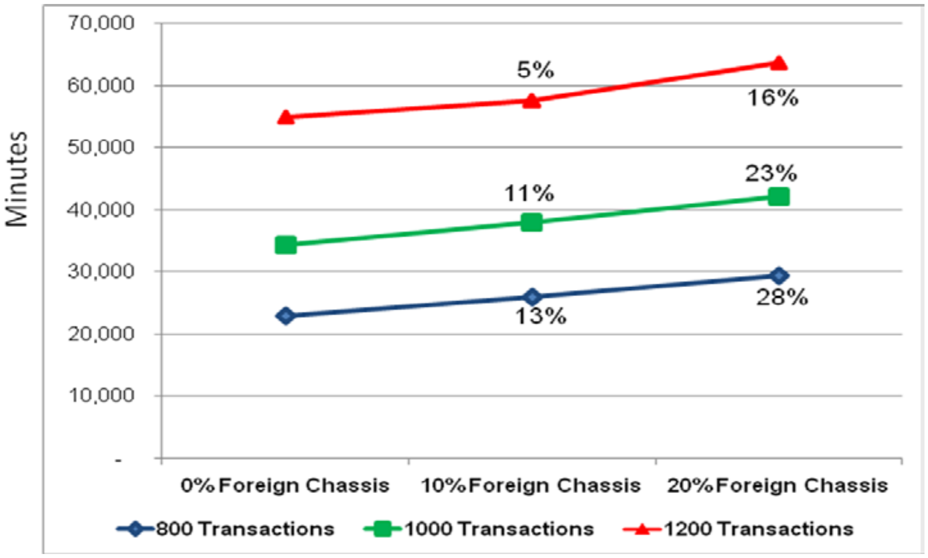


Figure 8: Percentage Increase in Total Network Movement Time (Minutes)

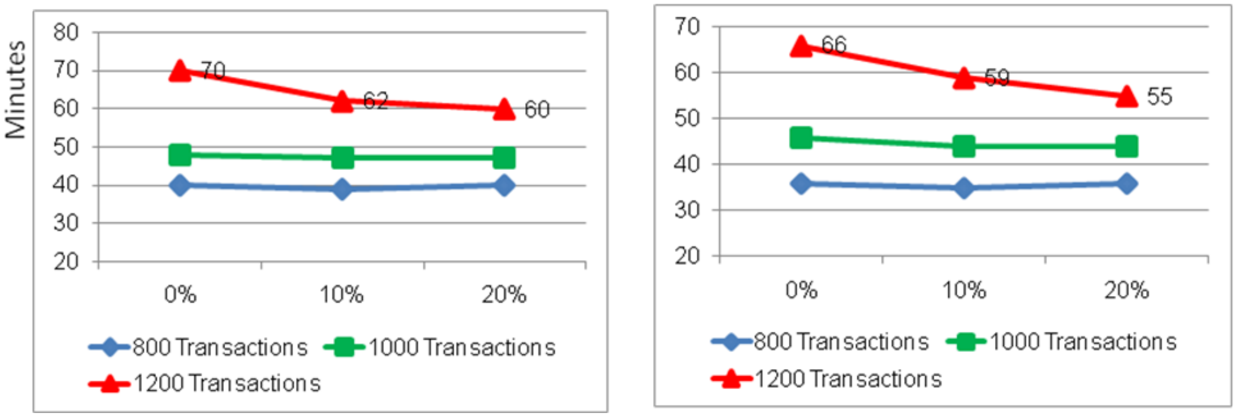
(With total network movement time of 0% foreign chassis case equal to 1%)

Figure 8 demonstrates several interesting similarities and differences among these scenarios. The general pattern of change in total intra-terminal network movement time is similar for all three cases of 800, 1000, and 1200 transactions, showing that as the percentage of transactions that involve foreign chassis increases, total intra-terminal network movement time increases. A closer examination of the pattern of change as it occurs within the 800 transaction case relative to the 1000 and 1200 cases reveals that as the percentage of transactions that involve foreign chassis grows from zero to ten to twenty percent, the change in total network movement time increases faster for terminals with less throughput capacity.

Specifically, for 800 transactions, a ten percent (10%) increase in the share of transactions that involve foreign chassis induces a thirteen percent (13%) increase in total intra terminal network movement time, compared with an eleven percent (11%) increase for 1000 transactions, and a five percent (5%) increase for 1200 transactions. The twenty percent (20%) increase in the percentage of transactions involving foreign chassis shows a similar differential in the rate of increase in total intra-terminal network movement time between the cases, with 800 transactions increasing twenty eight percent (28%), 1000 transactions twenty three percent (23%), and 1200 transactions five percent (5%). This consistent pattern of differential increases in total intra-terminal network movement time indicates that terminals with smaller throughput capacity tend to be more sensitive to the increased share of total transactions involving foreign chassis. With this being the case, the current chassis management and operational practices at the Ports of Los Angeles and Long Beach would have a negative impact on terminal operations as the percentage of transactions involving foreign chassis increases. This impact is more pronounced for terminals with less capacity as these terminals often have limited flexibility to absorb additional intra-terminal traffic movements resulting from short-term demand surges associated with the handling of foreign chassis.

5.2 IMPACT ON AVERAGE TRUCK TURN TIME AND EQUIPMENT MOVEMENT TIME

The total intra-terminal network movement time discussed in Section 5.1 includes the total movement times of trucks and UTRs within the intra-terminal network. In this section we break down the total network movement time separately for trucks and UTRs.



(a) Transaction Type 8 **(b)** Transaction Type 7

Figure 9: Changes in Average Truck Turn Time (minutes)

(a) Transaction Type 8: Dual Transaction with Wheeled Import and Foreign Chassis

(b) Transaction Type 7: Dual Transaction with Grounded Import and Foreign Chassis

In Figure 9, results of average truck turn times (minutes) for two representative transactions of *Type 7* and *Type 8* are shown for terminals with 800, 1000, and 1200 transactions and differing shares of foreign chassis at zero percent (0%), ten percent (10%), and twenty percent (20%). Transactions Type 7 and Type 8 are dual transactions with Type 7 dropping off an export and picking up an import stored on the ground at the terminal container yard (CY, a.k.a. stacked storage), while transaction Type 8 involves an import stored on chassis (a.k.a. wheeled storage). As Figure 9 demonstrates, as the share of transactions involving foreign chassis increases, there is no clear pattern of changes in average truck turn time among the three cases; 800, 1000 and

1200 transactions. Although average truck turn time for 800 and 1000 transactions changed slightly as the share of transactions involving foreign chassis increased, the average truck turn time for 1200 transactions clearly decreased as the share of transactions involving foreign chassis increased for both transaction types 7 and 8. In addition, average truck turn time for transaction type 7 involving grounded exports seems to be shorter than for transaction type 8 which involves a wheeled import.. This result is unexpected as truck turn time is usually shorter for wheeled CY operations. These somewhat "unexpected" outcomes trigger our interest to more closely examine the movements of terminal UTRs.

