Intermodal Productivity and Goods Movement

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Project Overview

A port terminal is an intermodal storage and transfer facility with the objective of optimizing the efficient flow of cargo. Not only does it serve as an indispensable node in the global supply chain network, but it also serves as a distribution center for both import and export commodities that ties the region to other U.S. trading partners. Consequently, it generates a significant amount of economic activity that links the region to its complex transportation network. Facing a new paradigm of trade patterns, changes in the shipping industry, as well as an increase in cargo volume, the efficiency of the port has become a central issue critical to the region's economic competitiveness. This project will analyze productivity issues at the Port Authority's New York/New Jersey intermodal transfer facilities linking port and surface transportation. Because of the complexity and variety of port issues involving the private as well as public sectors, the project concentrates on three critical areas and is divided therefore into three phases:

Phase I: Crane Performance (completed),
Phase II: Land Access to Port and Terminal Gate Operations, and
Phase III: Logistics Operations of Marine Container Terminals.

The overall objective of this project is to find ways to improve the efficiency of cargo flow through the facility in order to maintain regional competitiveness.

Recent Development in Container Shipping Industry

With the introduction of 6,000 plus TEU mega-size container ships, the Super Post-Panamax class, the world of liner shipping has entered a new era. The *Regina Maersk* was the first of twelve 6000TEU vessels put into service ordered by Maersk Lines. On order are vessels of 6674TEU for P&O Nedlloyd and 5700TEU vessels for NYK Lines.[1] There is already talk in the industry that a new class of 15,000TEU ships is being considered. The rationale for carriers to deploy such mega-size containerships is to take advantage of economies of scale, especially in crew and operating costs given the carriers' global deployment strategies and trade patterns. The debate is whether or not ships of this size will be

[1] Phillip Damas, "Big, Bigger, Biggest", American Shipper, July 96, 54-58.

built in large numbers and if so, will they become the standard for the industry? The 1998 Newbuilds Review indicates that "Vessels loading 4000TEU and above account for almost 60% (241,608TEU) of the backlog, compared with 35% in 1997."[2]

With this large number of Super Post-Panamax ships either in service or on order, the question of excess capacity looms. Excess capacity is also generated from the increase in vessel speed, given the trend of the latest cellular containership fleet to increase operational speed. The new-build orders for the next two years are for vessels larger than 5000TEU, with speeds in excess of 25 knots. This is also true of smaller vessels. For example, a vessel of 750 to 1000 TEU built in 1980 had an average speed of 16.4 knots; in 1998 the same class vessel has a speed of 18.1 knots. The 1200 to 1600TEU class in 1998 were built to operate at speeds of 19.5 knots.[3] The added speed and size of vessel provides flexibility, and, if utilized appropriately could also add to excess capacity.

Another important trend, as in the airline and railroad industry, is industry consolidation. Since the mid 90's, there have been a series of mergers and acquisitions, as well as the formation of global alliances. The recent Asian economic crisis, imbalance of trade and depressing freight rates in general have forced many carriers to cut costs further in the form of alliances and outright mergers. The once fragmented industry is heading towards a more rational structure to stem the tide of overcapacity and low profit. In replicating the airlines' successful implementation of the hub and spoke system carriers, in the liner industry have developed their own strategically located load-centers to further rationalize fleet deployment with the objective to improve asset utilization.

On the regulatory front, the passage of the Shipping Reform Act of 1998 further deregulates the liner industry, thereby, perpetuating the pace of consolidation. All players in the industry ranging from major carriers to niche players, from railroads to trucking firms, from big shippers to consolidators, from port authorities to labor unions, are all trying to take this unprecedented opportunity to gain competitive advantage and to be more responsive to the change in the regulatory environment as well as the changes in shippers' demand for higher quality service.

The carriers' drive to achieve greater efficiency and cost savings however, cannot be accomplished without the cooperation of port authorities around the world who very often provide the necessary funding to improve landside infrastructure to accommodate carriers' demand. The formation of such private-public partnerships and the dynamic interactions among the various stakeholders of ports shape today's intermodal freight world.

Impact on Port Industry

[2] "1998 Newbuilds Review" Containerization International, February 1999, p. 15.
[3] John Fossey, "Speed Merchant", Containerization International, March 1999, p.45, 47.

Given the developments occurring in the liner industry, the port industry around the world face serious challenges from different directions. On one hand, because of the dramatic increase in ship size, especially in draft and width, their impact is far reaching. The emergence of the Super Post-Panamax class has caused a ripple effect well beyond the traditional boundary of liner shipping. The new requirements of access channel depth, handling equipment especially gantry cranes, yard handling equipment, and intermodal linkage put the whole intermodal system to the test. The port industry is the first node in the intermodal system that has to respond immediately to such challenges.

Additionally, due to mergers and acquisitions, as well as the formation of global alliances among major carriers, the effective number of port customers has been reduced. The introduction of the mega-container ships leading to overcapacity has compounded the situation by causing downward pressure on freight rates. Such pressure will certainly bear down on port authorities and terminal operators. "Market doubts are beginning to rise over growth predictions made by the 'mega-carriers'. Forecasts that an annual growth rate of 8% can not only be sustained, but will be more than enough to absorb the 70-plus Post-Panamax newbuildings currently on order, are described as 'brazen' by the NY-based broker, the Commonwealth Group."[4] More recently, "Howe Robinson Research, a London shipping industry consulting firm, said that during the past five years slot capacity has grown by an annual average of 12%, while demand has grown at an annual average of 9%."[5] Of primary concern here, is whether or not the Port of New York and New Jersey is ready for these 6000TEU plus vessels? What strategy should the Port Authority undertake to maintain its competitive position among the East Coast ports?

The growing number of alliances and their oligopolistic economic powers are self-evident in terminal lease negotiations with the implied threat of moving their activity elsewhere. As a matter of fact, the visit by the 6,000 TEU *Regina Maersk* to Maersk Terminal in Port Newark on July 13, 1998 could not be a more obvious gesture to accentuate this point. Facing fierce competition to become a load center - the hub port in the region, the political and economic pressure to be more accommodating, given the dire consequence of losing a large portion of cargo volume to neighboring ports, has been placed squarely on the port authority

At the present time, due to Panama Canal lock restrictions, the East Coast of the U.S. is visited by vessels of 4000TEU from the Far East. The Trans-Atlantic vessels en route to the U.S. deploy up to 4300TEU vessels and to South America deploy 2000 to 2400TEU vessels. Vessel deployment patterns, however, could change quickly. For example, the Suez service, which allows for all water service between South East Asia/Indian Sub-Continent, and the East Coast of the U.S. without vessel size restrictions. The issue therefore is not whether the Super Post-

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[4] "Growth Doubts Weaken Container Market", Fairplay, 15th February 1996, p.47.

[5] Aviva Freudmann, "Demand is catching up to container supply", The Journal of Commerce, Special Report, September 22, 1999, p. 6c.

Panamax (SPP) vessels will be deployed along the East Coast ports, in particular the Port of New York/New Jersey, but when.

It is inevitable that in the future when economic development and trade volume warrant, the SPP container vessels will come, as these vessels have been deployed in trade routes between Fast East-Europe and Fast East-West Coast of United States. Given the high fixed cost of operating these mega-size container ships, carriers will seek minimize the number of port calls in a service route to reduce port costs further. This translates into a stringent requirement for fast turnaround time at ports. For port authorities and terminal operators, the issue is to determine an appropriate investment schedule in infrastructure (access water channels and intermodal linkages) and terminal handling equipment (gantry cranes, yard handling equipments) to accommodate the carriers.

Besides the need for improvement in physical assets, another side of the equation is how to improve the management of terminal operations and utilize new technologies for achieving greater efficiency. The port of Singapore, for example, is three times more productive than the average U.S. port in terms of containers handled per acre of terminal space. Sea-Land's terminal in Hong Kong handles 700,000TEU containers a year on 41.35 acres (16,929TEU containers per acre). By comparison, Sea-Land's Elizabeth, NJ, terminal handles under 400,000TEU on 264 acres (1,515TEU containers per acre). In addition, Sea-Land's Hong Kong terminal has only one berth and four cranes compared with the official count of six berths and seven cranes at Elizabeth, yet Hong Kong clears vessels nearly twice as fast.[6] In summary, "The port industry must strive to improve its service and value - vs. - cost ratio, ports must invest in the future and leverage technology to improve efficiencies. In short, ports must accommodate ocean carriers, railroads and trucks to load and unload...faster, cheaper and with more reliability."[7] *The terminal operator's productivity and efficiency are critical for carriers to realize the economic benefits the new mega-ship provides.*

Given shipping industry dynamics, the increasing trade volume, and the importance of the port to the regional economy, the following questions need to be addressed and answered. Does the port have the proper infrastructure to meet future demand? Are the port's local access roads to the highway adequate? What is the current cargo flow capacity of the port at each terminal? What is the current productivity of the equipment used? Where are the current bottlenecks? Can productivity be improved given the available resources? Are the overall intermodal facilities utilized efficiently? What can be done to improve the overall efficiency of the port with minimum additional investment?

[6] Sea-Land report Sept. 96.
[7] Tony Beargie, "US Ports Face Squeeze, Consultant Warns", American Shipper, December 1996, p. 83.

Overall Methodology

System of Intermodal Freight Movement

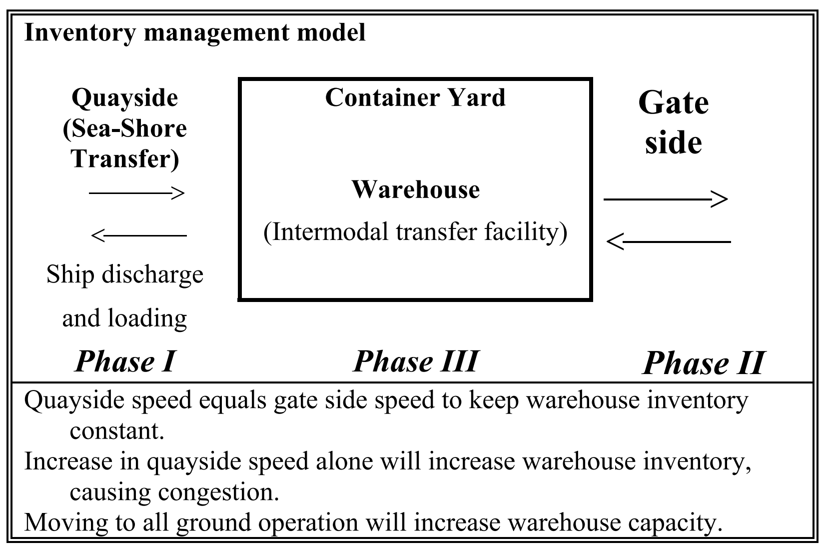
The whole system process of intermodal freight movement can be viewed as a pipeline that consists of many segments: sea carriage, sea to shore transfer, yard handling and interchange, intermodal gate interchange, and inland transportation. This project focuses on the landside of the freight pipeline.

A port facility is a multifunctional intermodal storage and transfer facility that includes three sub-systems: sea to shore transfer, yard handling and interchange and, intermodal gate interchange. Cargo flows generate activities including but not limited to; vessel loading and discharging yard handling and storage, inspections, gate processing, cargo documentation, communications, etc. The overall project analysis is based on a **systems analysis** and an **inventory management model** with the objective of improving the efficient flow of containers.

The system also involves many participants such as the Port Authority, Customs, labor unions, terminal operators, carriers, surface freight moving companies, and the like, some of which have competing interests. The system's operation is also subject to management procedures as well as import/export regulations.

Container Flow

Containers arrive at the port either by vessel or on the landside, via rail and truck. They are disseminated from the port in the same manner.. The movements on and off the intermodal facility (port) are in opposite directions, from the vessel to the yard to a surface intermodal transportation link, and vice versa, all taking place simultaneously. The number and speed of movement of containers onto the vessel needs to be matched by quick movements off the vessel and onto a surface transportation intermodal link. The movements on and off the facility should be "equal" to each other to optimize facility utilization. Under these circumstances the containers at the facility would be a constant. The container inventory at the facility has a theoretical maximum



depending on yard capacity and yard operations given the fixed yard size and dwell time. A grounded operation with 3 to 5 high containers will accommodate more containers than an all-wheeled operation. The annual yard capacity, at any given time, could be increased if container dwell time is shortened and the processing time at the gate is reduced. A smooth operation in the yard will contribute significantly to such an outcome. A one-sided improvement would cause congestion.

Intermodal freight movement is a sequence of many links between the various transportation modes. These modes depend on each other for implementing their schedule to provide an integrated outcome by coordination and synchronization of movements. The freight mover's (shipper, carrier, terminal operator) overall objective is to minimize the number of movements and the time they take, thus, minimizing cost. Advances made in improved management procedures, internal operations and infrastructure offer more cost-effective means of improving throughput in an intermodal facility. It can also increase the capacity of available terminal resources while eliminating hauling delay. The alternative is an increase in the size of the facility. Improved intermodal and terminal operations depend on advanced processes and the utilization of available information systems.. The precise predictability of each activity's time is critical due to the desire to keep it as close to a constant, which in turn will imply a low variance in the movement or activity. A low (or no) variance is essential for the customer and the service provider to achieve predictability and to reducing costs. Simultaneously, the container drayage schedules will also be improved.

Container terminal functions in specific physical area include the following:[8]

1. *Ship operation*. The container moves between the vessels and the yard storage area.
2. *Storage operation*. The containers are received into or delivered out of storage.
3. *Interchange area*. The container is received from or delivered to the over-the-road carrier.

Facing the daunting tasks to accommodate the recent increase of trade volume and mega-size containerships, there are obstacles including "**draft restrictions, landside infrastructure bottlenecks, inadequate crane outreach and insufficient port productivity.**"[9] The objective of the entire project is to make an attempt to enhance the credibility of the system by developing a low variance process (a deterministic model if possible), such that delivery could be practically on schedule, reduce inventory cost and lead to a possible just-in-time (JIT) inventory management system. A reliable and highly efficient system will also reduce the need for investment in intermodal cargo handling equipment, containers, and chassis, and could also be a substitute for public infrastructure investment. Otherwise, such investment would have to take place in order to expand facilities. This analysis is the core of intermodal relationships. These activities are also a function of complex external economic forces. More precisely

[8] Warren H. Atkins, Modern Marine Terminal Operations and Management, The Port of Oakland, 1983, 14.
[9] Damas, p. 56.

they also depend on: global trade volume, changing trade patterns, freight rates, mega-containership utilization, vessel age, new technologies, port investments, carrier consolidation, regional demand for goods movements and, accommodations at and beyond the ports (which in turn are subject to: demand for faster and lower cost services, demand for land at port facilities, warehousing management procedures, terminal facilities, access to transportation infrastructure, and others).

Advancements made in improved management procedures, internal operations and infrastructure investment, through managerial, electronic and automated means imply a reliable and more cost-effective operation and throughput improvement at an intermodal facility. Barring such, it would require an increase in the size of a facility. Enhanced efficiency could reduce the need for investment in intermodal equipment, containers, chassis, and other terminal resources. Inefficient operations could cause wasteful public infrastructure investments.

Methodology

Phase I of this project focused on the sea to shore cargo transfer issues such as strategic analysis of port development, crane productivity, and investment options in capital improvement. Based on the regional economic characteristics and cargo distribution patterns, this phase of the project, Phase II, will focus on land access to the port and gate operations. Because the overwhelming majority of containers are distributed within a 125-mile radius of the port, the most preferred mode for cargo distribution is truck. Given the high density of population and the concentration of economic activities, the land access issue and increasing congestion at terminal gates hinder the efficient movement of cargo, thus threatening the region’s economic competitiveness and viability.

In order to address these critical issues, the research team will first use traffic-engineering analysis to assess the capacity of land access to the port. Second, the core analysis will focus on terminal gate congestion, using system analysis and queuing models to calculate waiting cost as well as social costs. Third, based on the findings, the team will provide some recommendations to improve gate operations to help reduce congestion.

Phase II: Land Access to Port and Terminal Gate Operations

A. Scope

This phase focuses on the surface and infrastructure access investments and procedures (including electronic) needed to improve freight movement into and out of the port to alleviate congestion. This phase is particularly important if the port is expected to become a hub port and handle the 5.5 million containers or more annually (more than double the 1995 volume) by the year 2015, as predicted.[10] The Master Plan expects the port to handle 4.58 million TEUs by 2010, assuming 45-foot depths, and 5.44 million TEUs if the channels can be deepened to 50 feet.[11] At the present time only about 8% of the cargo that moves by truck through the Port of NY & NJ has its origin and destination beyond a 125 miles radius of the Port of Elizabeth - Port Newark Marine Terminal complex.[12] For the projected increase in container activity, including longer inland distribution distances, efficient port operation is a must.

The terminal operator must also focus on surface infrastructure access so as to enable smooth the flow of containers into and out of the terminal. This study's preliminary analysis is to present operation procedures based on the data provided by the terminal operators and then determine the appropriate procedures and infrastructure requirements for efficient operations to be implemented on a specific time period.

In this phase of the study we analyze the infrastructure accessibility to the gate and gate operations subject to engineering constraints and other limitations. First, the **road capacity** at the various facilities will be determined. It will be followed with a **gate operations analysis** and its contribution to congestion. The most demanding facility is the Port's Newark/Elizabeth Marine Terminal complex.

The main area in Phase II of the study includes the intermodal links primarily and the truck with respect to the terminal gates and the port. A detailed study of the present terminal gate structure/characteristics such as gate hours, gate variation, traffic flow, labor agreements, design, procedure etc., will be analyzed in detail. The goal of the analysis is to reduce the queuing length at the terminal gate itself.

To evaluate and improve on operational performance, the research team starts with a description of regional economic characteristics, followed by the analysis of the existing facilities and operations procedures and the calculations of

[10] New York - New Jersey Dredging Scenario Study, Final Report, Louis Berger & Associates, Inc., July 1996.
[11] Terry Brennan, "Corps backs 50-foot channels," The Journal of Commerce, September 10th, 1999, p.1, 15.
[12] Paul Richardson Associates Inc., The Port Authority of New York & New Jersey Dredging Impact Study, Draft, December 1994, page 22.

costs associated with gate congestions. Lastly, the team will provide recommendations on how to improve gate operation efficiency.

B. Introduction

The determination of the appropriate gate operation standard and the level of the terminal operators' investment are subject to the demand and supply of containers in the New York and New Jersey area, the carriers' schedule and the port terminal operators' quality of service objectives. This, in response to perceived competitive business forces. Thus, it is the traditional arguments of demand analysis. The larger the vessels, the larger number of container movements and the growing adoption of JIT managerial systems approach to inventory management, suggest that the terminal operators together with the port authorities will be expected to accommodate the business community more adequately and quickly. After all, carriers are free to choose any port to discharge and let the container move via barge or surface transportation to its final destination. In doing so, the carriers accomplish their narrow objective of cost minimization given market dynamics. The port authorities and the terminal operators have no choice but to accommodate carriers' demand for better infrastructure or face losing business to another ports.

The Port of NY/NJ remains very attractive to carriers due to the region's geo-economic characteristics. Thus, a carrier would prefer to stop at the port as the first and last stop on the East Coast in order to provide competitive inbound and outbound cargo transit time, optimal stowage and equipment repositioning. The Port of NY/NJ has all the characteristics of a hub port, but should the Port undertake the responsibility of becoming a hub port? A hub port could reduce the number of ports of call for vessel operators and could provide the economies of scale, cost service competition and efficiency gains ship operators are seeking.

The ability of the port to accommodate carriers' demand in an environment of global supply chain is subject to the port's facilities, land and vessel access to the port, terminal operations, logistics organization, vessel schedule, in short, port characteristics and the management of goods movement. Traditional demand, the motivating factor, is structured on past behavior, future expectations, and/or regional economic factors.