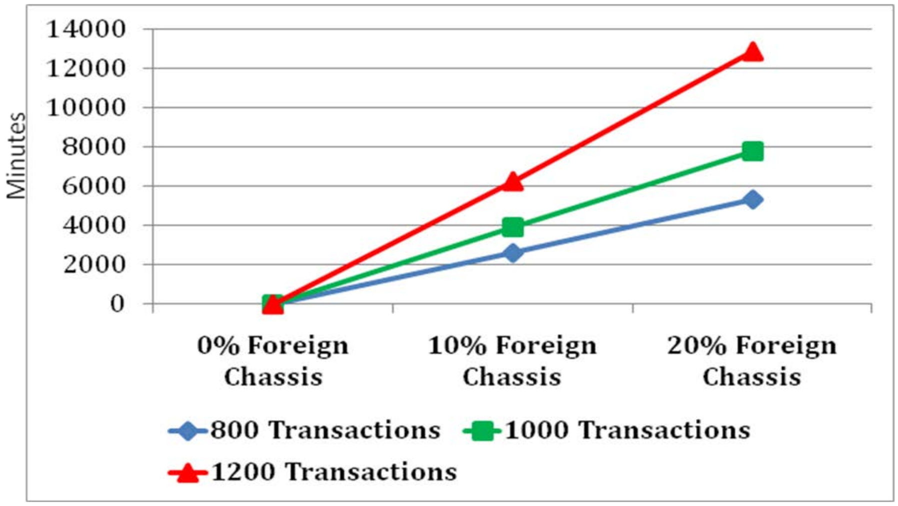


Figure 10: Changes in Total UTR Movement Time (minutes)

Figure 10 shows our simulation results for total UTR movement time for terminals with total transactions of 800, 1000, and 1200. Note that in Scenario 1, "with a port-wide chassis pool," there are no transactions (0%) involving foreign chassis, therefore no foreign chassis-related UTR services are required and total UTR movement time for this scenario is equal to zero. As shown in Figure 10, total UTRs movement time increased significantly as the share of transactions involving foreign chassis increased for all three cases; 800, 1000, and 1200 transactions. In addition, the larger volume of transactions a terminal network needs to accommodate (i.e. larger number of foreign chassis related transactions) the more UTRs movements are required within a terminal.

To further examine the UTR wait time within the intra-terminal network during terminal operations, total UTR wait times at the (1) flip line, (2) export and (3) import areas were extracted from the simulation results on total UTR operating time, and the results are summarized in Figure 11. Total UTR wait times at these service stations for the case of five percent (5%) transactions involving foreign chassis are set equal to 1. Figure 11 shows changes in the total UTR wait time index at these service stations for the three cases of 800, 1000, and 1200 transactions. As demonstrated in Figure 10, there is a clear pattern that UTR queue time at service stations increases as the percentage of transactions involving foreign chassis increases. Also, as activity level increases, the flip line and export block areas have a high likelihood of becoming congested (as demonstrated by the longer UTR wait times). These results are evidenced in the experience at the ports where export areas are often utilized for fully-grounded (e.g. stacked) container operations, and the flip area is arranged for short-term use and with limited capacity. According to our field survey,, in most cases, the flip line service station is served by one or two top loaders.

Combining the results of the discussions drawing from Figures 7 to 11, it is clear that under the current chassis management practice at the Ports of Los Angeles and Long Beach, there is a strong correlation between total intra-terminal movement time (minutes) and the share of a terminal’s transactions involving foreign chassis.

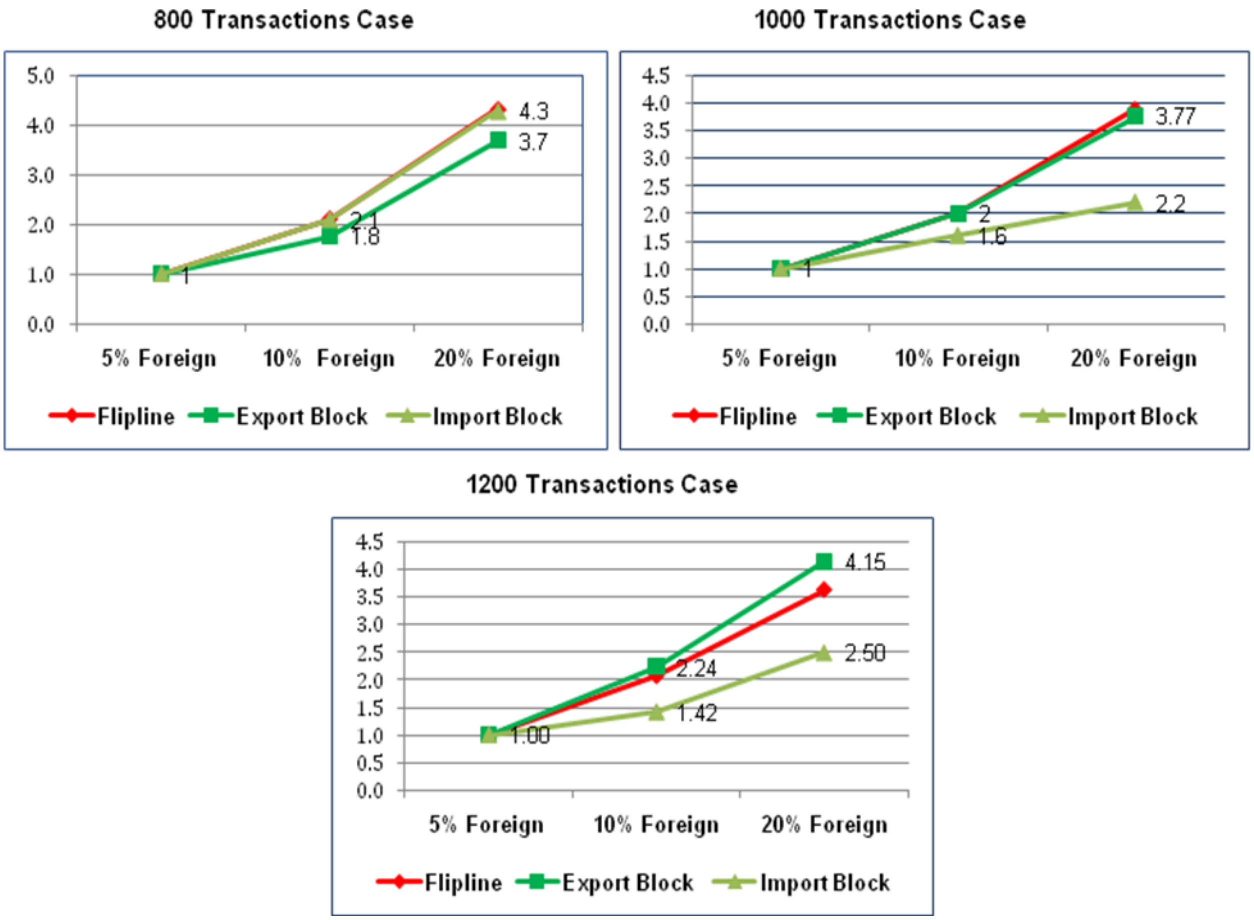


Figure 11: Changes in total UTR Wait Time Index at Different Service Stations (With 5% Foreign Chassis Case = 1)

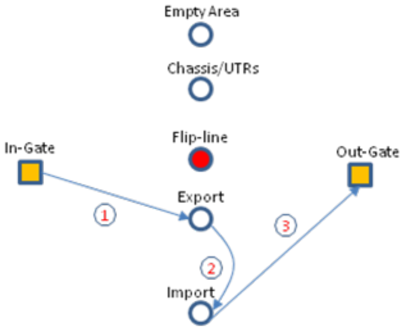
However, the increase in total intra-terminal movement time associated with the increase in transactions involving foreign chassis is due primarily to the additional movements required for and wait time incurred by UTRs, not for trucks. Most interestingly, in some cases, while total intra-terminal movement time increased, total truck turn times actually decreased. In these cases, the increase in total intra-terminal movement time is absorbed by the UTR operations. As trucks are being held at the flip line and the UTRs take over the operation from the flip line inward, a terminal’s ability to coordinate the sequencing of movements and services of UTRs could result in the release of trucks while UTRs complete the rest of the activities associated with the transaction.