Even though the Port Authority should accommodate both vessel and terminal operators and aim towards establishing itself as a hub port, they have the liberty to do so based on their own schedule and projection of needs based on regional economic conditions through cost-benefit analysis. One should also remember that the Port Authority is a public entity whose funding is subject to budget appropriation and public scrutiny. Thus, port investment needs to be a sound and optimal public policy to satisfy the needs of both the private sectors and general public.

C. Regional economic characteristics

The movement of containers is largely a function of regional economic activity, which, in New York and New Jersey drives the region's container movements. Such activity contributes to both regional and port growth. The rest of the activity is due to the hub status of the port, such as transshipment cargo.

The region as defined by the Regional Planning Association[13] consists of nearly 1600 cites, towns and villages that encompass nearly 13,000 square miles and comprises 31 counties. The region had a population of 19.7 million in 1990 and about 20.2 million in 1995 (see map in appendix) with the population that is estimated to reach 21 million in 2005 and 23 million by the year 2020. The region had 7.2 million households and 7.7 million housing units in 1990. During the years 1980 to 1990 the number of household and housing units increased by 6.4% and 7.5% respectively. The regional housing cost in 1987 was 2.2 times higher than the national average. The change of housing value for median income families in New Jersey and Connecticut is twice as high as the national average. The employment of individuals in production and craft is about 20% of the working population with most production destined for local market consumption. Thus, the nature of the region is such that the import of finished goods is a dominating economic factor.

The region is home to more than 600,000 business establishments, more than 1.5 million registered trucks, and more than 8.8 million employees. It is one of the largest and densest regions in the world with an average of 17,600 persons per square mile. The area is also home to the largest concentration of transportation facilities in the world, including three major airports, several marine container terminals, intermodal yard facilities and more than 11,000 miles of highways.[14]

D. Port infrastructure and competitive position

Vessel access restrictions to the Port of New York/New Jersey are primarily draft related. The main access channel, Kill Van Kull north of Staten Island, leading to Port Newark/Elizabeth Marine Terminal and Howland Hook Marine Terminal can accommodate 35-40 foot draft at Mean Low Water (MLW). Arthur Kill, west of Staten Island leading to Howland Hook Marine Terminal can accommodate 35 foot draft at MLW. Water channel to Brooklyn Red Hook Marine Terminal can accommodate 42 foot draft at MLW as well. In the year 2010[15] the port is expected to have a navigation channel with 45 foot draft at MLW to accommodate the 6000TEU vessels' draft requirements. On the other hand, for safety reason, under keel clearance requires 2 feet, which implies that the actual channel depth for navigation is two feet less than the authorized depth.

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[13] Yaro and Hiss, p. 20-56. The Tri-State Metropolitan Region as defined by USGS and US Census Bureau.
[14] Robert Paaswell and D. Petretta, "Goods Movement Characteristics in the New York City Region", University Transportation Research Center, Region II, City University of New York, April 1993.
[15] Terry Brennan, "Corps backs 50-foot channels," The Journal of Commerce, September 10th, 1999, p.1, 15.

Also, the tidal height in the New York and New Jersey Harbor is up to 5 feet. Therefore, deep draft vessels can ride the tide coming into the port.

Dredging and purchasing container cranes are complementary issues. Failing to dredge to 45 feet would cause a loss of cargo; "as channel depth decreases, cargo losses and added costs of serving New York rise exponentially. A 3-foot reduction in channel depth from 40 to 37 feet results in a 3-fold increase in cargo loss and 2.5 time increase in added costs per TEU..." A decrease to 32 feet will cause a 7-fold increase in cargo loss and 5 times added costs per TEU. Keeping the channel at 40 feet will cause a loss of cargo of 10.4% and added costs of $31.47/TEU. [16] In other words, the channel depth loss from 40 to 37 feet produces an elasticity of 2.79; i.e., a one percent decrease in channel depth will result in a 2.79% increase in cargo loss. In the year 2015 the elasticity will be 4.39. A different study found that if the draft in the port drops to 37 feet, NY/NJ would lose 12% of its volume or 181,900TEU.[17] In addition, failing to purchase the new class of container cranes would prevent the handling of SPP vessels. The economic loss would be similar to the above based on lost vessel service and vessel time.

Cargo is distributed to the region through road and rail intermodal links. "Approximately 92% of the cargo moving through the Port of NY has its origin or destination within a 125 mile radius of the Port Elizabeth - Port Newark marine terminal complex."[18] The region's inland transportation truck share includes 100% hauling to Philadelphia, 80% of the Baltimore traffic, and 70% of the Norfolk traffic.[19] Finished goods comprise about 75% of the container cargo moved. The high percent of finished goods that arrive are not matched by an equal percent of exports on the return trip, resulting in the shipping of many empty containers, about 20%. This amount was recently increased due to the economic crisis in the Far East. The movement of empty containers adds to the port congestion. Rail is a viable option for some commodities handled by the port and more so once the port becomes a major hub. Express rail exceeded its original capacity design of 125,000TEU in 1997 with 127,601containers, an 18.47% increase from 1996.[20] This was ahead of schedule.

Container vessels with a draft of more than 35 feet represent 18% of all the carriers, 7% of total annual calls and 52% of total TEU carried.[21] As of 1994 the port was visited by vessels ranging from 500 to 4000 TEUs with a draft of 21.9 to 44.2 feet.[22] Forecasts of future vessel service indicate that 6000TEU container-

[16] Berger, p. ES-6 and ES-8.
[17] Richardson, p. 29.
[18] Richardson, p. 22.
[19] Berger, p. VII-10.
[20] NJMT Cargo Activity report, various quarterly reports from 1991 to 1997.
[21] The Port Authority of New York & New Jersey Dredging Impact Study, Draft, Paul F. Richardson Associates, Inc., December 1994, p.12.
[22] Berger, p. VI-29

ships will be deployed to the East Cost via the Suez Express service.[23] The first signs of this trend started in mid 90s as more and more carriers launched their services from South East Asia to the U.S. East Coast. For cargo from South East Asia including Southern China, the Suez service provides a competitive transit time with lower costs. The trend is to substitute the Suez Canal for the current Mini Land Bridge for Asian cargo destined the Port of New York/New Jersey. The reasons indicated for this trend are based on three assumptions: "the importance of the Southeast Asia (Southern China, Indonesia, India), which is more amenable to an all-water route; the growing congestion on the cross-country rail system, which is being devoted more and more to domestic cargo; and reduction in ocean freight following the appearance of post-Panamax ships."[24] Obviously, the congestion at West Coast ports contributes to this trend as well. Therefore, the Suez service gives shippers another option to route their cargo depending on their logistics and supply chain requirements as well as competitive dynamics.

Other U.S. East Coast ports with the capability to accommodate vessels with draft in excess of 40 foot at MLW are: Baltimore (50 feet), Boston (42 feet), Charleston 45) feet, Hampton Roads (Virginia) (45-50 feet), Miami (44 feet), Philadelphia (40 feet) and Port Everglades (42 feet), while the Canadian port of Halifax in Nova Scotia has a 50 plus foot channel. Thus, ports north of Hampton Roads are in direct competition with the Port of New York/New Jersey. They could potentially cause cargo diversion such that some cargo originally destined for NY/NJ and Midwest would be routed through other ports. Furthermore, due to cheaper land cost, their port tariff structure could provide some leverage to help them capture a greater share of the market.

In conclusion, the port can accommodate up to fully loaded 4,000 TEU ships with drafts of approximately 43 feet. Without dredging to deepen the Kill Van Kull channel, the port would be at a disadvantage to compete with other East Coast ports to accommodate the 6,000 plus TEU ships. The consequence would be adverse to the regional economy.

E. The Port's economic impact

The port's direct impact on the region is in vessel services, trade services, cargo handling and storage services, as well as inland transportation activities. There is also an indirect impact on the region. According to the Port Authority,[25] the port is responsible for 2% of Gross Regional Product and 1.3% of total regional employment. In 1996 the Port of NY/NJ handled 5.6% of the total ocean borne foreign trade bulk and general cargo. The exports that pass through the port changed from 4.354 million tons ($17.739 billion) in 1992 to 4.921 million tons

[23] Berger, p.VI-35

[24] Berger, p. VI-36-37

[25] Economic Impact of the Port Industry on the New York-New Jersey Metropolitan Region, Economic Division, Office of Economic and Policy Analysis, The Port of NY & NJ, July, 1995, and Port of NY & NJ Oceanborne Foreign Trade Handbook 1994, The Port of NY & NJ, October, 1997, p. 2-9.

($20.083 billion) in 1996, while imports went from 8.383 million tons ($33.152 billion) to 9.410 million tons ($40.201 billion). In 1998 imports reached 12.2 million long tons. In 1994, imports accounted for about 71% of total container volume (import and exports)[26]. Thus, the Port of NY/NJ is an important and integral part of regional economic activity.

The Port of NY/NJ container activity grew through the years from 1.9 million TEU in 1991 to 2.83 million TEU in 1999. This exhibits an annual average growth rate in excess of 6%. The projections are for 5.53 million TEU in the year 2015 (table 1 and figure 1). In 1993 the 1.97 million TEU represented 38.7% of the North American Atlantic East Coast container traffic. In 1991 the Port of Newark/Elizabeth Marine Terminals handled 84% of the container traffic in the Port of NY/NJ. This peaked to over 90% in 1994 but declined to 78% in 1998 (table 1 and figure 2). The other marine terminals share increased substantially, most notably Howland Hook Marine Terminal's share increased to 7.9% in 1998. Statistical analysis also revealed that the number of vessels arriving since 1992 at the Port of Newark/Elizabeth Marine Terminals were declining all through 1996 but the TEU and container moves per vessel increased. This pattern changed in 1998 and subsequent years. The average number of containers per vessel discharged and loaded is 60% of the TEU count; it reached 645, 642 and 626 in 1994, 1995 and 1996 respectively, before declining to 575 in 1998, where Sea-Land, the largest container operator, averaged 1031, 938 and 1027 moves per vessel respectively. A future projection of port activity for the year 2015 is for 851 moves per vessel (table 1).[27] The number of containers handled per day increased through the years from 3,447 in 1991 to 4,857 in 1999, representing an annual average increase in excess of 5% (table 1 and figure 3). At this rate by 2015 the daily number of containers could reach 8500. However, the projected number of daily container handling for 2015 is 10,540 (table 1) taking into consideration the potential increase in vessel traffic, vessel size and the number of containers handled once the port is dredged. From intermodal traffic, the container volume at ExpressRail, built in 1991, reached the design capacity of 125,000 containers (lifts) in 1997, way ahead of projection. In 1997 it handled 127,527 and in 1998 it reached 155,062 and 158,800 in 1999.[28] ExpressRail, which started with 2.49% of the port of NY/NJ container cargo, handled 10.50% of the port cargo in 1998 and 9.42% in 1999 (table 1). This growth indicates the increasing importance of the port as a transshipment point The planned improvement in highway access to the rail intermodal facility at the port will further enhance the port's competitive position.

[26] Berger p.VII-15

[27] Shmuel Yahalom, "Intermodal Productivity and Goal Movement; Phase I, Crane Performance," University Transportation Research Center, Region II, April 1997, p. 16.

[28] Port Authority of NY & NJ web site, January 2001.

Table 1: The Number of Containers and Ships Handled in the Port of NY/NJ

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2015**
Port of NY/NJ										
TEU (thousands)	1,906	2,014	1,973	2,034	2,276	2,269	2,457	2,466	2,829	5,529
Containers (thousands)	1,113	1,205	1,181	1,219	1,340	1,335	1,460	1,477	1,685	
Ratio of containers to TEU[a]	0.584	0.598	0.599	0.599	0.589	0.588	0.594	0.599	0.596	0.593[e]
Port of Newark/Elizabeth Marine Terminal										
TEU (thousands)	1,592	1,812	1,777	1,881	1,954	1,813	2,026	1,944	1,764*	4,832[e]
Containers (thousands)	932	1,068	1,053	1,106	1,138	1,062	1,192	1,153	985	2,850[e]
Ratio of containers to TEU[b]	0.585	0.599	0.593	0.588	0.582	0.586	0.588	0.593	0.558	0.590[e]
% of total TEU[c]	83.53	89.97	90.07	92.45	85.85	79.90	82.46	78.83		87.41[e]
% of containers[d]	83.74	88.63	89.16	90.73	84.83	79.55	81.64	78.06		
Number of ships that arrived		2,248	2,055	1,716	1,772	1,696		2,005		3,355[g]
TEU per ship		806	865	1,096	1,103	1,069		970		1,440[e]
Containers per ship		475	512	645	642	626		575		851[e]
Containers/day (250 days)	3,447	3,950	3,894	4,090	4,209	3,928	4,409	4,264	4,857	10,540
Ships/day (360 days)		6.24	5.71	3.04	4.92	4.71		5.57		9.32
ExpressRail (lifts)	27,741	43,016	55,995	77,171	85,627	102,899	127,527	155,062	158,800	
% ExpressRail from total containers	2.49	3.57	4.74	6.33	6.39	7.71	8.73	10.50	9.42	
% ExpressRail from Port Newark/Elizabeth	2.98	4.03	5.32	6.98	7.52	9.69	10.7	13.4		

* First six month only.

** Port Authority memo "Outlook for Containerized Cargo" from 10/16/96. The memo includes listings of studies by: the Port Authority, Richardson, Louis Berger and VZM. The data reported in the text is from Louis Berger from the "New York - New Jersey Dredging Scenario Study," assumes ratio of total containers to loaded containers is 1.21.

[a] The proportion of containers to TEU

[b] The proportion of containers to TEU for the Port of Newark/Elizabeth only

[c] The percent of the Port of Newark/Elizabeth TEU from the total of TEU that arrived in the New York and New Jersey Harbor Marine Terminals

[d] The percent of the Port of Newark/Elizabeth containers from the total number of containers that arrived in the New York and New Jersey Harbor Marine Terminals

[e] Estimated by author based on earlier years analysis.

[f] Estimated and projected container fleet sailing by 40 foot canal depth (Berger p. VI-41).

[g] Estimated and projected container fleet sailing by 45 foot canal depth (Berger p. VI-41).

Sources: Port of NY & NJ Oceanborne Foreign Trade Handbook 1994, The Port of NY & NJ, October, 1995, p. 2-9 and NJMT Cargo Activity report, Quarterly reports from 1991 to 3rd quarter 1996.

Figure 1. Port of Newark/Elizabeth Marine Terminal annual number of containers (in thousands)

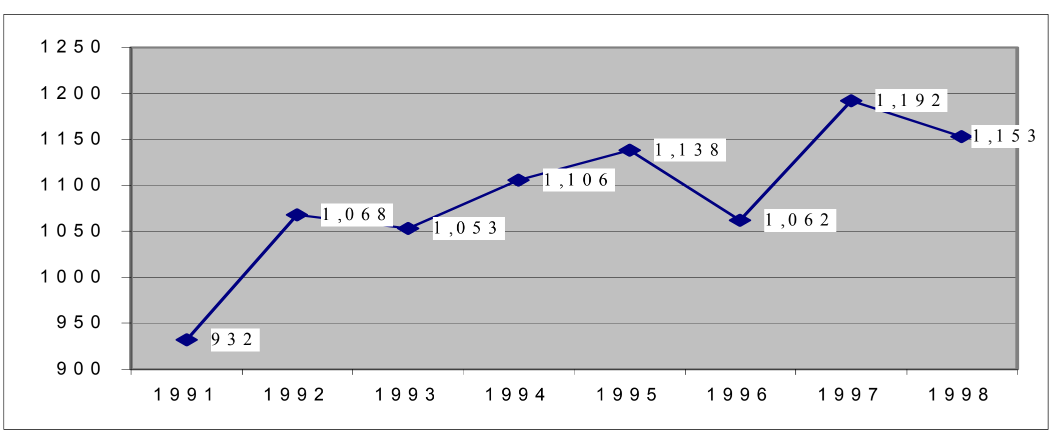
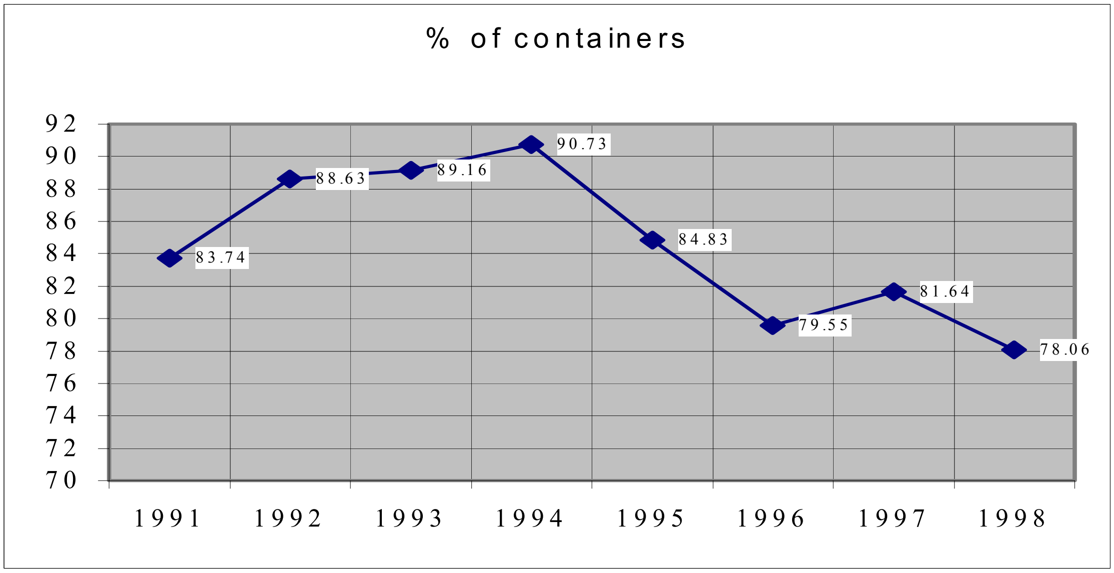
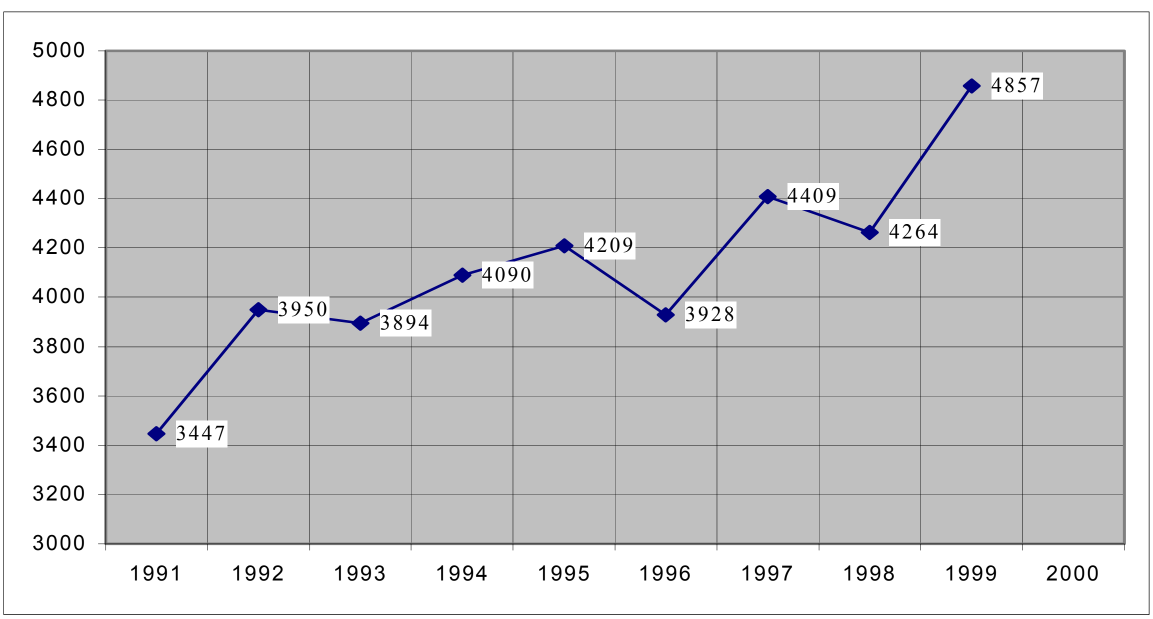


Figure 2. Port of Newark/Elizabeth Marine Terminal share of NY harbor containers



(in percent)

Figure 3. Port of Newark/Elizabeth Marine Terminal number of containers per day (250-day year)



F. NY/NJ Marine container terminals location and characteristics[29]

The Port's intermodal *container* terminal transfer facilities are located in the following 5 marine terminals:

- Port of Newark
- Port Elizabeth Marine Terminal
- Howland Hook Marine Terminal
- Brooklyn Marine Terminal, and
- Global Marine Terminal (not part of the PANY/NJ).

Each terminal has it own unique physical characteristics. Some marine terminals have gates in different locations for container check-in or -out. Others have gates in the same location. The physical location of the gates and the number of check-in/out gates differ by terminal operator.

Gate performance is a function of terminal activity, gate system configuration, gate processing technology, and operation. Local access roads to the terminal also influence gate operation. For example, access road capacity and traffic light configurations impact the traffic flow to the port and therefore could affect port activity.

The primary functions of a container terminal include:[30]

1. Furnish the necessary personnel and container handling equipment to receive, store, and deliver containers.
2. Prepare all necessary port documents for the receiving and delivery of containers and ensure that all port charges, customs duties, and freight charges have been paid.
3. Maintain a status report of all containers received, delivered, and on hand in the terminal for submittal to the steamship lines involved.
4. Maintain accurate inventory and locations of all containers and equipment.
5. Pre-plan all vessel loading and discharge operations from data applied by the steamship lines or their agents.
6. Provide the necessary personnel and equipment to service the loading and discharging (stevedore) operations of the vessel.
7. Prepare all cargo plans, hazardous cargo manifests, and related documents for delivery to the vessel and steamship line.
8. Maintain security for all containers and equipment in the terminal.
9. Prepare all reports related to the terminal functions and vessel operations.
10. Furnish adequate supervision to ensure proper performance of all operations.

F.1. Container terminal location

A marine terminal is frequently identified by the terminal operator's name and not the land parcel location. For example, the Port Newark Marine Terminal and Port Elizabeth Marine Terminal could be identified with Maersk/Universal, Maher, Sea-Land or ExpressRail. Below is a combination of location and survey characteristics pertaining to the terminals as they might affect gate operations and road congestion (see maps in appendix).

F.1.1. Port of Newark/Elizabeth Marine Terminal

Port of Newark/Elizabeth Marine Terminal complex is the largest terminal facility of the Port Authority of New York & New Jersey with a total of 2184 acres (Port Newark 930 acres and Port Elizabeth 1254 acres.) These terminals are

[29] In general the feature and the function of the marine terminal is described by Atkins (see "The primary functions of a container terminal").
[30] Atkins, p.23.

located on the western shore of Newark Bay and handle containers, automobiles and breakbulk, bulk and heavy lift. *Landside access and vehicle flow to Port Newark/Elizabeth Marine Terminals is determined to a large degree, to the north, by the intersections at Port Street and Corbin Street (NJ Turnpike exit 14) and Doremus Ave. (NJ Turnpike exit 15E and Routes 1 & 9), and to the south, by North Avenue which leads to McLester Street (NJ Turnpike exit 13A).* The flow of traffic is determined to a large degree by the characteristics of the signalized intersections and turns along the access roadways, specifically along Corbin St. and McLester St. The entrance to many terminals is from Corbin Street, which connects to the New Jersey Turnpike (there are also various exits including Route 1 & 9) and McLester Street through North Avenue to the Turnpike (exit 13A). This facility also has a ***Vehicle Processing Facility****,* involving vehicle storage and processing services primarily along the Port Newark Channel. The entrance is along Polaris Street (DAS) in Port Elizabeth, Craneway (FAPS) and Port Street (Toyota) in Port Newark. This operation occupies about 300 acres and is also the site of the ***Marine On-Dock Auto Rail Terminal***. The Port of Newark/Elizabeth Marine Terminals are home to several major container terminal operators: Maher, Maersk/Universal, and Sea-Land.

Maher Marine Terminal occupies two sites. The Maher Fleet Street site is 200 acres and the Tripoli Street facility is 243 acres. The primary activity at both is container and ro/ro. ***Maher Fleet Street*** terminal is along the Elizabeth Channel and the entrance is from Lyle King Street which connects to Corbin Street, which links to the New Jersey Turnpike (I-95). This site is also linked to the ExpressRail transfer facility. ***Maher Tripoli Street*** is along Bay Avenue next to the ExpressRail transfer facility. The entrance however, is from Tripoli Street. In order to access I-95, a trucker would have to get from Bay Avenue to Corbin Street or Tripoli Street to McLester Street.

Maersk/Universal Marine Terminal occupies an area of 224 acres (Maersk 153 acres and Universal 71 acres). Its primary activity is container and ro/ro. The terminals are located along the north Elizabeth Channel. The entrance to the Maersk Terminal is on Tyler Street, which connects to Corbin Street. The entrance to Universal's terminal is through Calcutta Street, which connects to Tyler Street through Export Street. These facilities do not have direct access to ExpressRail.

Sea-Land Marine Terminal is the largest terminal on the peninsula with an area of 254 acres. Its primary activity is containers. The entrance to the facility is on McLester Street. It too does not have direct access to ExpressRail.

ExpressRail. The ExpressRail Terminal, which opened in 1991, is an on-dock intermodal terminal. The entrance is on East Fleet Street next to the Maher Terminal in the Elizabeth Marine Terminal. CSX and NS railroads provide the service having the capability of handling double-stack container traffic. This service links the port with the Midwest, Eastern Canada, and many other inland markets.

F.1.2. Howland Hook Marine Terminal

Howland Hook Marine Terminal (187 acres) is located along the Arthur Kill Channel in Staten Island. It is reached by vessel through the Kill Van Kull Channel and handles containers; break bulk, and general cargo. The entrance is at the foot of North Washington Avenue or Goethals Road and Western Avenue. The entrance is near the Goethals Bridge and the Staten Island Expressway (I-278). Though currently inactive, the facility also has on-dock rail connections.

F.1.3. Brooklyn Marine Terminal

The Brooklyn Marine Terminal has facilities in Red-Hook (container terminal), South Brooklyn and Brooklyn Piers (6-8). Together they occupy 199 acres located in the Upper New York Bay.
The ***Red-Hook Marine Terminal*** (79 acres) has access to the east side of the Hudson River. The terminal handles containers, ro/ro and break bulk cargo. However, "for cargo headed west, Red-Hook offers a trans-harbor freight service which transports containers from Red Hook to New Jersey by barge. The terminal is operated by American Stevedoring Inc."[31] The entrance gate is situated on Hamilton Ave, and empty containers enter on Congress Street and Colombia Street. Next to the Red-Hook Marine terminal are the ***Brooklyn Piers*** numbers 6 through 8 (10 acres). They are leased for stevedoring and warehousing of break bulk cargo. The entrance gate to this terminal is at the foot of Atlantic Avenue.
The ***South Brooklyn Marine Terminal*** (110 acres) is located along Second Avenue between 30th and 39th Street in Brooklyn. The terminal handles ro/ro and break bulk cargo. The entrance gate is located at 2nd Avenue and 31st and 39th Street. The terminal has a rail yard as well.

F.1.4. Global Marine Terminal

The Global Marine Terminal (100 acres) is located along the Port Jersey Channel in Jersey City. It is the only privately owned container terminal in the Port district. The terminal is designed primarily for container operations but also serves ro/ro and heavy lift. The entrance to the terminal is through Port Jersey Boulevard. This facility has no on-dock rail connections to North Jersey rail yards but is one half mile from the Greenville yard. Also, along the same peninsula is the *Auto Marine Terminal*. This is a 130-acre facility with direct intermodal rail. The entrance to the facility is from Colony Road (BMW) and Port Jersey Boulevard for Northeast Auto Marine Terminal (NEAT).

[31] Port Guide NY/NJ, The Port of NY & NJ, 1996, p. 26.

F.2. Access road capacity

The infrastructure accessibility to the gate and gate operations are subject to engineering constraints and other limitations. **Road capacity** at the various facilities will be determined. The most demanding facility is the Port Newark/Elizabeth Marine Terminal complex.

Port Newark/Elizabeth Marine Terminal

This marine terminal complex effectively has two entrances, both paralleling the New Jersey Turnpike. To the north, the intersection of Port Street and Corbin Street (NJ Turnpike exit 14) is denoted as M1 on the map. To the south, North Avenue, leading to McLester Street (NJ Turnpike exit 13A) is denoted as M8 on the map (see map in appendix). There are several other local exits, including Routes 1 & 9. The main artery along Newark Bay that serves the terminal operators is Corbin Street.

These two entrances serve all the following facilities: Vehicle Facility, Marine On-Dock Auto Rail Terminal, Maher Marine Terminal (Fleet Street and Tripoli Street), Maersk/Universal Marine Terminal, Sea-Land Marine Terminal and ExpressRail. The facilities are subject to traffic by passenger cars, trucks, car carriers and tractor-trailers. Included in these movements are also the transfers of containers from the Marine Terminals to the ExpressRail intermodal facility. In 1998 this amounted to 155,062 containers lifts or 13.4% of the annual container activity of 1,153,000; in 1995 it was 7.52% (table 1). Thus, the number of containers that left the port via highway is proportionately smaller.

i. Capacity Analysis at North and South Entrances

The road and intersection capacities of the north and south entrances to the Port Authority's complex designated as M8 and M1 respectively, will be calculated and compared with the actual volumes at these locations. Capacity constraints, if any, will be identified. The entrances, located at the junction of North Avenue and Kapkowski Road and the second located at Port Street and Corbin Street, serve as the primary entrances to the Port Authority's complex, which includes Port Newark and Elizabeth Marine Container terminals. Thus, they could create a bottleneck in the system. The above entrances accommodate a variety of vehicles including trucks, passenger cars and buses; they also serve industrial sites surrounding the Port, which includes a shopping center.

ii. Methodology

The analysis entailed calculating **road** capacities and **intersection** capacities at the north and south entrances at the designed speed limit of 30 mph and comparing these values with the actual values of volume obtained from a 1994/1995 traffic engineering study prepared by the Engineering Department of the Port Authority of NY/NJ. The values used in the analysis are the actual values measured by the study team on October 27 and November 3, 1994. Furthermore, the analysis will apply this method to future anticipated volume as well. The calculations at a speed limit of 30 mph are optimistic due to the frequently observed speed of 15 mph due to the large number of trucks, their slow acceleration from stop to start, as well as their wide turns. The study applied the Institute of Transportation Engineers methodology to determine road capacity.

iii. Capacity Analysis

The capacity of the system is a measure of the facility's ability to accommodate a moving stream of vehicles under ideal conditions. It underlies most transportation planning and design decisions and actions and therefore is an important factor in designing a system that will incorporate anticipated demand. The following analysis defines the concept of capacity and describes the approaches to assessing the capacity at the North and South entrances. It also addresses the following questions:

1. What types of roadways or facilities are needed to accommodate a given level of vehicle flow?
2. What lane and road configurations are required to meet both current and future demand based on the projected growth patterns?
3. What is the possible use of information technology in managing the traffic flow and changes in flow pattern at the entrances so as to ease the flow of traffic?

Roadway capacity represents the maximum number of vehicles that can be accommodated or that pass through a given point over a specific period of time with reasonable expectancy under prevailing traffic and environmental conditions. The ability to move vehicles is generally influenced by:

(a) **vehicle composition** such as car, truck, bus, etc.,
(b) **physical road characteristics** such as lane width, grades, conflicts, turns, interference with others,
(c) **traffic stream**, traffic composition and/or vehicle occupancy and
(d) other **environmental conditions**. Posted and actual speed limits affect the flow as well.

iv. Level of Service

In order to communicate effectively about traffic flow and traffic capacity conditions, the concept of **level of service** is used. A key characteristic of service flow is defined as the "maximum hourly rate at which vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time under prevailing road conditions while maintaining designated level of service."[32]

The Institute of Traffic Engineers typically recognize six levels of service:

[32] Institute of Traffic Engineers, Planning Handbook.

Level of Service A: Free flow with individual users unaffected by the presence of others in the traffic stream.
Level of Service B: Stable flow with high degree of freedom to select speed and operating conditions with some influence from other users.
Level of Service C: Restricted flow that remains stable but significant interactions with others in traffic stream.
Level of Service D: High-density flow in which speed and maneuver are severely affected and comfort and convenience have declined even though flow remains stable.
Level of Service E: Unstable flow and near capacity level.
Level of Service F: Forced flow in which the amount of traffic approaching the point exceeds the amount that can be served and queues form characterized by stop and go waves, poor travel time, low comfort and convenience.

For most design planning purposes a level of service of at least D, C, or B is acceptable.

v. Capacity Computation/Intersection Analysis (at South Entrance M8)

A **signal-controlled intersection** is a capacity constraint on any network and is the most complex location of the traffic system. The analysis of the intersection therefore includes a variety of factors, including the geometric configurations of the intersection, turning radius, traffic volumes and composition and details of intersection signalization.

The capacity of the intersection is highly dependent on the **pattern of the signalization**. Given a range of potential signal control schemes, the capacity is far more variable than for any other type of facility where capacity is mainly dependent on static roadway geometry. In effect, signalization, which can be modified, allows considerable latitude in management of capacities of the intersection geometry. Moreover, the intersection also serves as a key factor in feeding the traffic into the lanes that connect the intersection. The concepts of capacity and level of service are central to the analysis of the intersection as they are for the other facilities. Capacity analysis results in computation of volume to capacity ratio (V/C ratio). Other factors that have stronger effects are quality of progression, length of green phase of traffic signal, cycle length and number of phases.

The research team made traffic counts on April 13, 1998, beginning at 7:15am at the North Avenue-Kapkowski Junction intersection in order to calculate the actual volume-to-capacity ratio. The observations made at the intersection during a typical morning peak hour traffic resulted in a count of 672 truck units per hour per lane at the south entrance intersection M8. The theoretical capacity of the intersection as given by the Highway Capacity Manual for a 15-sec. delay is calculated to be 687 truck units per hour per lane, a very close result with a small error. Thus, the V/C ratio for the 1997 was approximately 0.98, which indicates a

D service level. Anticipated growth however, is in the range of 10-15% between 1997 and 2000; thus, the V/C ratio at the high end is expected to reach 1.13 in 2000 and it could reach 1.97 in the year 2015 if the annual growth rate is maintained at 5%.

Table 2: Intersection Analysis at M8 location

Year	1997	2000*	2015*
Intersection capacity at North Ave. M8 (truck units per lane - tu)	687	687	687
Intersection volume at North Ave. at tu (5% annual growth)	672	773	1354
Volume to Capacity Ratio at North Ave. (Kapkowski intersection)	0.98	1.13	1.97

* Projected

The following observed values from the 1995 Traffic Study by the Port Authority Traffic Engineering Department indicates various levels of service at intersection M8 at various time periods.

Location M8:

		1995	1997	2000
• am Peak Hour	V/C Ratio =	1.08	0.98	1.13
	Level of Service =	E	D	E
• Mid Day	V/C Ratio =	0.73	N/A	N/A
	Level of Service =	C	N/A	N/A
• pm Peak Hour	V/C Ratio =	0.80	N/A	N/A
	Level of Service =	D	N/A	N/A

The junction located at M8 serves as a key location feeding the traffic into the lanes, and hence any congestion caused at this junction's intersection is carried forward creating additional congestion in the lanes.

F.3. Container crane characteristics and performance

The Port Authority's intermodal container terminal transfer facilities have container cranes as follows: Brooklyn Red-Hook Terminal (5 and 2 or order)), Global Marine Terminal (6), Howland Hook Marine Terminal (7), Port of Newark/Elizabeth at Maersk/Universal (8), Maher (16) (Fleet Street-9, Tripoli Street-7) and Sea-Land (7). The Port Authority and New York City own twenty of the cranes.

Most cranes were placed in service between 1967 and 1996, the majority (28) before 1980; thus, their performance is also outdated. One crane is out of order and 13 were elevated through the years. A large portion of the stevedoring operation is done with some 47 cranes. In the '90's there were only 4 newly built cranes; two at Maersk and two at Global. Brooklyn has two Post Panamax cranes on order.

The container cranes presently available can accommodate vessels of the Panamax class - 4100TEU (13 rows, 6 boxes high on deck, 160 to 170 40 ft containers or 320 20 ft containers in a bay), with a beam of 106 feet (32.2 meters). A Post-Panamax vessel of 5000TEU has 15-16 rows of boxes on deck and 13-14 rows under deck with a capacity of 200 boxes at mid-section. This class of vessels can carry 15-20 percent more, about 600-800 TEUs. The 5000TEU vessel needs a crane with an outreach of 140 feet (42.7 meters). The outreach range for most of the operating container cranes is 113 to 133 feet. However, the SPP vessel of 6000TEU, with 17 rows needs an outreach of 150 feet (45 meters). For 18 rows the outreach needed is about 153 feet (46.5 meters).

The crane lift height available at the present time is a maximum of 100 feet (30 meters). Only 9 cranes can reach this height, 6 reach 90 feet and 26 can reach 80-89 feet. A new crane needs a minimum lift height of 35 meters (115 feet). To handle a 6000TEU vessel, there is a need to invest in new cranes; an upgrade or overhaul is not feasible.

The current navigation channels can accommodate vessels with draft requirements of 38 feet with the exception of Red Hook. The Panamax vessel requires 40-foot clearance, the Post Panamax vessel requires 42-43 foot clearance, and the SPP vessel when fully loaded requires 45-foot clearance at low tide. Unless the vessel can "ride the tide," which would save 5 feet, the fully loaded SPP cannot enter the port. The draft world standard is 45 feet.[33] The Port Authority's dredging plan is to reach this depth by the year 2010. Indirect help for some of the problems could come by the operating draft and actual draft difference. The difference between the two is between 1 to 3 feet, which has allowed larger vessels to visit the port all along. Those vessels could even include 5000TEUs under certain configurations, including "riding the tide." However, the Port Authority should not count on it as high tides vary from day to day. Most important is that riding the tide would put restrictions on vessel schedules and most likely cause delay.

The dredging schedule indirectly determines a schedule for investment in container cranes, but it is not simple. If vessel building plans are on schedule and some 70 vessels of this size cruise the oceans by the year 2010, the New York / New Jersey harbor will have to be able to accommodate the newly built vessels even if they arrive for discharge and stowing of only 20-30% of their cargo. A sufficient number of cranes will be required to accommodate a 6000TEU vessel in order for it to turn around on schedule. A 4100TEU vessel needs 3 cranes to quickly handle its 17 bays, while a 6000TEU vessel will require at least four, even 5 cranes.

Although crane specifications provide for the level of possible performance, the actual performance is affected by other factors, including crane configuration, physical characteristics, vessel stowage, and yard arrangement. The

[33] Berger, p. VI-15.

physical characteristics that affect the port operations, in addition to cranes, include: vessel size, type of vessel serviced (hatch covers, cell guides, twist locks), equipment available at quayside and its age, type of intermodal link (truck, flat bed or rail), type of cargo (waste material), wear and tear, yard configuration, yard operation (wheeled or ground) and even weather conditions.