5.3. IMPACT ON INTRA-TERMINAL VEHICLE-MILE MOVEMENT (VMM)

As discussed earlier in Section 3.2, the introduction of the flip line procedure practice to handle transactions involving foreign chassis requires additional terminal resources for a flip line service station and equipment (UTRs and in-terminal chassis). This practice also incurs extra movements by UTRs in order to complete the same job order. In this section, we compare, movement by movement, a container transaction for a member pool chassis in one case, and a foreign chassis in the other. The intent of this exercise is to determine which part (s) of terminal operations can be attributed to the increase in total network movement time.

In Figure 12, diagrams of intra-terminal operations for double transaction types 4, 5, 7, and 8 are presented for comparison. Types 4 and 7 deal with wheeled import storage, and types 5 and 8 deal with grounded CY operations. As discussed earlier in Section 3.2, comparing transaction types 4 with 7 and transaction types 5 with 8, these pairs of transactions--4 & 7 and 5 & 8, are in fact the services of exactly the same job order. The principal difference, however, is that types 4 and 5 involve a pooled chassis whereas types 7 and 8 deal with foreign chassis. The diagram of intra-terminal operation shown in Figure 12 demonstrates again our findings as discussed earlier in Sections 5.1 and 5.2.

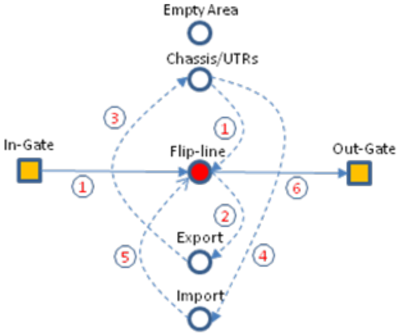
Type 4: Double, Export Drop-off, Pickup Grounded Import
with Pooled Chassis



1. Loaded export moves to export storage area
2. Truck/with pool chassis move to grounded import storage area
2. Loaded import moves to out-gate

Total of Truck moves: 3
Total of UTR moves: 0
Total Truck and UTR moves: 3

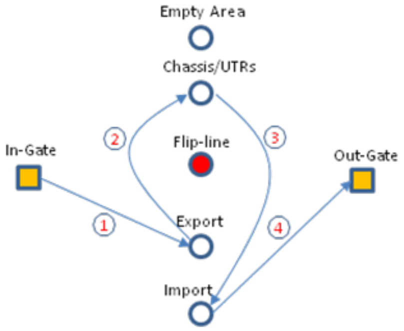
Type 7: Double, Export Drop-off, Pickup Grounded Import
with Foreign Chassis



1. Loaded export moves to flip-line
   at the same time, UTR/terminal chassis moves to flip-line
2. UTR takes loaded export to export storage area
3. UTR returns foreign chassis to chassis storage area
4. UTR picks new chassis and moves to grounded import area
5. UTR takes loaded import to flip-line
6. Truck/loaded import moves to out-gate

Total of Truck moves: 2
Total of UTR moves: 5
Total Truck and UTR moves: 7

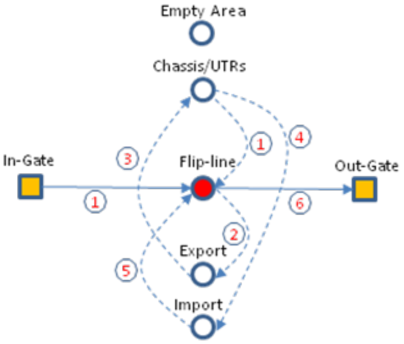
Type 5: Dual; Drop-off Export, Pickup Wheeled Import
with Pooled Chassis



1. Loaded export moves to export storage area
2. Truck returns chassis to chassis storage area
3. Bobtail moves to wheeled import area
4. Loaded import moves to out-gate

Total of Truck moves: 4
Total of UTR moves: 0
Total Truck and UTR moves: 4

Type 8: Dual; Export Drop-off, Pick Up Wheeled Import Pickup
with Foreign Chassis



1. Loaded export moves to flip-line
   at the same time, UTR/terminal chassis moves to flip-line
2. UTR takes loaded export/chassis to export storage area
3. UTR return (export) chassis back to chassis station
4. UTR only moves to wheeled import area
5. UTR takes loaded import moves to flip line
6. Truck receives loaded import & moves to out-gate

Total of Truck moves: 2
Total of UTR moves: 5
Total Truck and UTR moves: 7

Figure 12: Intra-Terminal Operations: W/ Chassis Pool vs. W/O Chassis Pool

Clearly a significant amount of extra movements are required by UTR services on transactions that involve foreign chassis. Most interestingly, the switching of some truck movements to UTR services inside the terminal gate, for both grounded and wheeled operations, explains the resulting truck turn time decrease within the overall transaction time increase demonstrated in our earlier analysis. In terms of total time duration and overall efficacy, the time reduction in truck turn time is not time saved or eliminated in the system, but is rather time transferred to terminal equipment operations. Our analysis shows that the chassis management and operational practices currently in place at the San Pedro Bay ports induce the need for extra movement and wait times incurred by terminal cargo handling equipment, such as UTRs and in some cases, top and side loaders, to perform the necessary flips. The distance and time travel of these extra equipment movements on any particular segment of an intra-terminal operations network vary significantly according to terminal land-use plans, terminal layout, and the size and operating volume of a terminal.

According to land use observations made during several terminal surveys noting the relative location of terminal facilities, the average UTR movement distance per transaction involving foreign chassis is typically in the range of 1.5 to 3 miles. For terminals that handle 800 to 1200 transactions per day and with 30 percent foreign chassis, UTR movements alone could generate several hundred thousand UTR-miles per year within a single container terminal, or millions of vehicle-mile-movements annually for the Ports of LA and Long Beach on an aggregated basis. An important finding of our analysis concerning the impact of terminal operations on vehicle emissions is that total truck and cargo handling equipment movement and operational time constitutes a more effective measure of mitigation policies, as opposed to measures targeting solely the reduction in truck turn times.

5.4 POTENTIAL IMPACT OF CURRENT CHASSIS MANAGEMENT PRACTICES ON AIR QUALITY: PRELIMININARY DISCUSSIONS

Cargo handling equipment (CHE) consists of various types of equipment and vehicles that fall within the off-road designation and are used to move cargo within terminals and other off-road areas. Emission reductions for off-road vehicles and CHE can be particularly challenging because the equipment uses a broad range of engine sizes for greatly varying applications. Demanding operating environments include excessive heat, dust, and moisture. Additionally, these engines are frequently naturally aspirated. Therefore, solutions to the emissions challenges used for on-highway vehicles, which are typically turbocharged, are not always practical (Cannon, James, 2008).