G. Gate function and operational characteristics

The main objective of the terminal operator is to move containers in and out of the terminal smoothly, efficiently and safely. This is achieved by controlling a variety of factors inside the yard (phase III of this project) and gate operations. The gate is a complex facility by itself and serves as both the first and last land link or interface between the port and the outside world via surface transportation. It is both the first Frequently the gate is congested from the outside in during the am hours and from the inside during the midmorning hours.

Container delivery and pick-up are determined by ship arrival and departure schedules and terminals operator recognize that vessel schedule is the most important overall factor and the driving force of yard operations.

G.1. Gate's function

A terminal gate complex, the gate, could be viewed simply as a check-in/out point at the entrance/exit of a terminal. The gate's function however, is much more complicated. For example, the gate is the point where legal responsibilities and liabilities are transferred between parties, and as a result, important information is processed at the gate. Shipping information including container number, size, ownership, type of cargo, weight, vessel and voyage, and destination is also processed at this time. Furthermore, for liability reasons, the physical condition of the container is checked as well. All this information is supplied to the terminal’s computer system, and the following documents are issued at the gate:

- security pass,
- Equipment Interchange Receipt (EIR) and Terminal Inspection Report (TIR), and
- spot ticket or routing slip.[34]

The gate therefore functions as a monitoring and information exchange point as well as a data collection unit. At the end of the day, appropriate record keeping could provide, at the very least, information regarding:

- inbound and outbound container moves
- inventory changes in the yard. The inventory check list includes containers (empty, loads and their size) and chassis
- data regarding weights of inbound/outbound cargo (most terminals only weigh inbound),

[34] For more information regarding these documents see exhibit A in appendix.

- roadability information (from the 41 point inspection at the roadability station),
- gate hours,
- dwell time,
- cargo destination,
- type of cargo,
- gate productivity.

Activities before entering the gate and after leaving the gate are of critical importance as far as the gate users are concerned. For example, the overall waiting time for a trucker has a major impact on his income and the cost to shipping lines, yet existing gate procedures does not presently collect this information.

The overall productivity of a marine terminal can be divided into three areas: vessel operations, **yard operations**, and gate operations. Gate productivity can be measured either by the number of transactions processed by the complex per unit of time or the amount of waiting time before the gate transaction takes place. Both are influenced by vessel schedule, time of day, day of week and type of transaction or type of cargo. This is the focal point of this phase of the study.

Waiting time is the amount of non revenue producing time a trucker must wait from the moment he arrives at the holding pen just outside of the gate facility until he reaches the gate or pre-gate itself where he is finally recognized. Since a driver's income is often a function of the number of round trips he is able to make, a trucker seeks to complete a pick-up before the lunch break. If he is unable to do so, he will have to wait around some 90 minutes for lunch to end.

A national survey of truck drivers expressed a general concern for "Time in Line to Gate" and, the "waste of time outside the main gate" was also seen "as a significant concern." A second issue of concern was "Coverage during breaks and meals." The truckers graded all terminal performances "26 percent F's. In some cases, particularly at ports, labor agreements constrain terminal managers."[35]

A gate's processing methodology also affects the processing time. At one extreme, processing methodology could be all manual (paper), and at the other extreme all electronic (paperless). At the present time there is a mix of methodologies; some gates operate predominantly manually while others somewhat electronically and still others completely electronically.

In general, there are two issues that need to be addressed: how to improve gate operations immediately and how to improve it in the long run. These questions need to be answered from the point of view of the trucker and the terminal operator. Thus, some of the questions might be:

What should gate hours be?
How many of the activities are functions of habit?
How much labor flexibility is available?
What activities should be part of the gate to speed up processing time?

[35] "1996 Intermodal Terminal Survey", ATA Intermodal Conference, Alexandria Virginia, 1996, p.12-14.

Could all these functions and others be handled in another way?
What is the gate productivity and what should it be?
Does the gate productivity affect traffic flow and therefore congestion?
Does electronic processing make a difference in gate time?
How will it change when the total amount of cargo doubles?
At the extreme, is there a need for a gate?
And last but not least, what does the Port Authority of NY & NJ aim for, in the short run and in the long run?

A terminal operator will plan the daily gate structure a week in advance. In turn this will determine speed, capacity and cost to all parties involved. In the long run the terminal operator will also determine the investment in operating priorities such as electronic information and communications capabilities in general, all of which are critical features affecting gate efficiency. A gate's performance therefore, is a function of terminal activity and the type of gate operation.

G.2. NY port terminal gate function and operations

The physical location of the gates and the number of check-in/out stations differ by terminal operator.

G.2.1. Maersk Marine Terminal

i. Gate lane operations

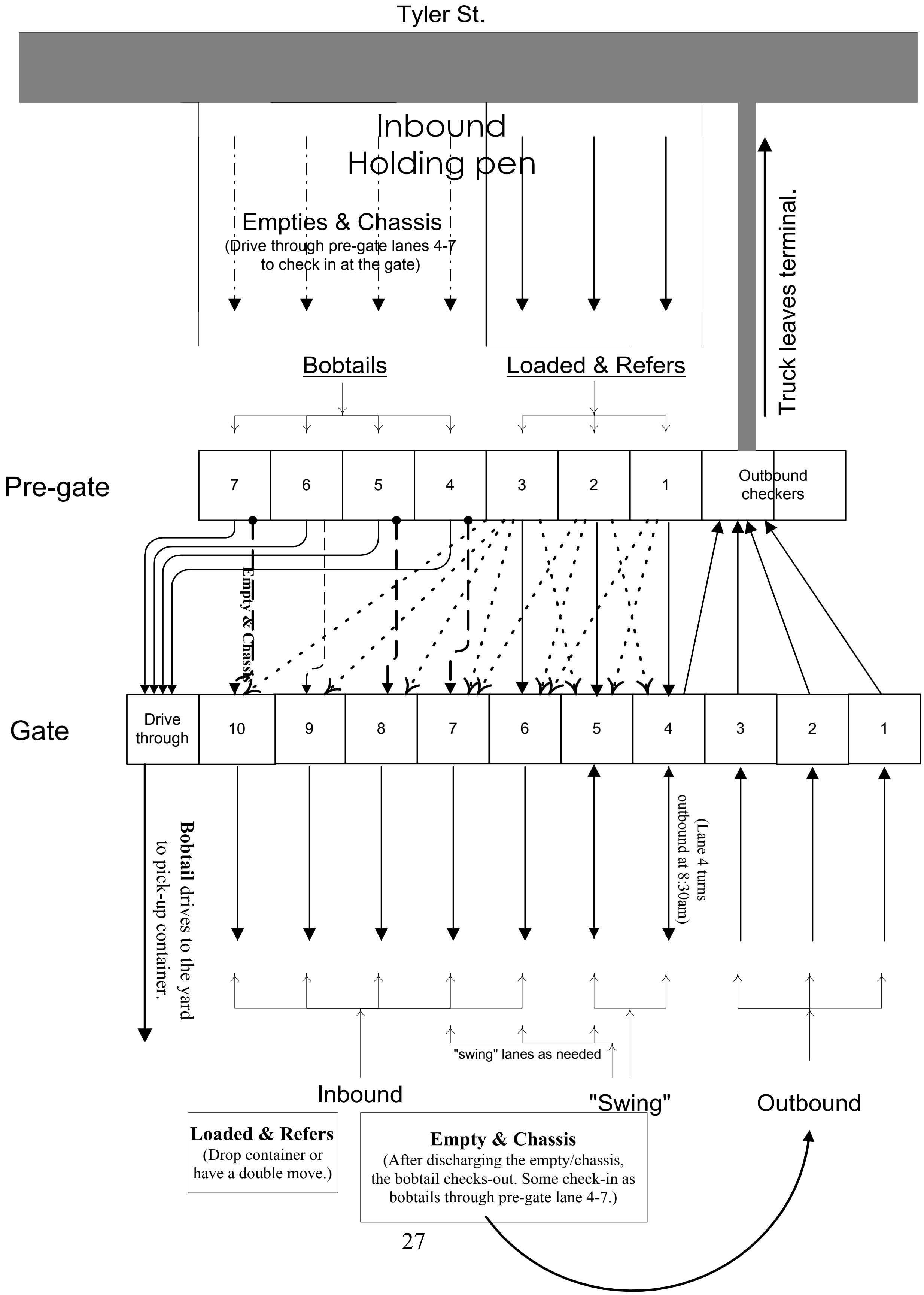
Maersk Terminal along Tyler St. is a 2-stage gate complex, with a pre-gate and a gate. A trucker who has business at Maersk Terminal arrives first at one of the 7 inbound pre-gate lanes, which open at 7am. There is an additional lane beyond pre-gate lane number 7. Trucks begin lining up in the holding pen before 7am; some arrive the night before. Truckers that arrive early are usually the independents, which make up about 70% of the volume.[36] Fleets on the other hand know the waiting time involved and will send their trucks at about 8amThe gate complex has a second row of gates, consisting of 10 lanes typically configured with 7 inbound lanes with an in-ground scale, and 3 outbound lanes. Lanes number 4 & 5 are the primary "swing" lanes so that Maersk's gate complex could operate up to 5 outbound lanes depending on need. However, it was also observed that the gate operated with 7 outbound lanes (see Figure 4: Maersk Terminal).

We distinguish between 5 types of trucks:

Trucks hauling loaded containers, denoted as ***load***.
Trucks hauling empty containers, denoted as ***empties***.
Trucks hauling chassis only, denoted as ***chassis.***
Trucks that do not haul anything, denoted as ***bobtails***,
Trucks hauling refrigerated containers, denoted as ***reefers.***

[36] Interview of Tom Heimgartner, President, BEST Transportation Inc., 11/19/98.

Figure 4. Mearsk Terminal



Bobtails are served by pre-gate lanes 4 through 7 and enter the terminal at the drive-through lane without any additional gate processing. Pre-gate lanes 1-3 serve ***loads*** and ***reefers***. A *load* and/or *reefer* served by pre-gate lane number 1 will usually proceed to gate lane number 4 (before 8:30am), 5 or even 6. A *load* and/or *reefer* served by pre-gate lane number 2 will usually proceed to gate lane number 5, but has a choice to proceed to gate lanes numbers 4 through 7. Similarly, from pre-gate number 3 one would try to select gate lane number 6 but would also look to gate lanes number 5 through 10. ***Empties*** and/or ***chassis*** go through pre-gate lanes 4 through 7 directly to a gate lane in order to enter the terminal. The *empties* and/or *chassis* usually look for gate lane number 6 through 10. An *empty* and/or a *chassis* discharges its box and leaves the terminal complex as a bobtail. In case he needs to pick-up a loaded container he must first check out at the outbound lane and then line up and reenter as a ***bobtail***. Typically, at the pre-gate or gate, a trucker submits his documents via a vacuum tube to the office across the way and upon approval proceeds to the gate or enters the terminal (see figure 1 for more detail).

Because of ship sailing schedules, the busiest day of the week is normally Friday (and Monday).[37] On this Friday the total number of inbound gate lanes available for *loads* and/or *reefers* was 6 before 8:30am and 5 thereafter. Lane 4 changed from an inbound lane to an outbound lane after 8:30am. There are times when only 4 inbound lanes are in operation: when lane number 5 "switches" to be an outbound lane. This last change probably takes place on a Friday at about 3:00pm.

ii. Processing time at the gate and potential output

On this Friday the average ***pre-gate*** processing time for a truck with a *load* container was observed to be 6 minutes, i.e. an average of 10 transactions per hour per lane. The average lane time at the ***gate*** for the same group was 10 minutes. The average trucker waited 5 minutes between the pre-gate and the gate. Thus, on the average, a loaded truck spent 21 minutes in pre-gate/gate processing before entering the terminal proper.

A close observation reveals that the processing time at the pre-gate facility during the am hours was not uniform. For *loads* and/or *reefers,* the average processing time for the first hour was 7.3 minutes (8.2 transactions an hour); between 8:00am - 9:00am it took an average of 8 minutes of processing time (7.5 transactions an hour). The average processing time for the half-hour between 10:40am and 11:10am (before the lunch break) decreased to 5 minutes (12 transactions per hour per lane). *Bobtails* averaged 3.67 minutes processing time at the pre-gate (16.34 transactions per hour). They entered the terminal skipping the gate right afterwards. *Empty* containers went directly to the gate lanes with an

[37] Observed by author on August 14, 1998 between 7:06AM and 11:20AM.

average of 6.67 minutes processing time (9 transactions per hour). Through the am hours, the number of trucks waiting in the holding pen kept declining to 0 by 11:17am.[38]

Given this processing time and a net 8-hour working day,[39] a single lane in the ***pre-gate*** complex could potentially process an average of 80 loaded container trucks or a total of 240 loaded container trucks for pre-gate lanes 1through 3. A single pre-gate lane could also process 131 (60/3.67 x 8) bobtails during a net 8-hour shift for a total of 523 bobtails a day for the pre-gate lanes 4 through 7. Since pre-gate lanes for loaded containers and bobtails are practically separated, the total potential output of the pre-gate is 763 trucks per net 8 hours a day. However, if lanes 1 through 3 are idle, bobtails might also use these lanes. One could therefore determine that the annual (260 working days) potential throughput is 198,349 containers (Table 3).

Table 3: Summary of pre-gate and gate activities

	Load & reefers	Empty & chassis	Bobtails	Totals
Pre-gate				
Number of lanes	3		4	7
Average processing time (minute)	6		3.67	
Number of transactions per hour	10		16.34	
Potential output per lane (net 8-hour day)	80		131	211
Potential output per day	240		523	763
Annual potential throughput (260 days)	62,400		135,949	198,349
Gate				
Number of lanes*	5.1875	5.1875		5.1875
Average processing time (minute)	10	6.67		9
Number of transactions per hour	6	9		6.67
Potential output per lane (net 8-hour day)	48	72		53
Waiting between pre-gate and gate (minutes)	5			
Total service time	21	6.67	3.67	
Movement distribution (%)**	43.9	56.1		
with **5.1875** lanes	249	374		277
with **6.1875** lanes	297	446		330
with **7** lanes	336	504		374

The ***gate*** complex serves *loads, reefers, empties* and *chassis*. Given that the processing time at the ***gate*** of a *load* and/or *reefer* is 10 minutes, over a net 8-hour working day, a lane in this gate complex could process 48 *loads* and/or *reefers* per lane per day. Since it takes 6.67 minutes to process an *empty* and/or *chassis*, over a net 8-hour day a lane could process 72 of them (50% more than loaded). The gate

[38] August 14, 1998 between 7:06am and 11:20am.

[39] The working day is between 7:00am and 4:30pm with a lunch break between 11:30am and 1:00pm.

overall processing time was determined to be 9 minutes per transaction (6.67 trucks per hour). A lane's daily capacity is 53 transactions (11.1% more than *loads* and/or *reefer* containers). Thus, the gate throughput in transactions per day is 277 (53 x 5 lanes + 10 for the 1.5 hours of the 6th lane) and 71,969 containers annually (table 3).

The ***pre-gate*** could potentially feed the ***gate*** with 240 *loads* and/or *reefers* per net 8-hour day. It could also serve 72 *empties* and/or *chassis* per lane (374 per day) given 7 lanes. Since it takes an average of 10 minutes to check in a *load* or *reefer*, lanes number 5 and 6 of the gate complex could serve 249 *loads* and/or *reefers* per day. Under these circumstances, and for practical purposes, the gate could serve only *loads* and/or *reefers* without any waiting time between the pre-gate lanes and the gate lanes. The 5-minute average waiting time between the two would slow everything and could be attributed to the entry of *empties* and/or *chassis*. Given the observed service time at the gate one can argue that there is a trade-off between *loads* and/or *reefers* and *empties* and/or *chassis* at a rate of 1.5; that is, for every 1.5 *empties* and/or *chassis* entering the lane queue, a *load* and/or *reefer* container could be served.

iii. Analysis of gate performance

A review of the data provided by Maersk[40] for September 8, 1997 through September 19, October 1 through October 24, 1997 and March 3 through March 7, 1998 (25 days) indicates that the gross movements, **inbound and outbound**, of containers at the gate complex averaged 5.81 containers per hour (10.19 minutes per container). Allowing for 90-minute lunches,[41] the **net** movement per hour increases to 6.85 (8.46 minutes per container). Thus, the number of containers that can be handled over a net 8-hour day is almost 54.8 per lane. Furthermore, a review of Fridays only (the busiest day of the week), indicates that the net movement (inbound and outbound) per hour was 7.47 (8.02 minutes per container) or 59.76 containers per net 8-hour day per lane.

An analysis of Maersk data for **inbound** movements only (lanes 6 through 10 for which data was available) revealed that for the same Fridays the average throughput was 6.83 transactions per hour per lane (8.47 minutes per transaction). This is 5.6% more time consumed than the overall indicated before (8.47/8.02 x 100). However, for the same period the average inbound net movement for the busiest Friday (March 7, 1998) was only 6.09 (9.51 minutes) per hour.[42] Thus, the average inbound move was 18.6% more time consuming than the overall move (9.51/8.02 x 100). These results are also based on a mix of inbound loaded, empty and chassis movements. Seventy seven percent of lane number 5's volume was loaded containers, lane number 6 handled 69.3% of loaded containers and lane number 7 handled 53% of the loaded containers thereby, collectively handling the

[40] Maersk provided a year of data starting with Sept. 1997. We used a sample of primarily busy time.
[41] Assuming that on the days we observed, the lunch break was a typical one.
[42] This date is used as an indicator for busy time in the future.

bulk of the inbound loaded containers. The remaining lanes handled 39.2%, 26.7% and 5.1% loaded containers respectively. Additionally, lane 4 also handled loaded containers for the first 90 or more minutes of the day (77.7% of its total daily activity), but it is also the first swing lane. Lane configuration and the difficulty of maneuvering trucks (see figure 4) suggest that these lanes (4, 5, 6, and 7) will handle primarily loaded containers with a similar distribution to that reported above. Since the per lane operation distribution time between inbound and outbound lanes is not available, we could not use the swing lanes in the analysis. Thus, using Fridays exclusively for inbound lane analysis (Table 4), lane number 5 had an average of 5.92 moves per hour for a loaded container (10.08 minutes per transaction). Lane number 6 had an average of 6.14 moves per hour (9.46 minutes per transaction) and lane number 7 had an average of 6.29 moves per hour (9.32 minutes per transaction).

Table 4: Friday net inbound gate moves

		Gate number						
Date		5	6	7	8	9	10	Ave
12-Sep	Number of moves	60	64	63	92	70	58	
	Net time	10.35	12.02	11.4	10.19	10.11	7.54	
	Number of minutes	635	722	700	619	611	474	
	Moves per minute	.0945	.0886	.0900	.1486	.1146	.1224	.10978
	Moves per hour	5.67	5.32	5.40	8.92	6.87	7.34	6.59
19-Sep	Number of moves	71	57	65	100	67		
	Net time	11.13	9.59	10.4	10.4	10.01		
	Number of minutes	691	599	640	640	601		
	Moves per minute	.1027	.0952	.1016	.1563	.1115		.11344
	Moves per hour	6.16	5.71	6.09	9.38	6.69		6.81
20-Oct	Number of moves				67	53	40	
	Net time				8.18	7.29	8.32	
	Number of minutes				498	449	512	
	Moves per minute				.1345	.1180	.0781	.11023
	Moves per hour				8.07	7.08	4.69	6.61
24-Oct	Number of moves		85	83	88	68	50	
	Net time		11.51	12.01	12.06	8.48	8.07	
	Number of minutes		711	721	726	528	487	
	Moves per minute		.1195	.1151	.1212	.1288	.1027	.11747
	Moves per hour		7.17	6.91	7.27	7.73	6.16	7.05
6-Mar	Number of moves		55	54	75	37	65	
	Net time		8.39	7.58	8.33	7.02	7.52	
	Number of minutes		519	478	513	422	472	
	Moves per minute		.1060	.1130	.1462	.0877	.1377	.11811
	Moves per hour		6.36	6.78	8.77	5.26	8.26	7.09
	Averages							
	Move per minute	.0986	.1023	.1049	.1414	.1121	.1102	.11381
	Moves per hour (1)	5.92	6.14	6.29	8.48	6.73	6.61	6.83
	60 min/(1)	10.14	9.77	9.53	7.07	8.92	9.07	8.79
	Minute per move	10.084	9.462	9.318	7.042	8.552	9.042	8.474

These results are very similar to those obtained from the observed data of 10 minutes per transaction for a loaded container. Maersk however, did not provide pre-gate information or waiting time between gates.

According to Maersk's **gate** complex data, the average daily inbound distribution was 43.9% loaded containers, 52.1% empty containers and 4% chassis. For the purpose of calculations, empties and chassis are combined (56.1%). Depending on the number of open lanes one can develop various scenarios of potential movements (Table 5). Using current operating procedures, the present distribution of inbound arrivals with 7 lanes, and the overall gate complex of 9 minutes per transaction, the potential throughput per day (net 8 hours) is 374 (93,500 annual moves). When using the Friday average processing time of 8.02 minutes, we obtain 382 potential throughputs per day (95,500 annual moves). Assuming that the distribution between the loaded and empty stays the same, the 7-lane complex will be able to handle 43,656 inbound loaded containers annually.

The results indicate no constraint from pre-gate to gate. Should a problem develop, a simple inbound lane reassignment or reconfiguration could alleviate this potential problem. There is obviously substantial potential for greater capacity if the number of empties entering through this gate could be reduced.

iv. Holding pen

Gate hours cause truck drivers to line up before the gate opens in order to obtain an early position for pick-up or delivery so as to maximize the number of runs a day. When the gate is closed, the waiting cost of positioning can be calculated.

On August 14, 1998 at 7:00am, we observed a full holding pen and an overflow of 20 trucks onto the north shoulder of Tyler St. The total number of *loads* waiting in the holding pen and on the street was 36. The holding pen also included 2 lanes of *empties* and 2 lanes of *bobtails*. Given an average of 6 minutes service time for a *load* at the pre-gate lane, the 36th *load* that arrived at 7am will take 72 minutes before it arrives at the pre-gate lane (8:12am) and 93 minutes before he leaves the gate lane (8:33am) to enter the terminal. Therefore, if the first hour on the observed date is representative with 7.3 minutes of service time, the 36th truck will actually approach the pre-gate lane after 88 minutes (at 8:28am) and leave the gate lane after 110 minutes (at 8:50am). Many *loaded* trucks however, arrived much earlier than 7am and by that time they may already have been waiting for an hour or more.

At 8:00am and 8:30am the number of trucks observed waiting in the holding pen was 12 (3x4). At 10:00am the number of trucks observed waiting in the holding pen was 6 (3x2), at 10:30am 10 trucks were waiting, at 11:00am 4 trucks were waiting and at 11:20am none were waiting. Lunch break starts at

Table 5: Inbound gate complex movements and potential movements

	Observed by research team				
	Loads & reefers	Empty & chassis	Bobtails	Totals	**Maersk data**
Pre-gate					**Friday**
Number of lanes	3		4	7	
Average processing time (in minutes)	6		3.67		
Number of transactions per hour	10		16.34		
Potential output per lane (net 8-hour day)	80		131	211	
Potential output per day	240		523	763	
Annual potential throughput (260 days)	62,400		135,949	198,349	
Gate					
Number of lanes*	5.1875	5.1875		5.1875	
Average processing time (in minutes)	10	6.67		9	**8.02**
Number of transactions per hour	6	9		6.67	6.83
Potential output per lane (net 8-hour day)	48	72		53	55
Waiting between pre-gate and gate (minutes)	5				
Total service time	21	6.67	3.67		
Movement distribution (%)**	43.9	56.1			
Gate potential calculations					
Potential throughput per day (8 hours):					
with **5.1875** lanes	249	374		277	283
with **6.1875** lanes	297	446		330	338
with **7** lanes	336	504		**374**	**382**
Potential annual throughput (250 days):					
with **5.1875** lanes	62,250	93,500		69,250	70,750
with **6.1875** lanes	74,250	111,500		82,500	84,500
with **7** lanes	84,000	126,000		**93,500**	**95,500**
Distribution of potential annual throughput with no cap					
with **5.1875** lanes	28,421	54,479		82,900	
with **6.1875** lanes	33,900	64,981		98,880	
with **7** lanes	38,351	73,513		111,864	
Distribution of potential annual throughput assuming cap equals to total					
with **5.1875** lanes	31,595	40,375		71,969	
with **6.1875** lanes	37,685	48,158		85,843	
with **7** lanes	42,634	54,482		97,115	
Distribution of potential annual throughput assuming cap equals total Maersk data					
with **5.1875** lanes	32,352	41,343		73,696	
with **6.1875** lanes	38,589	49,313		87,902	
with **7** lanes	**43,656**	55,789		99,445	

* The number of lane changes during the day. After 90 minutes lane number 4 changes to be an outbound lane. Thus, 0.1875 of an 8-hour day is added.

** Obtained from Maersk data.

11:30am. For practical purposes, the truckers perceive the pre-gate and gate complex to be closed for 1 3/4 hours or more for lunch. The trucking companies perceive the window of opportunity for completing a transaction to be between 8am -10am and 2pm - 3:30Pm. Trucks that arrived after 9:50am took an average of 25 minutes from the arrival at the holding pen to entering the terminal.

An informal oral survey of truck drivers in the holding pen conducted at about 7:15am indicated that they perceive their waiting time to be about one hour for the pre-gate lane. A third party[43] observed on 12/3-12/4 1998 (Thursday and Friday) an average waiting time of 51 minutes for a single move for trucks arriving at the pen between 6:30am and 7:10am.

v. Waiting cost

The direct waiting cost for trucks can be determined by the explicit direct cost of labor and fuel. Direct cost needs to be distinguished between the *independent truckers* and trucking *company employees*. Indirect costs include wear-and-tear on the trucks, employee turnover (150%) and other costs. A social cost could also be added, such as pollution from burning 1 to 1.5 gallons of diesel fuel per hour. For example, if a trucking company driver (30% of truckers) is paid $21 an hour, and an independent trucker (70% of truckers) earns $27.5 an hour,[44] and diesel fuel idling cost is about $1.00 an hour and given an average processing time is 6 minutes, the direct waiting cost of the 12th driver is $31.86.

Trucking company truckers - 30% of total	$21.0/60 x 0.30	= 0.1100 per minute
Independent truckers - 70% of total	$27.5/60 x 0.70	= 0.3325 per minute
Fuel cost per hour	$1.0/60	= 0.0167 per minute
Total cost per minute		0.4425
Total cost per hour		$26.55 an hour.

The average 12th driver's 72 minutes direct waiting cost 0.4425 x 72 = $31.86.

vi. Opportunity cost

The trucker's *opportunity cost* (OC)[45] of waiting is estimated at $48-$50 an hour.[46] Using this number, the 72 minutes generates a waiting cost of $60 an hour ($50/60 x 72 minutes). The $50 an hour figure is also used as "average trucker cost."[47]

Since at 7:00am on the observed day there were 36 trucks waiting (loaded or empty) for 3 pre-gate lanes, the last three drivers, one per lane, will have a total

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[43] Data provided by BEST Transportation Inc.

[44] The data was obtained during an interview of Tom Heimgartner, President BEST Transportation Inc., 11/19/98. This pay rate is direct salary and should be considered the low end of the pay scale.

[45] The *opportunity cost* is a much more realistic figure because it takes into consideration additional costs such as insurance, wear-and-tear, employee turnover and the additional waiting time an independent trucker incurs due to the inflexibility of trading off one assignment for another. This could be perceived as the direct and indirect cost.

[46] Determined from details provided by Tom Heimgartner, President BEST Transportation Inc., 11/19/98.

[47] Terry Brennan, "Sea-Land to open gates through lunch hour", Journal of Commerce, September 27, 1999, p. 20.

waiting cost of $95.58 before getting to the pre-gate ($180 using the OC figures). On a typical Friday, at 7am, with 40 trucks waiting an average of 72 minutes, the drivers could incur a conservative total daily waiting cost of $1,274 (31.86 x 40) or $2400 using OC figures, i.e., $6,372 and $12,000 respectively on a weekly basis (table 6). Using the observed Friday as a typical Friday workday, one can calculate that annual (52 Fridays) waiting cost is $66,269 ($124,800 using the OC figures). Since Monday is similar to Friday in volume, this amount is doubled. When using Friday as a typical workday of the week, 250 working days a year (sometime in the future when the port is busier) would generate, with the present operation, procedure and time frame, a crude total annual direct waiting cost of $2,548,000 ($4,800,000 using the OC figures).

vii. Queuing cost analysis

The queue that develops at certain hours of the day raises the question: Should the terminal operator alter the number of lanes available? Providing *too many* lanes will let the trucks flow into the terminal very quickly at the expense of the terminal operator. Providing *too few* lanes would shift the burden of waiting cost to the truckers. Is there an optimum point where all could be happy? Queuing theory aids in the analysis of the trade-off between faster service and longer lines while minimizing the **social cost**.

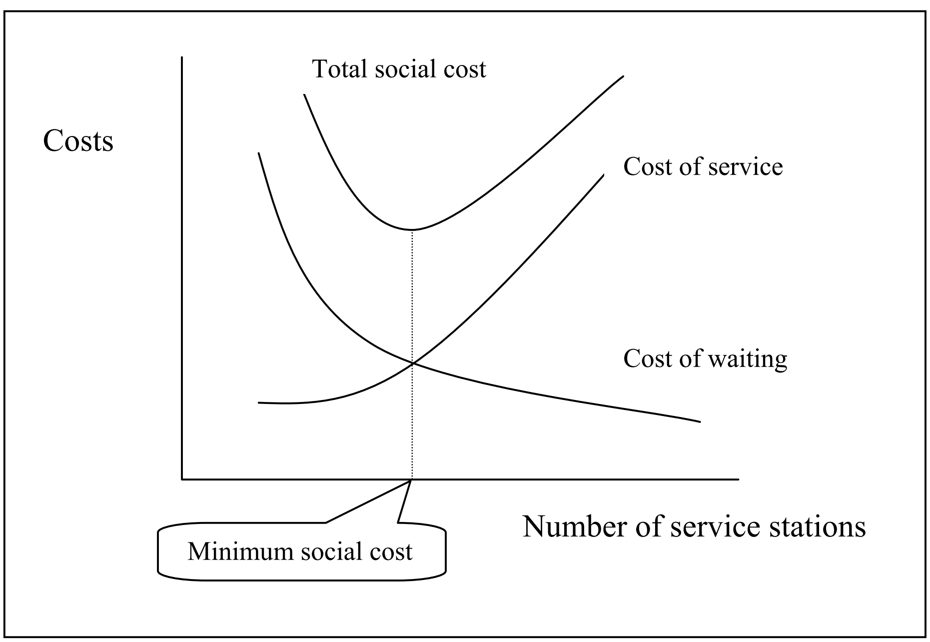
Table 6: Summary of Maersk truck waiting cost

	Hourly rate	Opportunity cost of hourly rate
Hourly truck rate ($)	26.55	50.00
Waiting time (min)*	72	72
Number of lanes	3	3
Holding pen size (trucks)	40	40
One truck waiting cost (72 min)	31.86	60
40 trucks waiting cost/hour	1,274	2,400
Weekly cost of the 72 min waiting time	6,372	12,000
Annual waiting cost of Fridays	66,269	124,800
Annual cost of 72 min of waiting	331,344	624,000
Annual cost of 8 hours of waiting (250 days)	2,548,000	4,800,000

* Truck arriving at 7AM and being last on line.

First, a short explanation of queuing theory. The analysis is based on arrival rate and service rate information in addition to the number of service lanes available, and the assumption of a steady flow of trucks to the gate complex. **There is *no* consideration given to the waiting line that is formed before the gate complex opens** Costs are borne by the service providers and service users. The optimum cost recommendation, in the case of a port terminal, is from the point of view of society at large. The queuing model's objective is to strike a balance between the two sides, which represents the minimum social cost. At the outset however, one should also identify that in the short run as in the case of a marine terminal, there is no loss of customers if service is slow; since the trucker is captive, he cannot pick up the container at another terminal. In the future however, the shipper might specify another shipping line or another port for delivery of cargo. Furthermore, ignoring the customer's costs implies shifting the entire expense to the customer and should be regarded this as poor customer service. In short, sometimes a small improvement in service may result in substantial reduction in waiting cost. This seems to be a growing issue for the future.

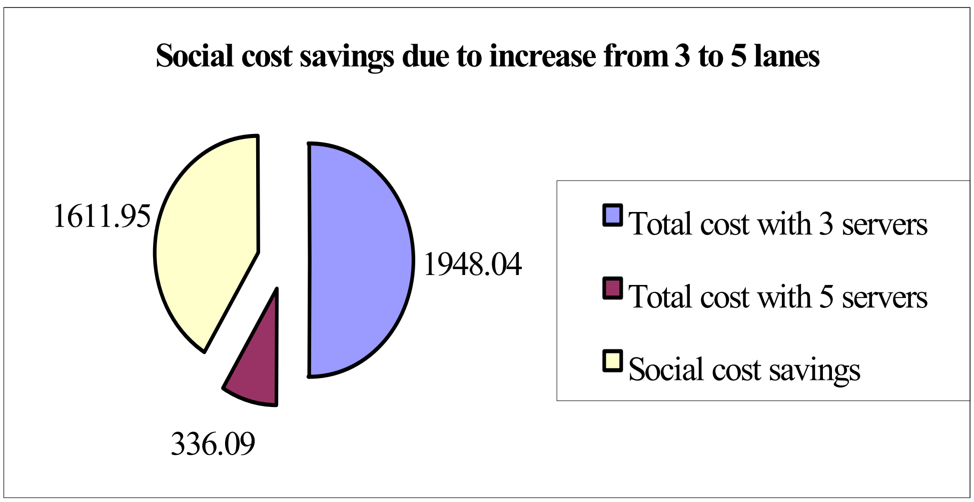
A queuing analysis for Maersk revealed that there is room for improvement. At 7:00am when the gate opened, there were 36 trucks already waiting for the three pre-gate positions. During the first hour of gate operation, the average pre-gate time per transaction was 7.3 minutes. Ignoring the line-up prior to the opening hour and assuming that the arrival rate per gate is 8 per hour,[48] the gate will be utilized 97.28% (see table 6, column G). There are 33.942 customers waiting, with 36.861 customers waiting and being serviced. The probability that a trucker will wait in a queue is 94.9%. The expected time in the queue is 85 minutes (60 minutes x 1.4143). Expected time in the queue and service is 92 minutes (60 minutes x 1.536). Using the low hourly cost for the terminal operator of $23.5 and for the trucker of $25.55 (excluding fuel cost), the cost of three lanes is $70.50 and the cost of waiting is $941.79 ($978.66 when fuel cost is added) (table 7 column G). An increase in the number of lanes to 5 would increase the lane cost to $117.50 an hour but the hourly waiting cost would decline to $82.32



[48] The calculations are restricted to this arrival rate because the arrival rate cannot exceed the service rate. If the opposite is true, the number of trucks in the queue will grow without limit.

($85.54 when fuel cost is added). The same analysis with 6 minutes per gate transaction would need 4 lanes with service cost of $94 and a waiting cost of $72.32 ($75.15 when fuel cost is added). In the first case there is an hourly social loss of only $812.48 ($1012.29 - $199.82) and in the second only $31.64 ($197.96 - $166.32) (see table 7, column C). Considering the early line-up and the arrival rate of 10 or more an hour, the situation becomes worse.

The terminal operator's actual cost of labor is most likely closer to $35 an hour, taking into consideration overhead costs. The trucker's cost per hour is also understated; it should be $50 an hour. Given these modifications the hourly social cost, with 3 operating lanes, reaches $1,948.04 but with 5 lanes its only $336.09 (table 7 column G). Social cost savings for the first case is $1,611.95 and for the second case is $72.91 (table 7 column C). Thus, an increase of the number of lanes is desirable.

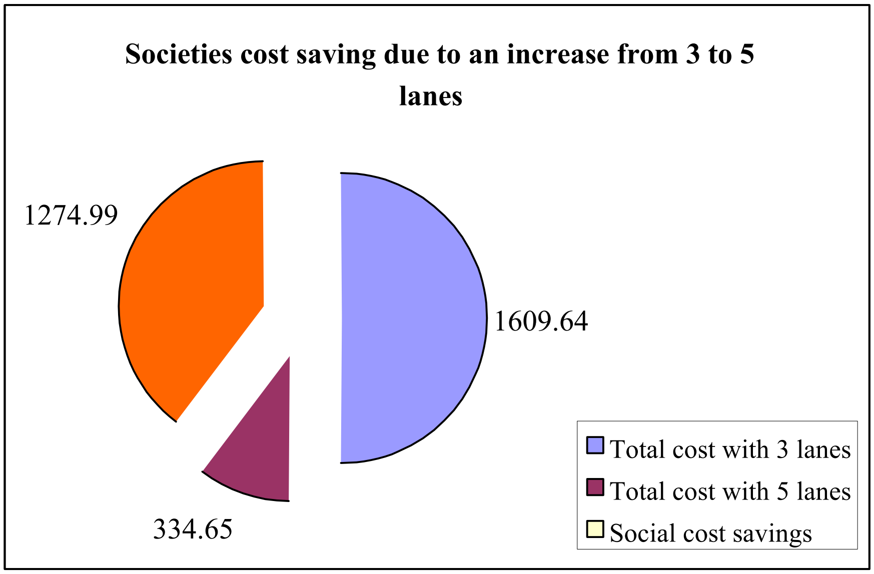


Given the limited maneuverability of a truck, one could also suggest that once a truck lines up, the analysis should follow a single rather than a multiple service station. At an arrival rate of 8 per hour and the average service transaction of 7.3 minutes, the service cost per lane is $23.50 per hour and the waiting cost per lane is $913.79 ($949.55 when fuel cost is added) per hour. The waiting cost is $1,788.24 when considering the trucker's opportunity cost at $50 an hour (see table 7, column F). This result is similar to that reported earlier. With 6 minutes per transaction and a single server, the waiting cost is only $102.20 per hour ($106.20 when fuel cost is added). Adding one lane would increase the hourly cost of service to $47.00 and the waiting cost would decline to $24.33 (see table 7, column A). However, when using the modified opportunity cost and employer's cost figures, for an additional service cost of $35 to open a second station, the trucker's waiting cost could decline from $200.00 to $47.62.