Table 2: Distribution (%) of Container Terminals CHE by Equipment Type

CHE Type	Los Angeles	Long Beach	Total	Distribution (%)
Yard Tractor	1114	823	1937	68%
Fork lift	96	101	197	7%
RTG Crane	101	96	197	7%
Side Pick	37	38	75	3%
Top Handler	133	153	286	10%
Sweeper	8	9	17	1%
Other	105	17	122	4%

Source: Port of Los Angles and Long Beach Air Emission Inventory Study, 2009

According to the most recent air emissions inventory study conducted for the ports, yard tractors (or UTRs) comprise the major category of CHE used at the two ports with 68 percent, followed by 10 percent for top handlers, and 1-7% for other CHE types as shown in Table 2. In December of 2005, CARB adopted a regulation designed to reduce emissions from CHE, including UTRs, starting in 2007. The regulation calls for the replacement or retrofit of existing engines with engines that use Best Available Control Technology (BACT). Beginning January 1, 2007, the regulation required newly purchased, leased, or rented yard tractors to be equipped with a 2007 or later on-road engine or a Final Tier 4 off-road engine. For all CHE, compliance dates are phased-in beginning December 31, 2007, based on the age of the engine and number of equipment units in each model year group (CARB's Cargo Handling Equipment Regulation, 2005).

Table 3: Yard Tractor by Engine Type and Diesel Engine Standards[1]

	2008 UTR by Engine Type					
	Count	Electric	LNG	Propane	Gasoline	Diesel
POLA	1114	0	0	55	0	1059
POLB	834	0	0	6	0	828

	2008 Count of Diesel Yard Tractor by Engine Standards					
	Tier 0	Tier 1	Tier 2	Tier 3	On-Road	Total
POLA	14	239	214	0	592	1059
POLB	53	279	238	0	258	828

Source: Port of Los Angles and Long Beach Air Emission Inventory Study, 2009

.Even with the 2007 regulation, the 2008 data on the distribution of yard tractors by engine type and diesel engine standards (Table 3) show a majority (about 97%) of total yard tractors currently operating at LA and Long Beach container terminals use diesel engines, with over 50% of these categorized by Tier 1 (27.5%) or Tier 2 (24%) engine standards. Operating within the port terminals, UTRs operate at low speeds (often at 5 to 15 mph, depending on terminal operational areas) and are generally powered by medium-duty engines, roughly 6.0 liters in size,

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[1] Table 3 summarizes the distribution of yard tractor by engine type and diesel engine standards which are based on model year and horsepower range. The count of diesel yard tractor with on-road engines is included. On-road engine standards are cleaner than Tier 3 off-road engine standards.

producing between 100 and 250 horsepower (ARB, Oct. 5, 2005). Regulation of off-road diesel equipment including UTRs generally lags a few decades behind the regulation of on-road diesel trucks. Fuel quality standards for off-road cargo handling equipment are also generally weaker than the standard now in place for fuels used by on-road vehicles, and will not be tightened to the levels now required for on-road trucks until the early part of this decade (Cannon, James, 2008). CHE, in general, do not constitute the most significant stationary source of port criteria pollutants, producing less than that of ocean-going vessels and heavy-duty vehicles. UTRs, however, generate over 50 percent of overall CHE emissions (2008 Air Emissions Inventory data). As the results of our analysis show, failing to implement a chassis pool system and continuing the current chassis management and operations at the Ports of Los Angeles and Long Beach will result in the potential increase of port air emissions attributable to:

- Increased VMT associated with extra intra-terminal UTR movements;
- Increased fuel consumption associated with increased overall intra-terminal operating time;
- Increased emissions associated with greater UTR wait time due to congestion at several service locations.

6. CURRENT DEVELOPMENT OF CHASSIS POOL MODELS AND THE IMPLEMENTATION OF A PORT-WIDE CHASSIS POOL SYSTEM AT THE PORTS OF LOS ANGELES AND LONG BEACH—INSTITUTIONAL ANALYSIS

6.1 DEVELOPMENT OF CHASSIS POOL MODELS AT THE PORTS OF LOS ANGELES AND LONG BEACH

Terminal-wide and contributed chassis pools at the Ports of Los Angeles and Long Beach may be the first step in creating a large, single pool for the San Pedro Bay ports complex. Multiple smaller chassis pools may not realize the maximum possible benefit that could be gained through a single large chassis pool. It is possible that a single pool would not work for a container throughput as large as that handled at the Ports of Los Angeles and Long Beach (Mongelluzzo 2006). These two ports combined handle more than 40% of the U.S. containerized imports; with an inventory of anywhere from 140,000 to 200,000 chassis on any given day (Mongelluzzo, 2006, *Interchange* 2005). Furthermore, these two ports are looking at an inevitable increase in container traffic over the next 20 to 30 years that their current methods of operation simply cannot handle.

The San Pedro Bay Ports are landlord ports; they simply lease out land to independent companies which operate the terminals. Therefore, their power is limited; they cannot simply establish a port-wide pool as was the case in Virginia. They could try to negotiate mandatory membership in a port-wide chassis pool as part of their terminal lease agreements. However, these lease agreements are established for very long periods of time (30 years on average). Waiting for many of the terminal lease agreements to be up for renewal will take a great deal of patience, and leases begin at different times and thus terminate at different times, making it next to impossible to gain chassis pool membership from all of the terminals all at once using this approach. Another issue to consider is that despite their proximity to one another and almost indistinguishable borders, the ports are competitors in the container industry. Thus, some of the same competitive advantage issues that have caused competing terminals to resist joining chassis pools may also impede the formation of a complex-wide chassis pool that involves terminals in both ports. The terminal operators at these ports will have to make improvements in the productivity and efficiency of their operations to prepare for the looming influx of container traffic, but it remains to be seen if a large cooperative chassis pool (port-wide or port-complex-wide) will be included in their plans. The need for change is evident however and in April 2013, the Ports of Los and Long Beach released a Request for Proposals for a chassis supply model and an implementation plan for the proposed concept. This would include an assessment of chassis pools.

6.2 BENEFITS OF CHASSIS POOL SYSTEMS

In order to determine the level of interest in Southern California chassis pools on the part of key stakeholders as well as the impediments to implementing pooled operations, we conducted open-ended interviews throughout the period of this study. We targeted terminal operators where chassis pools have been adopted and the truckers who are most affected by current chassis management practices (and who might benefit greatly from efficiently run pools). We also interviewed representatives from the shipper, rail, and ocean carrier communities, including the Ocean Carrier Equipment Management Association (OCEMA). Finally, we interviewed the Federal Maritime Commission (FMC) which has some regulatory authority over shared equipment. Ocean carriers and terminal operators are users of chassis, but they differ from the trucking community because they also manage chassis operations. These operations determine how truckers respond to different issues associated with chassis use. Terminal operators argued that, with regard to chassis pools, there are problems with billing. One would need to build scenarios into a billing system that would differentiate between drivers and terminals. Carriers argued that chassis pools should help truckers be more efficient and productive, and reduce congestion. Trucking companies, however, do not always maintain the same viewpoint; the trucking companies we interviewed covered the spectrum. One owned as few as 12 trucks, while another owned several hundred vehicles and had contracts with 1200 owner-operators. For truckers (many are owner-operators), there are a number of potential problems associated with chassis pools. These include an inability to pass fees to shippers where daily lease agreements require them (like the Maersk example).

The interviews suggest that there is an economic logic to chassis pools that ocean carriers and terminal operators understand (in other words, why chassis pools should work). Nonetheless, there is also recognition that there are institutional issues that argue against chassis pools and undermine the economic logic (why chassis pools have only worked in certain circumstances). Finally, the changing landscape of trade may suggest new life for proponents of pooled operations (why chassis pools might yet work).