Table 7: Queuing Analysis (hourly data)

	Model (6 minutes per transaction) A	B	C	D	E	(7.3 minutes) F	G
# of servers	1	1	3	3	3	1	3
Source of population	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Mean arrival rate	8	9	24	27	29	8	24
Service Distribution	Exp.	Exp.	Exp.	Exp.	Exp.	Exp.	Exp.
Service time	0.1	0.1	0.1	0.1	0.1	0.1216	0.1216
Mean service rate/server	10	10	10.00	10.00	10.00	8.224	8.224
Mean service utilization	80.00	90.00	80.00	90.00	96.667	97.28	97.28
Exp. Customers in queue	3.200	8.100	2.589	7.354	27.193	34.792	33.942
Exp. Customers in system	4.000	9.000	4.989	10.054	30.093	35.765	36.861
Prob. Customer has to wait	0.8	0.9	0.647	0.817	0.938	0.973	0.949
Exp. Time in queue	0.4	0.9	0.108	0.272	0.938	4.349	1.4143
Exp. Time in system	0.5	1.0	0.208	0.372	1.038	4.471	1.536
Old system (a) (used as reference)							
Number of servers	1	1	3	3	3	1	3
Cost of service (@$23.50)	23.50	23.50	70.50	70.50	70.50	23.50	70.50
Cost of waiting (@$25.55)	102.20	229.95	127.46	256.87	768.87	913.79	941.79
Total cost	125.70	253.45	197.96	327.37	839.37	937.29	1012.29
Old system optimal (a)							
Number of servers	2	2	4	4	5	2	5
Cost of service(@$23.50)	47.00	47.00	94.00	94.00	117.50	47.00	117.50
Mean number in system	0.952	1.129	2.831	3.512	3.193	1.274	3.222
Cost of waiting (@$25.55)	24.33	28.83	72.32	89.72	81.58	32.56	82.32
Total cost	71.33	75.83	166.32	183.72	199.08	79.56	199.82
Social cost savings	**54.37**	**177.62**	**31.64**	**143.65**	**640.29**	**857.73**	**812.48**
Current system (b)							
Number of servers	1	1	3	3	3	1	3
Cost of service (@$35.0)	35.00	35.00	105.00	105.00	105.00	35.00	105.00
Cost of waiting (@$50.0)	200.00	450.00	249.44	502.68	1504.64	1788.24	1843.04
Total cost	235.00	485.00	354.44	607.68	1609.64	1823.24	1948.04
Optimal system (b)							
Number of servers	2	2	4	4	5	2	5
Cost of service(@$35.0)	70.00	70.00	140.00	140.00	175.00	70.00	175.00
Mean number in system	0.952	1.129	2.831	3.512	3.193	1.274	3.222
Cost of waiting (@$50.0)	47.62	56.43	141.53	175.58	159.65	63.72	161.09
Total cost	117.62	126.43	281.53	315.58	334.65	133.72	336.09
Social cost savings	**117.38**	**358.58**	**72.91**	**292.11**	**1274.99**	**1689.52**	**1611.95**

Additionally, when using 6 minutes per transaction and the mean arrival rate of 29[49] with a three-lane complex (see table 7, column E), lane utilization will be at 97%. There are 27 truckers waiting. The probability for a trucker waiting is 94%. The expected time in the queue is 54 minutes. The waiting cost is $768.87 an hour. An increase of the number of lanes to 5 would increase gate-operating cost to $117.5 and the waiting cost will decline to $81.58 (table 7 column E). Social cost savings will be $640.29 ($839.37 - $199.08). Using the modified figures will generate social savings of $1,274.99.



Queuing analysis indicates that there is a social benefit to opening more gates in the early hours and when the arrival rate is high.

viii. Sensitivity analysis

An increase in average service by one transaction per hour (from 10 to 11 or 9.1%) would provide a Friday savings of $116 ($1,274 x 9.1%) and a crude annual Friday savings of $6,030 ($66,269 x 9.1%). Using the OC figure it would generate a savings of $11,357 for Fridays. Depending on the typical waiting day, these numbers could be $30,160 for 260 typical days like Friday. This also indicates that the increase in service by one transaction an hour, a 10% increase, would cause a savings of 9.1% or a *transaction elasticity* of -1.1. This indicates that an increase of 10% in the number of transactions per lane would result in 11% savings of direct waiting cost to the truckers.

[49] The largest number for the system to calculate. (See previous footnote for reason.)

A reduction of service time by an average of one minute, from 6 to 5 minutes (16.67%), would provide a Friday savings of $212 ($1,274 x 16.67%) and a crude annual Friday savings of $11,047 ($66,269 x 16.67%). Using the OC figure it would generate a savings of $20,804 for Fridays. Depending on the typical waiting day, these numbers could be $55,207 for 260 typical days like Friday. This also means that a reduction of one minute (16.67%) of service time would generate savings of 20% or a *service time elasticity* of -1.2, indicating that a reduction of service time by 10% would save the truckers 12% of their cost.

G.2.2. Sea-Land Marine Terminal

i. Gate lane operation

Sea-Land Marine Terminal's gate complex along McLester Street has a total of 24 lanes: 16 inbound and 10 outbound with 2 "swing" lanes. Sea-Land has dedicated lanes to increase efficiency. The complex includes 4 inbound and 2 outbound lanes for *bobtails* only, and 2 outbound express lanes. In addition, they opened an annex gate on the south side of the terminal where they receive *empties* and *chassis* for return only. Some *bobtails* and *empties however,* are mixed with the *loads* at the inbound main gate. Lanes 11 through12 are designated for ILA movements into the facility. Should these two lanes become idle, *loads* are directed to them. The gate is open from 7:00am - 11:45am and 1pm- 4:30pm. There are times however, when the gate is kept open until 6:00pm. Since October 4, 1999, the gate complex opens at 6:00am, operates continuously through lunch and closes at 5:00pm.[50] For practical purposes however, the gate closes to inbound traffic approximately one hour before the formal closing time.

ii. Gate processing time and potential output

The busiest day of the week is normally Friday.[51] The average **inbound** gate processing time at the main entrance, where a processing clerk handles two lanes simultaneously, was 5 minutes (12 transactions an hour). It was observed that a *bobtail* took only 3 minutes to process. On the **outbound**, after the truck leaves the gate, it stops at a checker's point. The checker holds the truck an average of 1.42 minutes. The holding pen for the outbound trucks, beyond the gate checkout, can accommodate 7 trucks per lane (total 21 trucks). Thus, the 7th truck takes 10 minutes before it reaches the road from the time it leaves the gate.

Given that the average inbound processing time is 5 minutes per transaction, a single lane could handle 12 transactions an hour; therefore the gate facility (10 dedicated inbound lanes) can handle 120 trucks per hour or 960 trucks per net 8 hour day. Using the 16 lane inbound flow with a 5 minute transaction time, the complex has the ability to handle 192 trucks per hour.

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[50] Terry Brennan, "Sea-Land to open gates through lunch hour", Journal of Commerce, September 27, 1999, p. 20.
[51] Observed by author on August 21, 1998 between 11:30am and 3:30pm.

On August 21, 1998 at 11:45am, a busy time before the lunch hour, we observed an empty inbound holding pen at the gate facility however; the outbound holding pen was full. A truck that just left the gate had been waiting 10 minutes to and get on the road.

At 11:46am trucks started the inbound line-up for the gate opening at 1:00pm. By 1:00pm the holding pen was at 90% of capacity or 124 trucks (*load*, *empty*, *chassis reefers* and *bobtails*) out of the 138-truck potential capacity observed on this date.[52] The arrival rate for the 75 minutes that the gate was closed was 1.65 trucks per minute. However, the arrival rate between 12:21pm- 1:00pm increased to 1.8 trucks per minute. Given that the average processing time is 5 minutes, a truck that arrived at 1:00pm and is the 10th on line would have to wait 50 minutes to enter a gate. However, the truck that is first on line and arrived at 11:45am would wait 75 minutes for service at the gate that opens at 1pm. A second truck on the same waiting line that arrived at 11:47am would not be served before 1:05pm, a total wait of 78 minutes, etc. The arrival rate between 1:pm and 2was 12 trucks per hour per lane, maintaining a 75-minute waiting time. After 3:00pm the arrival rate dropped to 4 per hour per lane. At any point in time between 1:00pm and 3:00pm the holding pen was full. After 3:00pm the number of trucks in the holding pen declined due to lower arrival rates. This low arrival rate is closely associated with turn-around time and the 4:30pm scheduled close of the gate. The turn-around time dictates the time of gate closure for new arrivals. This occurs at about 3:30pm.

On October 8, 1999,[53] after the gate complex hours were extended (6:00am to 4:00pm), it was still observed that at 6:00am the holding pen was full, with two trucks overflowing into the street. At 8:00am the holding pen was still at 75% capacity. The transaction time was still 5 minutes, while the total waiting time for this time of day did not change.

iii. Holding pen cost and waiting cost

The direct waiting cost per truck using the Maersk approach, indicates that the 10th truck that arrived at 1pm and was waiting 50 minutes to get to a lane clerk had a direct waiting cost of $22.125 (.4425x50). If each lane is occupied with 10 trucks, the direct waiting cost is $221.25. However, the waiting time for the trucks that arrived before 1pm is larger. It starts with a maximum of 75 minutes for the first truck that arrived at 11:45am, it increases for the second truck that arrived at 11:46am, and it declines to a lower amount when the arrival rate drops below 12 trucks per hour. The waiting cost will show a real decline however, once the number of trucks processed by the clerks is faster than the arrival of new trucks. It takes a long time to clear the backlog of waiting trucks.

[52] The holding pen capacity is a function of type of trucks that arrive. The holding capacity would be larger if more bobtails line up or if more 20ft containers line-up.

[53] This was a Friday before a three-day weekend. With future increase in volume this unusual day could become the norm.

On the observed date, the holding pen was not full (table 8); it had an average of 9.5 trucks per lane. The line-up per lane varied including a shorter service time for bobtails and the spotty (random) utilization of gates 11 and 12, with gate 8 out of service due to computer problems. Thus, a snapshot of the total cost for the line-up in the holding pen at 1:00pm (prior to gate reopening) was

Table 8: Simulated Sea Land holding pen waiting cost before gate opens (ordinary cost)

Trucks waiting per lane	Arrival time	Waiting time (min)	cost per min x waiting time	Lane: 1	2	3	4	5	6	7	8	9	10	Total waiting cost	Commutative waiting cost
1PM gate reopen time															
1	11:45	75	33.19	33.19	33.19	33.19	33.19	33.19	33.19	33.19	33.19	33.19	33.19	331.88	331.88
2	11:50	70	30.98	30.98	30.98	30.98	30.98	30.98	30.98	30.98	30.98	30.98	30.98	309.75	641.63
3	11:55	65	28.76	28.76	28.76	28.76	28.76	28.76	28.76	28.76	28.76	28.76	28.76	287.63	929.25
4	12:00	60	26.55	26.55	26.55	26.55	26.55	26.55	26.55	26.55	26.55	26.55	26.55	265.50	1194.75
5	12:05	55	24.34	24.34	24.34	24.34	24.34	24.34	24.34	24.34	24.34	24.34	24.34	243.38	1438.13
6	12:10	50	22.13	22.13	22.13	22.13	22.13	22.13	22.13	22.13	22.13	22.13	22.13	221.25	1659.38
7	12:15	45	19.91	19.91	19.91	19.91	19.91	19.91	19.91	19.91	19.91	19.91	19.91	199.13	1858.50
8	12:20	40	17.70	17.70	17.70	17.70		17.70	17.70	17.70	17.70	17.70	17.70	159.30	2017.80
9	12:25	35	15.49	15.49	15.49	15.49			15.49			15.49	15.49	92.93	2110.73
10	12:30	30	13.28	13.28	13.28				13.28			13.28	13.28	66.38	2177.10
11	12:35	25	11.06	11.06								11.06		22.13	2199.23
12	12:40	20	8.85	8.85										8.85	2208.08
13	12:45	15	6.64	6.64										6.64	2214.71
14	12:50	10	4.43	4.43										4.43	2219.14
15	12:55	5	2.21	2.21										2.21	2221.35
16	13:00	0	0.00	0.00										0.00	2221.35

Average processing time per truck is 5 minutes.

estimated at $2,221.35. This includes trucks that arrived between 11: 45am and 1:00pm. Again, this is only the waiting time in the holding pen at 1pm just as the gate is about to open. It does not take into consideration the waiting time for the truck to reach the gate after 1:00pm when it opened. An estimate of this time at 5 minutes per transaction indicates that the truck driver will have to wait about 45-50 minutes. However, it was also observed that one driver who arrived at 1:01pm, checked into the gate at 2:52pm and exited into the terminal at 2:57pm, a total of 116 minutes (111 minutes of waiting time) or a direct waiting cost of $49.12 (.4425x111). We observed the holding pen full at 2:00pm and 1/3 full at 3:00pm. At 2:00pm, again, the outbound waiting time peaked.

On October 8, 1999, after gate hours were extended, it was still observed that at 6am the holding pen was full, with two trucks overflowing onto the street. At 8amthe holding pen was still at 75% capacity. The truckers' waiting cost for this time of the day did not change. We proceeded to determine the truckers' direct waiting cost, assuming a full holding pen at 1pm, an arrival rate of 12 trucks per hour per lane, between 1:00pm and 3:00pm and the average waiting time per truck of 75 minutes. At the low end of the pay scale of $26.55 per hour per truck, the 75 minutes waiting cost is $33.19 (.4425x75). The entire holding pen of 124 trucks had a direct waiting cost of $4,115.25 per hour (124 trucks x $33.19), i.e., $32,922 for an 8-hour day or $164,610 per week.

Using this observed date as a typical day, one can also determine a waiting cost of a full holding pen for one hour; using the $26.55 per hour waiting cost it is $3,663.90 (138 x $26.55). On the observed day between 11:45am and 3pm, the total crude waiting cost is estimated to be $9,549.15.[54]

This situation is very similar to what was observed on 8/21/98. If this pattern repeats every day, at a future date when the activity at the port increases as forecast, and if the holding pen is permanently full, the annual direct waiting cost for <u>this hour alone</u> could reach $1,028,812.5 ($4,115.25 x 250 days). The extended gate complex hours starting in October improve the truckers' situation only during lunch. It indicates that at opening time (6am) the holding pen was full and the truckers' waiting cost for the first hour was $4,646.6 (140 x $33.19) assuming average waiting of 75 minutes. However, on October 8, 1999, the gate complex handled 155 trucks between 6am and 7am, i.e., it took 6.19 minutes processing time per truck, nearly 24% longer than the average 5 minutes transaction time. It is reasonable to estimate some additional 20% in the truck waiting cost. One should however note the benefits derived from continuous gate operations through lunch, which may enable a trucker an additional daily run and potential improvement to his income.

Drivers, in an informal oral survey, stated that on the average they wait approximately *45 minutes* to get to the gate.[55] The direct waiting cost for the holding pen is $2,469 (124 trucks x $19.91). If the holding pen is full at least once a day and on average each truck waits 45 minutes, the annual direct waiting cost for <u>this period alone</u> could reach $617,250 ($2,469 x 250 days). Obviously, if generalizing that truckers have to wait on average 45 minutes any time they arrive at the port, it would yield an annual cost of $4,937,680[56] (table 9). The truckers' perception, true or not, of waiting time is a very important input in their decision-making process. They will select a pick-up time based on anticipated congestion in order to optimize their time and income unless delivery is specified.

The direct cost of waiting after 3:00pm is a function of waiting time that levels off due to the declining arrival rate with the anticipation of gate closing.

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[54] $9541.15 = $2221.35 (11:30AM-1:00PM) + $3663.90 (1:00PM-2:00PM) + $2442.60 (2:00PM-3:00PM) + $1221.30 (3:00PM-4:00).

[55] "The truckers maintain that the lunch hour closing had cut their productivity 30% because of gate congestion that requires drivers to wait in line an average of 2 hours". Terry Brennan, "Sea-Land to open gates through lunch hour", <u>Journal of Commerce</u>, September 27, 1999, p. 20.

[56] $4,937,680 = 992 trucks per day of 8 hours x $19.91 waiting cost per truck x 250 working days.

Table 9: Summary of Sea-land waiting cost for 124 trucks

	Hourly rate	Opportunity cost of hourly rate	Hourly rate	Opportunity cost of hourly rate	Hourly rate	Opportunity cost of hourly rate
Waiting-cost for:	**75 minutes**		**60 minutes**		**45 minutes**	
Hourly truck rate ($)	26.55	50.00	26.55	50.00	26.55	50.00
Waiting time (min)	75	75	60	60	45	45
One truck waiting cost	33.19	62.50	26.55	50.00	19.91	37.50
Simulated waiting cost before gate opens (tables 8 & 9)	2221.35	4183.17				
Trucks waiting cost/hour	4,115	7,750	3,292	6,200	2,469	4,650
Trucks waiting cost per 8-hour day (a)	32,922	62,000	26,338	49,600	19,750	37,200
Truck waiting cost per week (a x 5 days)	164,610	310,000	131,688	248,000	98,766	186,000
124 truck annual cost of waiting (a x 250)	8,230,500	15,500,000	6,584,500	12,400,000	4,937,680	9,300,000

The holding pen capacity is 138 trucks. The number of lanes available is 10.

iv. Opportunity cost

The trucker's *opportunity cost* (OC) of waiting was previously estimated at $48-$50 an hour. Using this number, the 75 minutes waiting time generates a waiting cost of $62.50 per hour ($50/60 x 75 minutes).

Since at 1:00pm on the observed day there were 124 trucks waiting in the holding pen, the total opportunity cost for waiting in the line-up in the holding pen at this time (before the gate reopens) is estimated to be $4,183.17 (Table 10**).** The waiting cost before was $2,221.35, i.e., over 88% of straight time.

Using this observed date as a typical day, one can also determine a waiting cost of a full holding pen for one hour, using the $50 per hour waiting cost $6,900 (138 x $50). For the observed day between 11:45am and 3:00pm, the total crude waiting cost is estimated to be $17,983.17.[57]

Using the truckers' perceived waiting time of 45 minutes and their opportunity cost indicates that their waiting time is valued at $4,650 (Table 9, 45 minutes @ $0.833 a minute x 124 trucks), i.e., $37,200 an 8-hour day and $186,000 a 5-day week.[58] This figure was $2,469 before. If this repeats every day, in the future when the activity at the port increases as forecasted, and the holding pen is permanently full, the annual opportunity cost of waiting for this hour alone, or for that matter any hour, could reach $2,010,068 ($1,069,185 x 1.88). A recent visit to the port indicates that the waiting still exists during the morning hours.

[57] $17,983.17 = $4183.17 (11:30am-1:00pm) + $6900 (1:00pm-2:00pm) + $4600 (2:00pm-3:00pm) + $2300 (3:00pm-4:00pm)

[58] "Sea-Land's limited gate hours had translated into lost trucker revenue of more than $250,000 a week based on average trucker costs of $50 per hour at the port, truckers claim. … lunch hour closing … requires drivers to wait in the line an average of 2 hours." Terry Brennan, Journal of Commerce, September 27, 1999, p. 20. However, a one-hour waiting in the holding pen, on the observed date, would generate a weekly loss of income of $248,000 ($50 an hour x 124 trucks x 8 hours a day x 5 days a week).

Table 10: Simulated Sea Land holding pen waiting cost before gate opens (opportunity cost)

Waiting per lane	Arrival time	Waiting time (min)	cost per min x waiting time	Lane: 1	2	3	4	5	6	7	8	9	10	Total waiting cost	Commutative waiting cost
1PM gate reopen time															
1	11:45	75	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	624.98	624.98
2	11:50	70	58.33	58.33	58.33	58.33	58.33	58.33	58.33	58.33	58.33	58.33	58.33	583.31	1208.29
3	11:55	65	54.16	54.16	54.16	54.16	54.16	54.16	54.16	54.16	54.16	54.16	54.16	541.65	1749.93
4	12:00	60	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	499.98	2249.91
5	12:05	55	45.83	45.83	45.83	45.83	45.83	45.83	45.83	45.83	45.83	45.83	45.83	458.32	2708.23
6	12:10	50	41.67	41.67	41.67	41.67	41.67	41.67	41.67	41.67	41.67	41.67	41.67	416.65	3124.88
7	12:15	45	37.50	37.50	37.50	37.50	37.50	37.50	37.50	37.50	37.50	37.50	37.50	374.99	3499.86
8	12:20	40	33.33	33.33	33.33	33.33		33.33	33.33	33.33	33.33	33.33	33.33	299.99	3799.85
9	12:25	35	29.17	29.17	29.17	29.17			29.17			29.17	29.17	174.99	3974.84
10	12:30	30	25.00	25.00	25.00				25.00			25.00	25.00	125.00	4099.84
11	12:35	25	20.83	20.83								20.83		41.67	4141.50
12	12:40	20	16.67	16.67										16.67	4158.17
13	12:45	15	12.50	12.50										12.50	4170.67
14	12:50	10	8.33	8.33										8.33	4179.00
15	12:55	5	4.17	4.17										4.17	4183.17
16	13:00	0	0.00	0.00										0.00	4183.17

Average processing time per truck is 5 minutes.

v. Queuing cost analysis

A queuing analysis of Sea-land's performance indicates that there is room for improvement. The average gate transaction time is 5 minutes (12 transactions per hour). A clerk at the gate handles two lanes simultaneously. Queuing analysis does not address the queue that formed before the gate opened. It address only the flow of trucks to the gate at the rates specified below, i.e., it assumes no waiting before the gate opens. All the calculations once the queue of the pre-opening gates are added provide for a much worse situation.

In a one service lane analysis, as the mean arrival rate increases from 7 to 10, with the same mean service rate of 12, the expected customers in the queue will increase and so will their expected waiting cost (Table 11). Given a cost of waiting of \$50 an hour and service cost of \$17.50 per lane, the social cost with 10 truck arrival rates could reach \$266.90 (Table 11 column D). However, this social cost could be reduced if a lane is added, i.e., a savings of \$181.51. The same table also indicates that the system with 10 service stations and a mean arrival rate of 80 is operating just right (column E). Should the mean arrival rate increase to 100, the social cost would reach \$712.91. An increase in the number of lanes from 10 to 12 would reduce the social cost by \$66.48 (Column F). Furthermore, a clerk dedicated to each lane increases the cost of providing the service to \$385.00but would reduce the cost of waiting from $537.91 to $463.15 and provide a social cost savings of $39.76 (column F).

Table 11: Queuing Analysis (hourly data)

	Model (5 minutes per transaction)					
	A	B	C	D	E	F
# of servers (gate lanes)	1	1	1	1	10	10
Source of population	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Mean arrival rate	7	8	9	10	80	100
Service Distribution	Exp.	Exp.	Exp.	Exp.	Exp.	Exp.
Service time	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833
Mean service rate/server	12	12	12	12	12	12
Mean service utilization	58.31	66.64	74.97	83.30	66.64	83.30
Exp. Customers in queue	0.8156	1.3312	2.2455	4.155	0.3481	2.4281
Exp. Customers in system	1.3987	1.9976	2.9952	4.988	7.0121	10.7581
Prob. Customer has to wait	0.5831	0.6664	0.7497	0.8330	0.1742	0.4868
Exp. Time in queue	0.1165	0.1664	0.2495	0.4155	0.0043	0.0243
Exp. Time in system	0.1998	0.2497	0.3328	0.4988	0.0877	0.1076
Current system (a)						
Number of servers	1	1	1	1	10	10
Cost of service (@$17.50)	17.50	17.50	17.50	17.50	175.00	175.00
Cost of waiting (@$50.00)	69.93	99.88	149.76	249.40	350.60	537.91
Total cost	87.43	117.38	167.29	266.90	525.60	712.91
Optimal system						
Number of servers	2	2	2	2	10	12
Cost of service (@$17.50)	35.00	35.00	35.00	35.00	175.00	210.00
Mean number in system	0.6373	0.7496	0.8723	1.0078	7.0121	8.7285
Cost of waiting (@$50.00)	31.86	37.48	43.61	50.39	350.60	436.43
Total cost	66.86	72.48	78.61	85.39	525.60	646.43
Social cost savings	**20.57**	**44.90**	**88.65**	**181.51**	**0**	**66.48**
Current system (b)						
Number of servers	1	1	1	1	10	10
Cost of service (@$35.0)	35.00	35.00	35.00	35.00	350.00	350.00
Cost of waiting (@$50.0)	69.93	99.88	149.76	249.40	350.60	537.91
Mean number in system	1.3987	1.9976	2.9952	4.988	7.0121	10.7581
Total cost	104.93	134.88	184.76	284.40	700.60	887.91
Optimal system						
Number of servers	2	2	2	2	9	11
Cost of service (@$35.0)	70.00	70.00	70.00	70.00	315.00	385.00
Mean number in system	0.6373	0.7496	0.8723	1.0078	7.5561	9.263
Cost of waiting (@$50.0)	31.86	37.48	43.61	50.39	377.81	463.15
Total cost	101.86	107.48	113.61	120.39	692.81	848.15
Social cost savings	**3.07**	**27.4**	**71.15**	**164.01**	**-7.79**	**39.76**

In order to determine the overall cost of the gate complex operation, one has to add the cost of waiting during the time the gates are closed as well. This cost is substantially larger and it is borne exclusively by the truckers.

vi. Sensitivity analysis

An increase of average gate transaction from 12 transactions per hour to 13 transactions per hour, an 8.3% increase, would reduce the average transaction time from 5 minutes to 4.615 minutes (7.7%) or a savings of 7.7%. It would produce a *transaction elasticity* of -1.08. This result indicates that an increase of 10% in the number of transactions per lane would result in a 10.8% savings of direct waiting time to the truckers.

A reduction in time by an average of one minute, from 5 to 4 minutes, a 20% reduction, would result in a change in the average number of transactions from 12 to 15 per hour, and would generate an average savings of 25% per hour of waiting or a *service time elasticity* of -1.25. This indicates that a reduction of service time by 10% would save the truckers 12.5% of their cost.

In comparison given an average one-minute service time reduction generates an annual direct waiting cost savings of $599,040. These results are conservative because they do not include indirect and other social costs.

In comparison to the annual waiting cost discussed above, an average one-minute service time reduction would provide an annual direct waiting cost savings of $599,040. Again, these results are conservative because they do not include indirect and other social costs.

The *transaction elasticity* for Maersk (-1.1) and Sea Land (-1.08) and the *service time elasticity* for Maersk (-1.2) and Sea Land (-1.25) are very similar, indicating that an overall decrease of service time by 10%, a cost borne by the terminal operator, would generate savings of more than 20% to truckers. It also indicates a direct shift of resources from the gate complex to the trucker. They could also be perceived as a social resource reallocation issue. It seems that the recent expansion of gate operating hours is a movement in this direction even though this extended operating time still does not address the actual time it takes to process a transaction.

G.2.3. Howland Hook Marine Terminal

i. Physical Layout of Gate Complex

The main gate entrance of Howland Hook Marine Terminal (HHT) is located at the intersection of Goethals Road and Western Avenue. It is a 2 - stage complex (see figure 5) in which the 1st stage gates, four lanes at the entrance, are for security purposes only, with two lanes designated for inbound traffic and two for outbound. It has however, the flexibility to adjust based on inbound and outbound traffic conditions. The 2nd stage, the main gate complex, has 16 lanes for inbound and outbound truck traffic that are serviced by eight service stations (booths); which means that each booth services two lanes. Normally, ten lanes are configured for inbound traffic and the remaining six lanes are for outbound traffic. After the main gate complex, there is a customer service center that helps truckers solve problems such as insufficient information and improper documentation. Adjacent to the customer service center is the roadability station where outbound equipment inspection and repair are performed if necessary.

ii. System Set Up

The gate system is operated based on the following guidelines:

- Each booth serves two lanes. For inbound traffic, booth one, two, three, four, and five serve R and S, N and P, L and M, J and K, and G and H lanes respectively. Similarly, for outbound traffic, booth six, seven, and eight serve E and F, C and D, and A and B lanes respectively.
- The terminal operator utilizes **Flex-Time** in that 6 inbound lanes (L/M, N/P, R/S) and 2 out bound lanes (A/B) are opened at 6am Two (2) additional inbound lanes (J/K) and two outbound lanes (C/D) are opened at 8Lastly, another two inbound lanes (G/H) and two outbound lances (E/F) are opened at 9:00am.
- The terminal will operate through lunch hour depending on inbound traffic volume; it has several options to accommodate truck traffic. It could close for lunch all lanes that opened at 6:00am from 11:00am to 12noon, while lanes that opened at 8:00am could close from 12noon to 1:00pm, and lanes that opened at 9:00am could close from 1:00pm to 2:00pm respectively. It can also use FlexTime scheduling to keep 6 to 8 lanes open between 10:00am and 2:00pm
- Since the first crew starts at 6:00am, the terminal could respond by using FlexTime scheduling to affect lane closure based on the traffic volume at a particular time and day. The 6:00am lanes could extend their operating hours beyond the typical 8-hour period.
- Gate cut-off time is 5:00pm, that is, the terminal is open to inbound traffic until 5:00pm.and closes at 6:00pm. The terminal will remain open beyond 6:00pm at the shipping line's request and if the shipping line agrees to pay the additional cost.
- All equipment information processing (TIR, EIR, and Data Input) is done at the main gate complex.
- Based on the physical layout of the gate complex, starting at 6:00am, R/S and N/P lanes are designated for empty and loads, and the L/M lanes are designated for bobtails, flat beds, and bare chassis. At 8:00am inbound bobtails and bare chassis are shifted to J/K lanes, and L/M lanes accept empty and loads. With the opening of G/H lanes at 9am, the inbound bobtails, flat beds, and bare chassis are also shifted from J/K to G/H lanes.

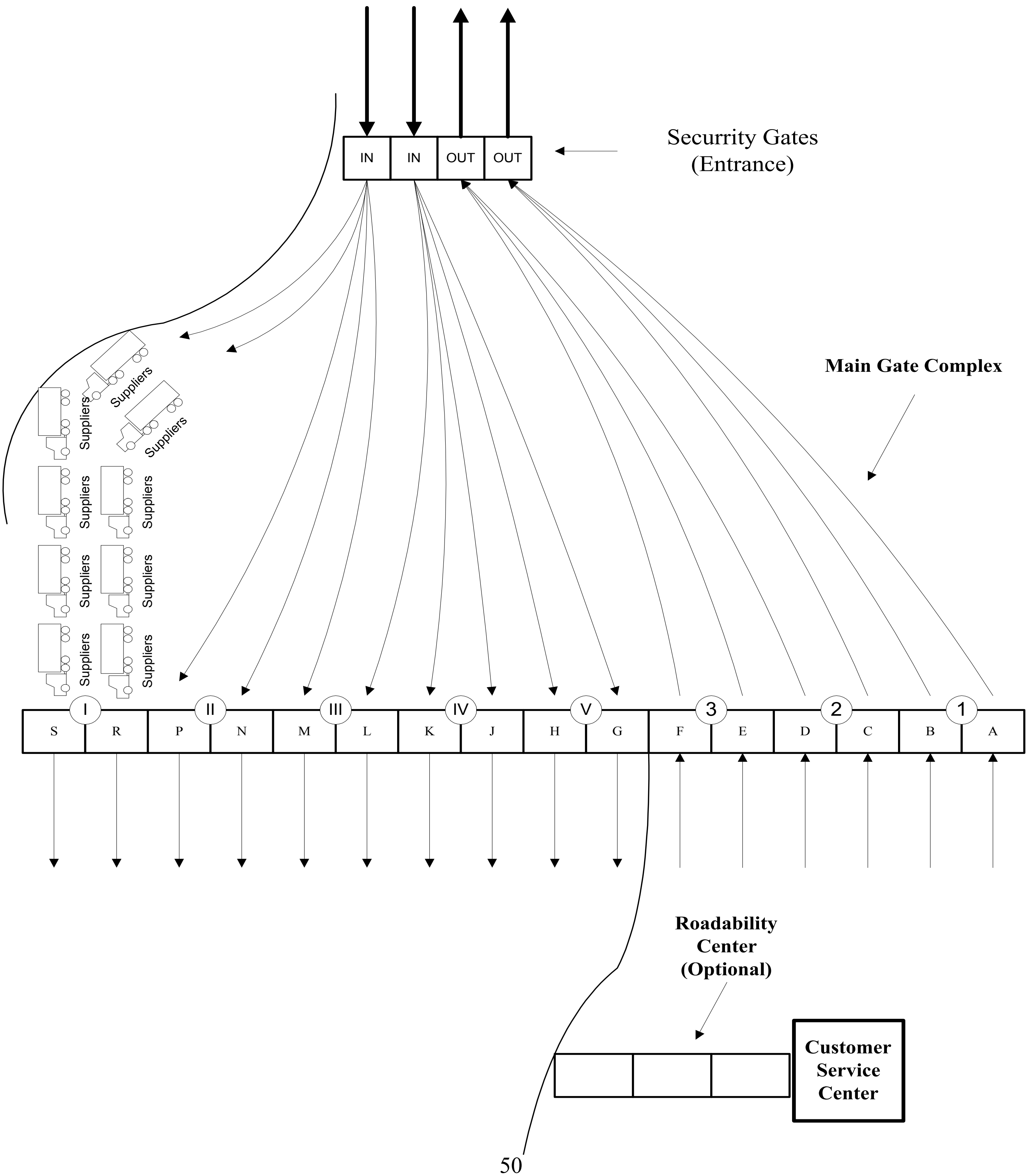
- Each of the two outbound lanes A/B, C/D, and E/F is closed for one hour between 11:00am and 2:00pm
- The whole system remains quite flexible. Each lane can process any type of equipment move whether it is a load or an empty, chassis/flat bed, or bobtail, therefore there will be no operational problems during lunch hours in shifting traffic.
- In order to maintain gate productivity, there is a customer service center that helps drivers solve problems. If a driver comes in with improper or missing information, such as missing booking number, incorrect vessel/voyage information, etc., he is directed to the customer service center. The operation of that particular processing lane will not be delayed. Gate productivity can be maintained.
- TIR is manually processed. Most importantly, the TIR clerk goes out to inspect the equipment's physical condition together with the driver while trucks are waiting in queue before they get to the booth for information processing. By the time the truck gets to the booth, the TIR in most cases is completed.

iii. Gate Operations and Procedures

Gate operations are carried out according to the following steps:

1. All equipment, including loaded containers (including reefers), empties, bobtails, chassis or flat beds coming to the terminal have to come through the security gate and obtain a gate pass. All drivers must have the Sea-Link card issued by the Port Authority of NY/NJ. Without this card, the driver will be rejected.
2. After the security check, drivers go to the main gate complex getting on queue for equipment inspection and information processing. As mentioned earlier, each booth is manned by a single clerk who services two lanes; and outside the booth there is one TIR clerk on each lane to perform equipment inspection. While the drivers are waiting in queue, the TIR clerk inspects the next in line's equipment before the driver pulls into the booth. By the time the truck at the booth finishes its information process and enters the terminal and the next in line truck pulls into the booth, the TIR inspection is completed.
3. The primary tasks performed at the main gate complex include processing cargo and/or equipment information on the dock receipt such as booking number, container/chassis number, size, port of loading/discharging, final destination, commodity, vessel/voyage, packaging, weight, scaling and equipment physical inspection. Information for single and/or double moves is processed at the same time. Double move drivers do not have to exit and re-enter the gate to process the second move once the first move is finished.

Figure 5. Howland Hook Marine Terminal Gate complex



4. Upon finishing the information processing and equipment physical inspection, an Equipment Interchange Report (EIR), a Terminal Inspection Report (TIR), and a terminal routing instruction to designated terminal area for drop off or pick container/chassis (Routing Slip) are issued to the driver. The driver can proceed to the terminal yard to drop off and/or pick up equipment accordingly.
5. If there is a problem such as incorrect vessel and voyage information for a particular container or no booking information in the terminal's computer system, the trucker is directed to customer service for resolution.
6. After dropping off or picking up a box, the driver goes to the outbound lane at the roadability inspection station (if he so chooses) or to the main gate complex waiting in queue to get processed for outbound equipment.
7. At the main gate complex, outbound equipment information is processed against cargo bookings, import container release, certain equipment reposition or termination moves, in which an outbound EIR and TIR (driver signed) are issued to the driver. At the security gate, the gate pass is collected. Thus, all the terminal equipment transactions for this particular driver are completed.

iv. Observation at the Main Gate Complex

According to Howland Hook's system set-up, there are five categories of inbound truck traffic:

1. Trucks that haul loaded containers are denoted as loaded (LDD).
2. Trucks that haul empty containers are denoted as empties (EMP).
3. Trucks that haul bare chassis are denoted as chassis (CHZ).
4. Trucks that haul empty flat beds are denoted as flat beds (FLB).
5. Trucks that have nothing attached are denoted as bobtails (BOB).

An observation was taken on August 27, 1999 at Howland Hook Container Terminal (HHT). The following was observed:

1) Approximately five minutes before 6:00am, there were about 20 trucks waiting outside the security gate, forming the two inbound lanes.
2) At 6:00am, the gate opened, and trucks went through security checks at a rate of less than 15 seconds per truck and arrived at the main gate complex within a minute. At the main gate complex, Booth I (lane R/S), Booth II (lane N/P) and Booth III (lane L/M) were open for inbound traffic. LDD and EMP were lined up against R/S and N/P lanes, and CHZ, FLB and BOB were lined up at L/M lanes. Meanwhile, outbound Booth 1 (lane A/B) was open for outbound traffic.
3) At approximately 7:00am, the waiting line for R/S and N/P lanes was about 6-7 trucks each. And the waiting line for L/M lanes was about 4-5 each.
4) At 8:00am inbound Booth IV (lane J/K) and outbound Booth II (lane C/D) lanes were opened for inbound and outbound traffic respectively. Also, BOB, CHZ and FLB traffic were shifted from L/M to J/K lanes. However, small amount of BOB, CHZ and FLB were still directed to L/M lanes. The

waiting lines for R/S and N/P lanes were 5-6 trucks each, and 4-5 trucks each for J/K lanes.

5) At 9:00am inbound Booth V (G/H) lanes were opened, and BOB, CHZ and FLB traffic were shifted from J/K to G/H lanes. Also, outbound Booth III (E/F lanes) was opened for outbound traffic. The waiting lines for R/S, N/P and L/M were down to 3-4 trucks each, and 2-3 trucks each for G/H lanes.
6) Around 10:00am, the waiting lines for all lanes were further down to 1-2 trucks each.
7) R/S, N/P, L/M, and A/B lanes were closed from 11:00am to 12noon, J/K and C/D lanes were closed from 12:00noon to 1:00pm. G/H and E/F lanes were closed from 1:00pm to 2:00pm
8) At about 1:30pm, the waiting lines for all inbound lanes were about 3-4 trucks each.
9) Although two lanes were designated for BOB/CHZ/FLB, the BOB/CHZ/FLB traffic could also go to other lanes whenever possible to reduce the waiting lines. Traffic assignment remained quite flexible.

v. Gate Processing Time and Potential Output

Since information processing is done at the booths, gate processing time and potential output will be calculated on a per booth basis (each booth serving two lanes). On this day, the average processing time for BOB/FLB/CHZ was observed to be approximately 2.8 minutes and 4.2 minutes for LDD/EMP respectively. Thus, each booth can process 21.5 bobtails, chassis or flatbeds per hour, or 14.3 empties or loads per hour, respectively. Due to FlexTime scheduling, the capacity of the gate complex varies according to actual operating hours. Nonetheless, an estimate for the minimum and maximum capacity could be made based on the FlexTime set-up and the inbound traffic ratio between BOB/CHZ/FLB and EMP/LDD. Normally, the composition of inbound traffic is more or less determined by the vessel schedules calling at HHT. Based on the information provided by HHT, ship arrivals of major shipping alliances are on Monday and Tuesday. As cargo cut-off time for Tuesday ships is at 5pm on the same day, a large volume of export cargo is delivered on Tuesday. In addition, many customers also come to HHT to pick up import cargo that was discharged on Monday. Therefore, Tuesday is the busiest day of the week. According to HHT, in order to accommodate such a large volume of traffic, FlexTime is utilized to its full extent. No lane is closed during lunch hour (Table 12) and gate personnel stagger their lunch breaks. Additionally, booths that open at 6:00am will not necessarily close at 3:00pm, but can be kept open until 5:00pm as needed.