Why chassis pools should work

There are now approximately 800,000 chassis in the U.S., 2/3 of which are owned and controlled by ocean carriers. Ocean carriers will determine if chassis pools become part of standard business practice in equipment management. Carriers indicate that the economics of chassis management favor pooled operations, and many carriers would prefer to get away from providing chassis altogether. Less equipment translates into savings in maintenance and repair and less money spent on repositioning. While carriers need both chassis and containers to meet peak needs, unused equipment during slow months takes up space and is non-working capital. And unlike containers, which are branded with the carrier’s name and logo on it, chassis are not. If the equipment is maintained properly, then pooled chassis work particularly well for carriers during slow months when they can order only as much equipment as needed. Chassis fitness standards, mandated by the Federal Motor Carrier Safety Administration in 2010 roadability legislation, should help to eliminate the need for finger pointing over chassis maintenance. Unless there is still a commercial advantage in providing quality equipment to customers, there should be fewer obstacles to forming chassis pools. One comparable model for equipment sharing is vessel slot sharing agreements which allow one carrier to place containers on another carrier’s vessel. Furthermore, there is legal structure currently in place to support shared equipment arrangements. The 1984 Shipping Act allows for chassis pools and facilitated the early use of shipper pools to meet peak requirements in the early 1990’s.

Why chassis pools have worked only in certain circumstances

Chassis pools have not gained widespread acceptance in this country; they have proven successful in only certain regions under unique circumstances. While pools should theoretically reduce maintenance and repair (M&R) costs, interview respondents said that control of these costs actually remains a principal impediment to chassis pool formation. Maintenance and repair mechanics are paid on a percentage basis and carriers are hesitant to give up control of chassis to a third party that may not maintain chassis in a way that carriers otherwise would (despite standards outlined in roadability legislation). Carriers therefore see the potential for increased operational costs with pooled operations, and the need to recover increased M&R costs through increased lease rates. Their perception is that chassis pools are good when business is booming, but when business is slow, there is little incentive to draw from a pool.

There are also serious labor issues associated with pools. While mechanics are often members of the International Association of Machinists (IAM) and not the International Longshore and Warehouse Union (ILWU), carriers are hesitant to have pooled chassis management as they fear this may become an issue in future labor agreements. This sentiment is particularly strong in ports on the east coast, but the scope and scale of difficulties involving labor groups vary from port to port.

One of the principal questions with regard to chassis pools is why they appear to be more prominent on the east coast. Interview respondents indicated that in effect, on the east coast the pools are common user (neutral) pools. Pools run by terminals include those in New York and Memphis. A regional pool is operated by Container Chassis Management (CCM) LLC. There is also the Hampton Roads model where carriers wanted a co-op model, not a neutral pool. In the South Atlantic, there were actually two existing pools which formed a single pool because it brought advantages to both members.

The interviewees also suggested that there are more operating ports along the east coast with more involvement on the part of city and local government including the New York-New Jersey Port Authority. Furthermore, the geography of port operations on the east coast may favor pools. There are many smaller ports that compete with each other, and each port has chassis that need to be stored. This arrangement of competing chassis proves largely inefficient, creating a demand for pooled operations. All respondents agreed that the Southwest will likely be the last region to enter into chassis pools. West coast ports have enjoyed pre-existing agreements which would have to be discarded or modified to form new chassis pool arrangements. The common sentiment was that these existing internal agreements seem to work well and reduce the pressure for chassis pools. Most respondents were confident that neither distance nor volume is an impediment to pooled operations on the west coast. Maintaining safety stocks is however critical. Reducing the number of chassis needed and eliminating the need for flipping, additional moving and repositioning is also important. Respondents also indicated that operators would need an effective technology-based system to manage a port-wide or port-complex-wide pool, particularly over great distances and involving large numbers of chassis. Right now, chassis pools are in need of more cost-effective subscription systems to make them work. In the Chicago intermodal gateway, few shipping lines have joined the proposed regional pool for this reason. The large third-party pool operators like Flexi-van and Trax, use management software to manage chassis pools. For subscribers, this is an advantage of the neutral pool concept. However, both carriers and truckers expressed concerns in our interviews that a limited number of pool options may allow third-party operators to potentially increase management fees unfairly. Current management fees may be as low as 19 cents per chassis. Furthermore, joining a pool does not eliminate all equipment-related costs. Chassis users are still required to forecast future chassis need. As a result, chassis related operation costs might increase even with chassis pool operations. Every chassis pool is given anti-trust immunity, except in those cases where terminal operators are operating as a leasing company (e.g. acting like Trax or Flexi-van). Pools involved with negotiating rates have to go to the FMC for approval; but the FMC has a general exemption for equipment arrangement, and existing carriage agreements usually cover equipment. No respondent felt that federal oversight was a serious impediment. Liability was seen as a non-issue by respondents. In fact, receiving lower insurance rates is one potential benefit of joining a chassis pool. Respondents did caution however that a pool arrangement that does not leave room for flexibility is an obstacle.

Why chassis pools might yet work

Most respondents were in agreement that changes in roadability laws would be an incentive to join pools. The recent FMCSA rules on maintenance and management of intermodal chassis make clear that drivers are responsible for confirming and checking the safety and suitability of equipment they use on public roadways. However, equipment owners are also responsible for maintaining chassis and ensuring that each piece of equipment leaving a terminals and rail yard is in good working condition. Pools centralize the maintenance and repair (M and R) inspection process and could make it easier to track equipment and comply with the roadability regulations. Safety systems and maintenance systems are now an unavoidable cost, so that has become another incentive for shipping lines to join a chassis pool. Chassis pools might yet work simply because chassis are expensive and there is an increasing understanding that the cost of a chassis should also include real estate, mechanics and stocks. With a better-managed pool, the need to compete via chassis or brand your chassis in terms of maintenance becomes less of an issue. Maersk is the primary example of a company which branded its chassis but has moved toward pooled operations of its equipment Also, despite the concerns respondents had about third party managers, 3rd party operators do have some efficiencies. While terminals may have an incentive to go to wheeled operations in the short term to avoid labor costs on the docks, the real issue is over the long term: terminal congestion is bad for business. Chassis pools help.

7. CONCLUSIONS AND FUTURE RESEARCH

Handling of container cargo is processed through an integrated and dynamic system of operations. It is not a question of just one segment of the system in isolation, but the system as a whole. Without a proper understanding of this systemic operation, any regulation and/or policy focusing on one particular area of would prove to be impractical, tending to merely switch the difficulty to a different part of the system.

We argue that the current chassis management practices at the Ports of Los Angeles and Long Beach, with the absence of a cooperative chassis pool, have a negative impact on overall container terminal performance with regard to effective capacity, system operation times, and air emissions. The transfer of containers from trucks to UTRs within the terminal exacerbates the air emission issue in that container operations and emissions within the terminals are more difficult to track and regulate. This suggests the benefits of focusing on emissions generated by container handling equipment within the terminal, in addition to targeting emissions created by trucks outside the terminal gates. In other words, a better understanding of the dynamic relationship between intra-terminal operations and the source of emissions could potentially benefit policy measures by placing a focus on yard equipment in addition to trucks. An important policy implication of our analysis concerning the impact of container terminal operations on vehicle emissions is that evaluating and monitoring both truck and CHE movement and operational time would constitute a more effective measure of mitigation policies, as opposed to measures fixed solely on the reduction of truck queuing and turn times. Missing these in-terminal movements works to diminish the effectiveness of policies designed to make overall port operations more "green" and efficient. There remain a number of institutional issues that need to be discussed and overcome in order to form a chassis pool system in the Southern California region in the foreseeable future. The development of such a system would certainly benefit the ports by freeing up dozens of acres now used for chassis storage that could be used more productively for cargo handling. Benefits would also be realized with a reduction of terminal congestion and emissions by streamlining the movements and operations of trucks and cargo handling equipment, particularly yard tractors.

Future Research: Quantifying the impact of the current chassis management system at the San Pedro Bay ports requires terminal level detail of terminal land-use, and information regarding total activity hours, size and model year of all UTRs used at the 13 container terminals. The recommended emission estimation approach for UTRs would be consistent with CARB's latest CHE emissions estimation approach (CARB 2007 model), however, this is beyond the scope of this particular study.

Given the uncertainty of the evolution of chassis operations in this country and the impacts of chassis ownership and management practices on terminal efficiency, other possible extensions of our work include:

- Simulation models to assess the impact of wheeled compared to stacked operations on overall terminal and drayage productivity
- An assessment of the economic impacts of chassis and terminal operating practices through estimation of operating costs under different scenarios

Finally, the issue of chassis utilization may be another area fruitful for research including the efficiency and cost impacts of wheeled operations and the evolution of fleet management and costs if chassis are retired with the increased use of pools.

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APPENDICES

Timeline of Chassis Management Changes

2009	Maesrk introduces the DCLI program in the Northeast and Ohio valley. Truckers are charged $11 daily for the use of chassis.
April 2010	Expansion of Maersk DCLI chassis program to the Gulf and Pacific Northwest (Houston, New Orleans, Portland, Seattle). Drayage companies can use Maersk's chassis multiple times a day for a single charge ($11). Atlantic Container Line phases out chassis. ACL will no longer provide chassis for trucking companies/owner operators.
June 2010	Advent's chassis.com becomes industry standard for managing, reporting, and distributing Driven Vehicle Inspection Reports (DVIR). Truckers use the chassis.com to file DVIR for the use of chassis.
July 2010	OOCL announces that it will stop providing chassis for motor carriers as of September 1, 2010. CMA CGM ceases to provide chassis to truckers in the U.S. The company states that it will generate greater operational efficiency and reduce environmental impacts. Maersk extends the (DCLI) program to the Southwest and Gulf regions, including Dallas, San Antonio, El Paso, Atlanta and Tampa.
August 2010	NYK Line announces it will no longer provide truckers with chassis for containers that are picked up or delivered to its terminal at the port of Oakland. Evergreen announces it will phase out its chassis business at the port of Boston on

	August 15, 2010 and plans to eventually expand the program to other areas of the U.S. NYK Line postpones changes in the chassis policy at the port of Oakland due to needed upgrades in its internal data links. Hapag Lloyd notifies truckers at the port of Oakland that containers and chassis kept beyond the company's allotted "free time" will carry a higher daily fee. Truckers fear that other steamship lines will follow Hapag Lloyd's move. They add that any across-the board increase in equipment may result in greater congestion at marine terminals. Maersk announces that it will stop providing chassis for containerized cargo at California ports starting October 1, 2010. As a result, drayage companies will be required to lease chassis through the Direct Chassis Link (DCLI) program. Direct ChassisLink, which Maersk set up as a neutral provider of chassis to truckers, said it will extend service to California and other southwestern U.S. points in the fall 2010 in the final step in a national rollout. DCLI pioneers what is fast becoming an industry-wide move by container ship lines out of chassis ownership. Cosco, CMA CGM, NYK Line, Orient Overseas Container Line, Atlantic Container Line and Evergreen Marine announce that they are exiting the chassis business, beginning in smaller ports and inland locations.
October 2010	First week of Maersk DCIL program in California ports. Truckers do not report any problems obtaining chassis but are concerned about whether costumers will reimburse them if chassis are returned early or later than expected due to heavy traffic or delays. Yang Ming announces that it will cease providing chassis in 9 East Coast ports in

	November 2010. Hyundai announces that it will stop providing chassis on the West Coast sometime in 2011.
January 2011	Maersk is the only carrier on the West Coast which no longer provides free chassis. CMA CGM has a timeline to stop providing chassis in March 2011. TRAC Intermodal extends its web-based TRAC Connect program to the South Atlantic. The program rents chassis to truckers by the day for use at multiple terminals. TRAC Intermodal is selected as the preferred chassis solution provider for CMA CGM due to the size of its fleet, its sophisticated operating system, and the high quality of its regulatory compliance/liability program. TRAC will provide rentals, leasing and other related services to the intermodal drayage community on a short to medium term basis. Flexi-Van adds chassis rentals and leasing for motor carriers. ILA retains chassis pool maintenance on the east coast. Hamburg Sud stops providing chassis at Philadelphia area terminals. Shippers, agents or consignees will procure equipment directly from the Metro chassis pool and other chassis providers.
February 2011	Hapag Lloyd announces that it is getting out of the chassis business starting April 1, 2011. Hapag Lloyd announces that it will gradually implement a revised chassis program for merchant haulage inland transports throughout the U.S.A.
March 2011	eModal adds a new chassis control

	functionality to the eModal intermodal community system. It provides real time commercial validation of chassis interchange in marine and rail terminals and container yards. Hamburg Sud and Alianca announce the end of chassis provision in Baltimore as of May 1, 2011. It had previously dropped chassis from Philadelphia
April 2011	ILA calls off a strike at the port of NY-NJ after reaching a new agreement with the Metro marine Maintenance Contractors Association allowing ILA to inspect containers/chassis and decide if they are safe to use. Ocean carriers continue to establish and change their chassis divestment policies.
May 2011	Ocean Carrier Equipment Management Association launches a chassis provisioning information section on the OCEMA website. Lowe's calls for a uniform chassis system ANL, CMA/CGM, OOCL and US Line no longer provide free chassis at the Port of Oakland. MSC establishes charge for chassis at Port of Oakland.
July 2011	Trac begins a pilot program that includes maintenance and repair costs in its daily rental fee for chassis rather than billing truckers for repairs.
August 2011	CCM requests amendment to its cooperative agreement so that it can manage its chassis pools directly. Move is done in an effort to provide more flexibility and open the pools to accommodate the rapidly changing chassis industry.
September 2011	FMC requests additional information from CCM delaying the amendment to the

	cooperative agreement. Hamburg-Sud no longer provides free chassis at Port of Oakland.
October 2011	Institute of International Container Lessors (IICL) challenges CCM chassis pool immunity claiming it will put them in unfair competition with IICL members.
December 2011	Hyundai no longer provides free chassis at Port of Oakland.
January 2012	Federal Maritime Commission permits CCM to directly manage its intermodal chassis pool. CCM operates 6 regional chassis pools that manage about 130,000 chassis for member lines.
July 2012	NYK Lines stop providing chassis in Denver and Salt Lake.
March 2013	FMCSA adds fifth equipment marking to its rules, allowing chassis to be identified through a system that uses technology to match equipment to company responsible for its maintenance.
April 2013	Ports of Los Angeles and Long Beach issue RFP for chassis supply model.

List of Companies and Agencies Interviewed

Organization	**Date Interviewed**	**Where Interviewed**
ATA	3/17/10	Telephone
Drayage Company	1/20/09	On Site
Drayage Company	7/28/09	On site
Drayage Company	1/20/09	On site
Drayage Company	4/07/09	On site
Federal Maritime Commission	9/23/08	Phone
Intermodal Association of North America	10/14/09	Phone
Marine Terminal	2/12/08	On site
Marine Terminal	2/28/08	On Site
Marine Terminal	2/4/08	On site
OCEMA	1/12/09	On site
Ocean carrier	9/10/09	Phone
Shipper	12/20/06	Phone
Class I Railroad	6/24/09	Phone

Sample of Interview and Survey Questions

IMPACT OF STREAMLINED CHASSIS MOVEMENTS AND EXTENDED HOURS ON TERMINAL CAPACITY AND SOURCE SPECIFIC EMISSIONS REDUCTION

Thank you for taking the time to answer our research questions about chassis movements and extended gate operations at the Ports of Los Angeles and Long Beach. **No names are used in our research. All answers remain confidential.**

This research has been funded by a grant from the METRANS Transportation Research Center at the University of Southern California and California State University, Long Beach. METRANS receives funds from the U.S. Department of Transportation (US DOT) and the California State Department of Transportation (Caltrans) to perform research on transportation problems that are critical to large metropolitan regions. METRANS emphasizes research that is directed at solving significant transportation problems and also results in publications in refereed journals. Please refer to the website at www.metrans.org.

The key objective of this research will be to assess the impacts of chassis pools and extended gate hours on terminal capacity and source-specific emissions. The goal is to investigate how different operational procedures would change (1) the current number and sequence of vehicle movements necessary to process a container; and (2) the time it takes to conduct the container handling process within a terminal.

Our research includes interviews with people associated with various types of chassis management structures as well as a number of in-depth interviews with key participants in international cargo movements, such as shipping lines, terminal operators and port tenants, trucking companies, and intermodal rail and transportation agencies.

Key findings from our analysis will be presented in a final report and be submitted for publication with relevant academic and industry journals.

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Questions for Trucking Companies

1. How long has your company been in the intermodal trucking business? _____years

2. Number of intermodal trucks:

Company owned _______ Driver-owned (owner operator)_______

3. Number of intermodal drivers:

Company drivers _______ Owner-operators ______

4. Which intermodal lanes do you service? (Check all that apply)

☐ Riverside
☐ Orange County
☐ Imperial County
☐ San Bernardino
☐ Ventura County
☐ Los Angeles

5. Is your company a land bridge carrier? Yes No

Is your company an in-house carrier for a steamship line(s)? Yes No

Does your company do store door billing to a steamship line? Yes No

6. Terminals you serve: (circle all that apply)

Pier A Berth 88 (Zim/MSC)

Berth E-20 LB CUT

Berth 234 LB ITS

Berth T136 Hanjin

Berth 136 TI TraPac

Berth 233 TI Evergreen

Pier C Berth C-60 (Matson)

Berth F-10 LB LBCT

Berth 246 LB PCT

Berth 127 SP WBCT

Berth 214 TI YTI

Berth 300 Global Gateway APL

Berth 400 Maersk

Operational Procedures

7. How many containers did you move on average in 2007?

weekly___________ monthly ___________

8. What are your operating hours for intermodal trucking?

Weekdays: ______ a.m. to ______ p.m.

Saturdays: ______ a.m. to ______ p.m.

Sundays: ______ a.m. to ______ p.m.

9. Have you instituted a second shift or weekend shift since the start of PierPass? Was there one before?

____

10. Where does night time staging occur? ______________________________________

11. Do you use any intermediary services during off-peak hours?

Yes Somewhat No

12. Is your company taking part in the PierPass RFID truck tag program? ___________

Use of Chassis Pools

13. Terminals you serve which also take part in chassis pools: (circle all that apply)

Pier A Berth 88 (Zim/MSC)
Berth E-20 LB CUT
Berth 234 LB ITS
Berth T136 Hanjin
Berth 136 TI TraPac
Berth 233 TI Evergreen
Pier C Berth C-60 (Matson)
Berth F-10 LB LBCT
Berth 246 LB PCT
Berth 127 SP WBCT
Berth 214 TI YTI
Berth 300 Global Gateway APL
Berth 400 Maersk

14. What are your average turn times for a dual transaction (empty in / load out)?

____

15. Do chassis pools enable you/your drivers to improve turn time for an import pick-up?

Yes Somewhat No

16. Do chassis pools enable you/your drivers to improve turn time for an export drop-off?

Yes Somewhat No

17. Do chassis pools enable you/your drivers to improve turn time for a dual transaction?

Yes Somewhat No

18. Do chassis pools enable you/your drivers to avoid roadability stations more often?

Yes Somewhat No

19. How are you/your drivers made aware that a chassis you are carrying belongs to a chassis pool?

In-gate/buckslip Trouble Window Other ____________

20. What (dis)advantages do you see for truckers serving terminals where chassis pools exist?

Survey on Truck Trip Activities by Truck Driver

1. Date:_________________________ (mm/dd/y)
2. Are you an Independent Owner Operator (IOO)? _________Yes ___________No
3. Which terminal did you serve today for this particular trip: (check all that apply)

   ☐ Pier A Berth 88 (Zim/MSC)
   ☐ Berth E-20 LB CUT
   ☐ Berth 234 LB ITS
   ☐ Berth T136 Hanjin
   ☐ Berth 136 TI TraPac
   ☐ Berth 233 TI Evergreen
   ☐ Pier C Berth C-60 (Matson)
   ☐ Berth F-10 LB LBCT
   ☐ Berth 246 LB PCT
   ☐ Berth 127 SP WBCT
   ☐ Berth 214 TI YTI
   ☐ Berth 300 Global Gateway APL
   ☐ Berth 400 Maersk

4. What was the job order for this particular trip? (Circle one that applies and fill in the time)
   a. Single **export drop-off with chassis** and then **bobtail out gate**:
      i. What time did you arrive at the terminal gate?_____________________
      ii. What time did you leave the terminal gate? _______________________
   b. Single **export** drop-off and then **chassis and bobtail out gate**:
      i. What time did you arrive at the terminal gate?_____________________
      ii. What time did you leave the terminal gate? _______________________
   c. Single **import** container pick-up:
      i. At container **stacking area** ______
      ii. At container **on-wheel area** ______
         1. What time did you arrive at the terminal gate? ________________
         2. What time did you leave the terminal gate? __________________

d. Dual **export** drop-off and **import** container pick-up:

i. Did you drop off and pick up container at the same terminal? _____Yes _____No

If the answer is NO, please check the terminal where you picked up an import

☐ Pier A Berth 88 (Zim/MSC)

☐ Berth E-20 LB CUT

☐ Berth 234 LB ITS

☐ Berth T136 Hanjin

☐ Berth 136 TI TraPac

☐ Berth 233 TI Evergreen

☐ Pier C Berth C-60 (Matson)

☐ Berth F-10 LB LBCT

☐ Berth 246 LB PCT

☐ Berth 127 SP WBCT

☐ Berth 214 TI YTI

☐ Berth 300 Global Gateway APL

☐ Berth 400 Maersk

ii. Did you have to swap the chassis before picking up the import container?

__________ Yes ____________No

iii. Where did you swap the chassis?

1. At the flip line_____ how long did it take to swap? _______Minutes
2. At the chassis storage pit _____how long did it take to swap? _______Minutes

iv. Why did you have to swap the chassis? (Check one that apply)

Foreign chassis _____Bad chassis_____ Other
____

1. What time did you arrive at the terminal gate? ____________________________
2. What time did you leave the terminal gate? _______________________________

5. For this particular trip, how long did you spend (including waiting time) at: (fill in all that apply for this particular service trip)

a. An in-Gate? ________________________________(in minutes)

b. An out-Gate? ________________________________(in minutes)

c. Flip line? ___________________________________(in minutes)

d. Export storage stack? __________________________(in minutes)

e. Import storage stack? __________________________(in minutes)

f. Import on-wheel area? _________________________(in minutes)

g. Empty storage area? ___________________________(in minutes)

h. Chassis storage area? __________________________ (in minutes)

i. Other? ____________________(in minutes) Specify
____

6. For trip using PierPass Only:

a. Has the time you are required to wait in line at the terminal gate (in-gate, out-gate or both?) decreased due to PierPass? _____Yes ______No

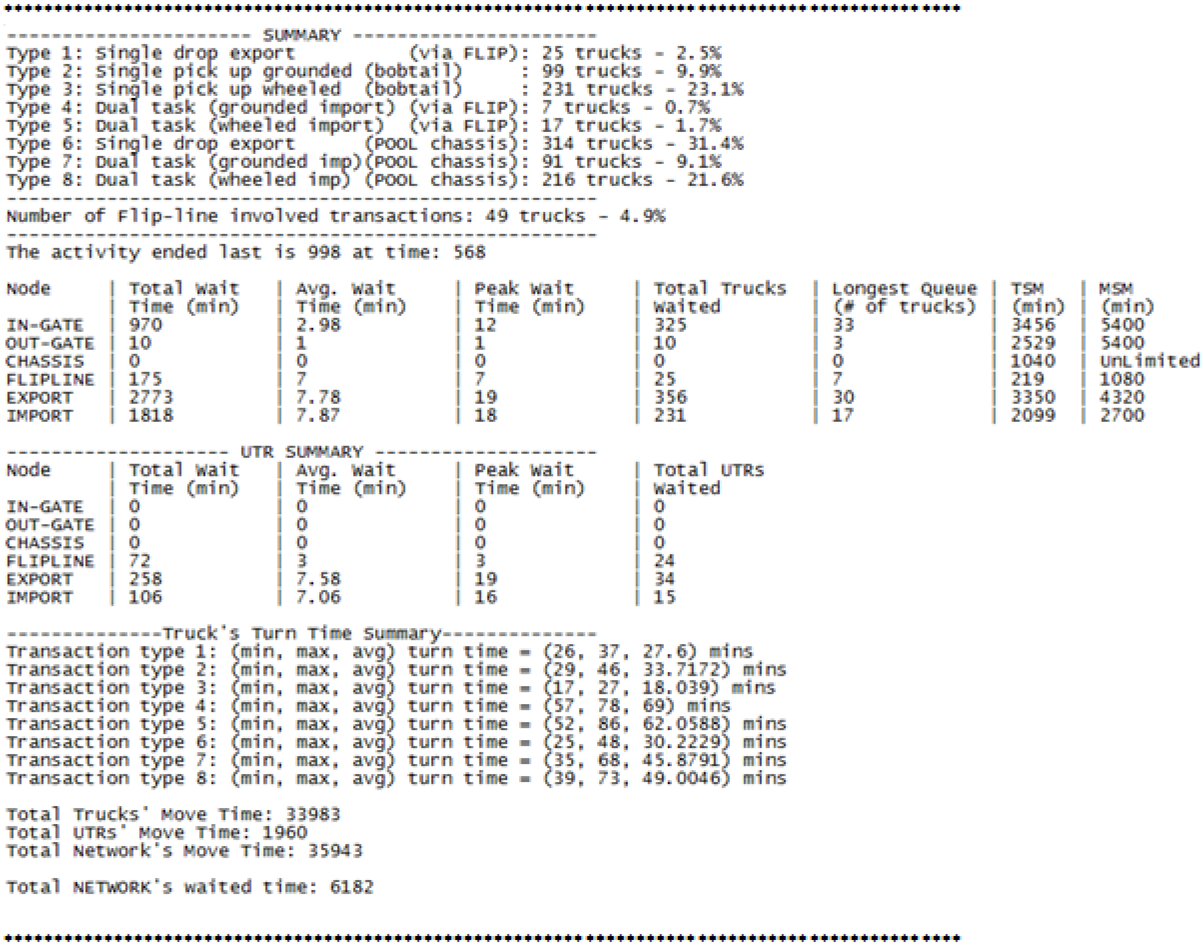
b. Is your company taking part in the PierPass RFID truck tag program? _____Yes _____No

c. What (dis)advantages do you see for truckers serving terminals where chassis are shared among ocean carriers (aka where chassis poolsexist)?

  i. Shorter turnaround time overall
  ii. Fewer problems with chassis such as less frequent visits to Flip line
  iii. Not much difference in terms of turn time for truck
  iv. Others
  ____

THANK YOU

Example of Simulation Output Data for a Random Trial.



```
***************************************************************************************
---------------------- SUMMARY ----------------------
Type 1: Single drop export          (via FLIP): 25 trucks - 2.5%
Type 2: Single pick up grounded (bobtail)     : 99 trucks - 9.9%
Type 3: Single pick up wheeled  (bobtail)     : 231 trucks - 23.1%
Type 4: Dual task (grounded import) (via FLIP): 7 trucks - 0.7%
Type 5: Dual task (wheeled import)  (via FLIP): 17 trucks - 1.7%
Type 6: Single drop export      (POOL chassis): 314 trucks - 31.4%
Type 7: Dual task (grounded imp)(POOL chassis): 91 trucks - 9.1%
Type 8: Dual task (wheeled imp) (POOL chassis): 216 trucks - 21.6%
-----------------------------------------------------
Number of Flip-line involved transactions: 49 trucks - 4.9%
-----------------------------------------------------
The activity ended last is 998 at time: 568

Node     | Total Wait     | Avg. Wait      | Peak Wait      | Total Trucks   | Longest Queue | TSM   | MSM
         | Time (min)     | Time (min)     | Time (min)     | Waited         | (# of trucks) | (min) | (min)
IN-GATE  | 970            | 2.98           | 12             | 325            | 33            | 3456  | 5400
OUT-GATE | 10             | 1              | 1              | 10             | 3             | 2529  | 5400
CHASSIS  | 0              | 0              | 0              | 0              | 0             | 1040  | UnLimited
FLIPLINE | 175            | 7              | 7              | 25             | 7             | 219   | 1080
EXPORT   | 2773           | 7.78           | 19             | 356            | 30            | 3350  | 4320
IMPORT   | 1818           | 7.87           | 18             | 231            | 17            | 2099  | 2700

-------------------- UTR SUMMARY --------------------
Node     | Total Wait     | Avg. Wait      | Peak Wait      | Total UTRs
         | Time (min)     | Time (min)     | Time (min)     | Waited
IN-GATE  | 0              | 0              | 0              | 0
OUT-GATE | 0              | 0              | 0              | 0
CHASSIS  | 0              | 0              | 0              | 0
FLIPLINE | 72             | 3              | 3              | 24
EXPORT   | 258            | 7.58           | 19             | 34
IMPORT   | 106            | 7.06           | 16             | 15

--------------Truck's Turn Time Summary--------------
Transaction type 1: (min, max, avg) turn time = (26, 37, 27.6) mins
Transaction type 2: (min, max, avg) turn time = (29, 46, 33.7172) mins
Transaction type 3: (min, max, avg) turn time = (17, 27, 18.039) mins
Transaction type 4: (min, max, avg) turn time = (57, 78, 69) mins
Transaction type 5: (min, max, avg) turn time = (52, 86, 62.0588) mins
Transaction type 6: (min, max, avg) turn time = (25, 48, 30.2229) mins
Transaction type 7: (min, max, avg) turn time = (35, 68, 45.8791) mins
Transaction type 8: (min, max, avg) turn time = (39, 73, 49.0046) mins

Total Trucks' Move Time: 33983
Total UTRs' Move Time: 1960
Total Network's Move Time: 35943

Total NETWORK's waited time: 6182

***************************************************************************************
```