As previously mentioned, inbound traffic is divided into two major categories, LDD/EMP and BOB/CHZ/FLB. The calculation of gate capacity potential will be based on the estimated distribution between these two categories. Among all inbound traffic, some are single moves; others are double moves. Therefore, the percentages of single move and double move have to be factored in for gate capacity potential calculation. Such outcome will provide an indication of container moves in and out of the terminal other than gate transactions.

Table 12: HHT Gate hours using FlexTime (Heavy Traffic)

Hour	Booth I	Booth II	Booth III	Booth IV	Booth V	Total
6-8 AM	2	2	2	0	0	
8-9	1	1	1	1	0	
9-10	1	1	1	1	1	
10-11	1	1	1	1	1	
11-12	1	1	1	1	1	
12-1 PM	1	1	1	1	1	
1-2	1	1	1	1	1	
2-3	1	1	1	1	1	
3-4	1	1	1	1	1	
4-5	0	0	1	1	1	
Total	**10**	**10**	**11**	**9**	**8**	**48**

Due to the flexibility in lane assignment, any lane can process any type of inbound traffic; the distribution of the two categories of traffic is based on the estimated percentage of traffic for each category according to the historical data provided by HHT, other than by specific lane assignment.

Calculation of Capacity Potential Based on the observation and the data provided by HHT, the capacity potential is calculated based on the following (see Table 13):

A. Calculation Guidelines

1. Total cumulative operating hours for inbound traffic is 48, close to maximum in a day according to the FlexTime opening and closing schedule as well as traffic pattern that the volume of inbound traffic tapers off in late afternoon. Therefore, two of the inbound booths opened at 6:00am and the other boots are closed.
2. Gate processing productivity is the same for every booth. There is no change in processing productivity when gate personnel are taking lunch.
3. There is no system malfunction during the day that the terminal computer system and all the printers used for issuing EIR and routing slip are working properly throughout operating hours.

4. The distribution of operation hours in serving the two categories inbound traffic is based on observation as well as on the data provided. Nonetheless, the distribution is somewhat arbitrary, but close to reality.
5. The percentage of double move is estimated from the data provided by HHT.

Table 13: HHT Gate Capacity Potential Calculation

	BOB/CHZ/FLB Category I	LDD/EMP Category II	Total
Processing Time (Minutes)	2.7	4.2	
Number of IB Gate Transactions per Hour	22.2	14.3	
Max Gate Operating Hours of 48			
Estimated Processing Time Allocation	15.0	33.0	
Daily IB Gate Transactions	333	471	805
Percentage of Double Move			33.00%
Container Moves per Day			1,070
Container Moves per Year (250 Days)			267,500

B. Calculation
1. The number of inbound gate transactions per hour is obtained by taking 60 minutes divided by average processing time per gate transaction.
2. The daily inbound gate transactions for processing BOB/CHZ/FLB and LDD/EMP are obtained by taking the average inbound transactions per hour times the respective operating hours.
3. Adding both daily inbound gate transactions for Category I and II together, the total number of inbound transactions per day is obtained.
4. The total daily container/equipment moves equals:

   Total daily gate transaction (1 + % of double move)
5. The estimated annual gate processing capacity potential is obtained by taking the total daily container/equipment moves times the number of business days in a year (250 days).Sam you were using 260 in you analysis

vi. Performance Analysis

The gate operating system is based on FlexTime and proactive gate management. Based on observations and the above analysis, the HHT gate system operates quite well. FlexTime at HHT provides an effective tool to smooth out truck arrival peaks and reduce the negative effects of bottlenecks. More importantly, such a mechanism also helps to reduce truckers' waiting time at the gate. To some extent, it may provide an indirect incentive for a trucker to come to the terminal earlier so that he could make an additional run in a day. On the observed day there was no queue at this terminal.

G.2.4. Red Hook Marine Terminal

The Port Authority of New York and New Jersey's Brooklyn Red Hook facility, operated by American Stevedoring Inc., is unique to the New York/New Jersey port system. While physically situated on a 32-acre site in the Borough of Brooklyn, its main gate operations (cargo receiving/delivery and container storage) are located at the Port of Elizabeth.

In 1998, the Red Hook facility handled a total of 48,000 container moves, a number expected to reach some 60,000 moves in 1999. This growth is expected to continue into the future. Imports arriving at this port facility are primarily destined for the NY/NJ metropolitan region (approximately 60% of total volume), with the remainder bound for regions beyond via truck, rail or barge.

Even though the scale of operations at this facility is substantially smaller than those of the other NY/NJ ports, Red Hook serves a special role to its customers, the smaller shipping lines. It provides the 17 shipping lines it serves with a level of service they would not be able to obtain at the major terminals, as well as providing break bulk service, which is only available here. This service is vital to commerce in the NY/NJ metropolitan area.

Cargo/ containers bound to/from any of the 17 shipping lines using the Red Hook facility, for the most part, are received/delivered at the Elizabeth gate facility and are transferred to/from the Brooklyn pier facility via barges. American Stevedoring currently leases from the Port Authority one 420TEU (4500 tons) barge and rents a second for the purpose of reducing labor overtime expense. Outbound cargo cutoff time is noon the day prior to sailing for timely transfer from Elizabeth to Brooklyn. At this time, these barges transfer containers between the two facilities approximately seven to ten times per week.

There is also a secondary gate operation at the Brooklyn site, which handles a small portion of total cargo activity.

i. Elizabeth, NJ

The Elizabeth gate operation consists of 2 inbound lanes (gates 1 and 2), 2 outbound lanes (gates 3 and 4), and one bypass lane (gate 5) dedicated to empties, chassis and oversize cargo. These gates operate between the hours of 8:00am to 12noon and 1:00pm to 5:00pm with a 3:30pm inbound cut off time. While not presently in use, terminal management is considering the FlexTime option to better serve the needs of its customers. Since the observations were made management has adopted FlexTime operations.

Queuing for gate processing begins around 6am with gate operations commencing at 8:00am. A typical Monday will find some 40-50 trucks waiting for the 8:00am start of service.

The gates are staffed by a single operator who is able to process trucks through at a rate of approximately four minutes per vehicle. At this rate, maximum gate throughput at the Elizabeth gate facility is equal to approximately 350-400 trucks per day. TIR processing follows the inbound documentation check stage, again carried out by a single operator with an elapsed time of approximately 3-4 minutes. Total gate processing time at the Elizabeth gate is 7-8 minutes. Thus, waiting lines are usually not an issue.

ii. Brooklyn, NY

On August 4, 1999 the investigators visited the Red Hook Brooklyn facility. At 7:35am 14 trucks were counted queued up at the pre-gate area mostly for cargo drop-off although several were waiting to pick up cargo, including containers and breakbulk. Of the trucks delivering to the port, the preponderance of these vehicles originated their trip in Canada, and most arrived at the facility between midnight and 3am.

The pre-gate and gate commence operations at 8:00am with 2 gates for processing inbound traffic. The inbound delivery process is a two-step process similar to that at the Elizabeth facility. Following the document check, a TIR inspection is performed for a total gate processing time of approximately 12-14 minutes per truck.

The investigators were unable to gain direct access to the operation and could therefore not more precisely examine and determine the process at this gate.

H. Recommendations

The movement of goods along the global supply chain network via the intermodal system is a complex process. It involves numerous parties that often have competing interests. There is no single solution appropriate to all for expediting the process, but one addressing the needs of all participants involved would be desirable. As economic development continues, the region's population increases, and container volume keeps growing, the question of how to accommodate the increasing needs for intermodal freight capacity becomes a pressing one. The capacity question must be assessed in four critical areas: operations, physical expansion, managerial procedures, and the application of technological innovations. Improved gate productivity in general is a win-win situation for all parties involved. It enhances all parties' performance, improves competitiveness, and helps reduce overall costs.

Gate Operating Hours:

- Even though it is not suggested that the gate should operate without a waiting line, the critical question is: What is the optimum waiting time and cost to accommodate all parties involved? Since at the present time the burden is disproportionately borne by truckers, the terminal operators will have to provide a solution that is more equitably balanced. Recognizing the truckers' burden, and facing high container volume growth, the terminal operators should increase the number of hours the gate complex is open. In addition, they should keep the gate open through lunch.

- Current gate operation has only one shift. Opening and closing hours are based on estimated truck volume; overtime hours are simply added to the normal 8:00am – 5:00pm shift. This has increased the burden to either terminal operators or carriers. A two-shift system starting early morning and ending midnight could significantly increase gate capacity. Truckers would have the flexibility of avoiding rush-hour traffic, as some of them have already cleared the metropolitan area or major arteries. Any change in current management – labor set up, however, requires the willingness of all parties to cooperate for the good of the region. . Weekend shifts during the peak season should also be considered.

Gate Complex Expansion:

- Where no physical or environmental constraints exist, serious thought should be given to construction of additional gate lanes. As indicated in the analysis, the effect of opening additional lanes could immediately reduce waiting costs significantly. Such an option might be easiest to implement in terms of management decision-making as container volume warrants such additional costs.

Pick Up and Delivery by Appointment:

- The terminal operator has additional ways to reduce the truckers' waiting time and improve productivity in general. These include better communications with truckers, and a move towards pick-up and delivery of containers by appointment through the use of the Internet or other advanced communication technology. By knowing the timing of container pick up and delivery, terminal operators can forecast traffic volume, thereby, enabling them to better prepare in terms of labor, equipment, gate operating hours, etc. The terminal operator therefore, could improve service to his clients and better manage his resources. Customized and consistent service could reduce drivers' waiting time, increase productivity, and reduce overall costs.
- The truckers should have complete documentation upon arrival at the terminal, thus reducing waiting time due to errors in documentation. During our observation, many truckers had long turnaround time (including waiting time) because of incomplete information. The lack of complete information or having incorrect information not only causes delays at the gate, but also adds to congestion. It requires the coordination/cooperation of all parties

concerned such as carriers, truckers, freight forwarders, customs brokers, and terminal operators.

Utilize State of the Art Information Technology:

- All stakeholders of the port; terminal operators, shippers, truckers, carriers, railroads, government agencies (federal, state and local), and logistics service providers, must adopt new information technology such as computerized gate processing, automated document processing and transmission, and any other computer applications that would improve the flow of information.
- State of the art gate technology such as Computer Character Recognition (CCR) should be employed by terminal operators to improve and standardize gate productivity.

OCR and CCR Applications. The components of an OCR or CCR system are high-resolution digital cameras, electronic strobes and sensors, input/output devices, image capturing and graphical user interface software (See Figure 6)[59]. Such a system is integrated with the terminal operations computer system in order to support all gate functions. The operation of the system is as following:

- When a moving truck with/without the container(s) that it carries enter the detection zone, the sensors are activated; and the system is triggered into operation.
- The system now starts the recognition process. It captures a sequence of images of driver, truck license plate, chassis number, and container number and type.
- The images are sent to the terminal computer information system for container and license plate identification.
- After applying certain logic and validation/verification, the terminal computer information system generates a routing slip, and an equipment interchange receipt for the driver.
- The driver then follows the instruction on the routing slip to drop off and/or pick up container and chassis.
- On the way out, the imaging process takes place again for any outbound equipment[60]

The system has the following advantages over existing manually operated gate systems:[61]

[59] See/Container, High-Tech Solutions Inc, www.htsol.com/.
[60] Ibid
[61] Ibid

Figure 6: OCR/CCR System Set Up

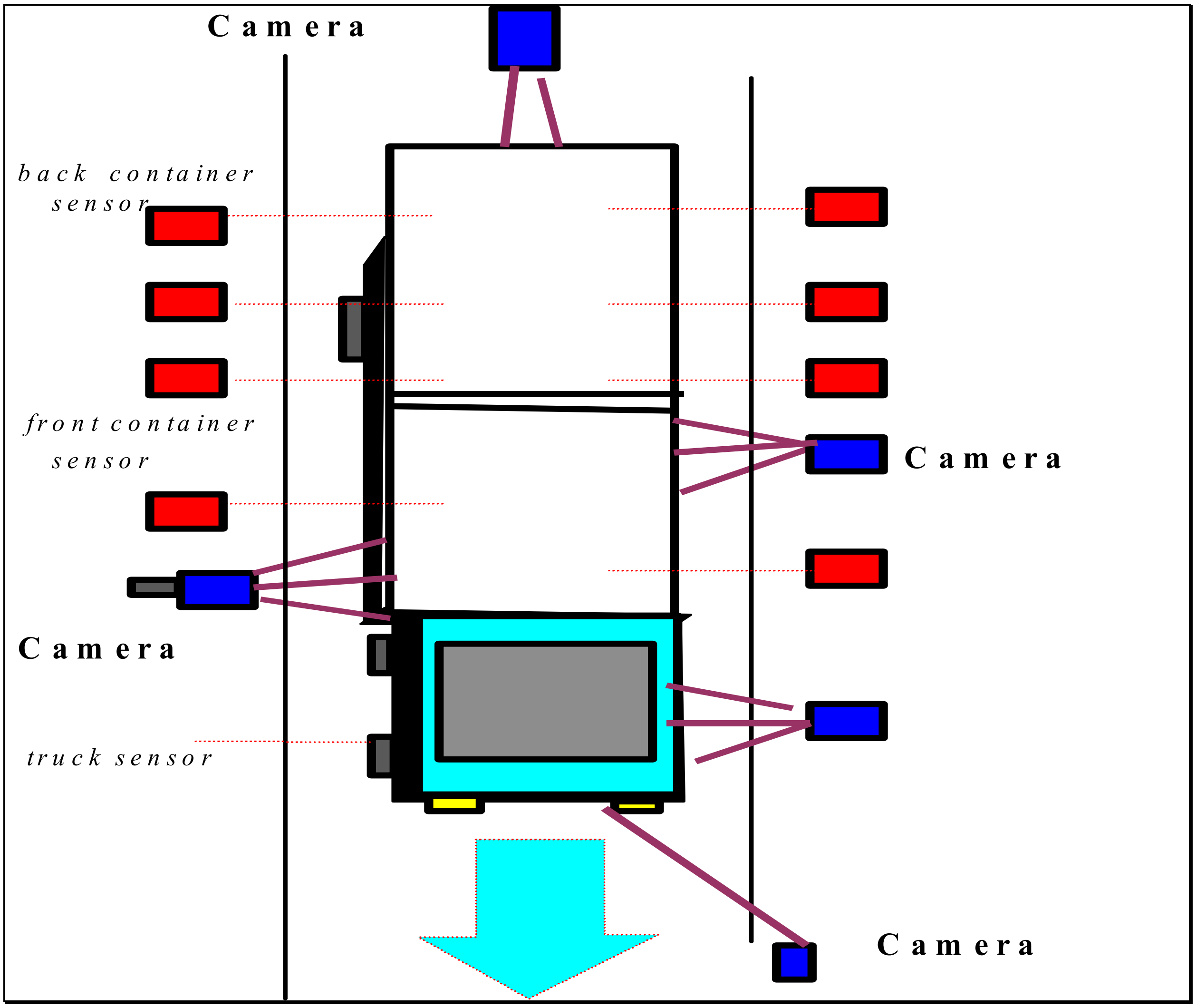


Figure 7: Computer Character Recognition

- Fully automatic process that capture container and chassis numbers (See Figure 7), reducing manual key-in errors.
- Simultaneously handles container & truck identification.

- Increases security to deter cargo theft as the image of the driver's face is taken and stored in the terminal computer system.
- Reduces gate-processing time dramatically such that gate capacity can be expanded without building more lanes and adding personnel.
- The reduction in gate processing time reduces the need for overtime hours at the gate, thus providing a saving on high overtime labor costs.
- Improves customer service level, as driver does not have to wait in a long line. Truckers can make more local drayage per day.
- Provides real-time gate traffic information; it enables terminal management to proactively take actions before congestion builds up or mitigate congestion effectively.
- Gate personnel can operate the system in a comfortable and secured remote site that is less affected by adverse weather conditions.
- Equipment interchange information can be transmitted to customers such as shipping lines, shippers, trucking companies, and freight forwarders instantly.
- Dramatically reduces the amount of paper work to all parties.

Major container terminals in Europe and Asia have already employed such technology and proved it effective. The container terminals in Singapore and Hong Kong claim that gate processing time is less than one minute. Meanwhile, some terminals in the US such as Maher Terminal and APL Terminal at Los Angeles have also employed such technology. The adoption of such technology in the US, however, is quite slow primarily due to the concern of labor relationship. With the increase of container volume and land space constraints for physical expansion, it is imperative to adopt new technology to improve gate productivity. It requires closed cooperation from all stakeholders. It will not be easy, but it is the only way to ensure parity between productivity improvement and port investment.

There is, however, a caveat that improvement in gate productivity will not necessarily lead to overall terminal productivity improvement. Any improvement in gate productivity has to occur in synch with yard handling productivity. The large amount of traffic passing through the gate may cause yard congestion if yard handling cannot keep up. A systematic view of such technology adoption should therefore be in place. Such synchronization in gate processing and yard handling productivity is necessary to ensure full utilization of the new technology.

The port and its terminals serve as an indispensable node in the global supply chain. Its efficiency is critical to regional economic competitiveness. Therefore, all efforts should be made to ensure its viability. Land access and terminal gate congestion adversely affect the port's overall capacity, which in turn causes a spill over into the local economy and subsequently the regional economy. Public agencies such as port authorities should encourage port users to implement the recommendations suggested above. Though, no single option can provide all the answers, the combination of extended gate hours, physical expansion, and phased in implementation of new technology to improve productivity could be very effective in preparing the port to meet its new challenges and maintain its leading position along the East Coast.

Bibliography

The bibliography listed is a collection of books, articles, conference proceedings, reports, newspapers reports and even some brochures.

"Automatic Equipment Identification Systems for Advanced Data Acquisition and Management in Marine Terminals and Intermodal Container Fleets", AMTECH, Dallas, Texas.

"Container Cranes 1996/97, Supplement", Port Development International, April 1996.

"Growth Doubts Weaken Container Market", Fairplay, 15th February 1996.

"Report on the IAPH Survey on Container Gantry Cranes, concluded in August 1994", The International Association of Ports and Harbors (IAPH), January 1996.

"Too many ifs... Mega-carriers gamble all", Fairplay, 1st February 1996.

“1996 Intermodal Terminal Survey”, ATA Intermodal Conference, Alexandria Virginia, 1996.

“1998 Newbuilds Review” Containerization International, February 1999.

“Port Authority Summary of Activities by Terminal”, various issues.

Atkins, Warren H., Modern Marine Terminal Operations and Management, Port Management textbook, Port of Oakland, 1983.

Auguston, Karen A., “The Latest Word on Overhead Crane Modernization,” Modern Material Handling, 1989.

Barber, Rebecca, “MIT Keeps Close Eye on Costs,” Port of Baltimore Magazine, Oct. 1990.

Beritzhoff, Michael R, "Opportunities and Challenges in Developing the Oakland Joint Intermodal Terminal", Terminal Conference, Paper # 34, New Orleans, Dec. 7-9, 1994.

Bohman, Michael T, "Technology Promotion Teamwork and Transportation," XXI ICHCA- International Biennial Conference, May 1993.

Brennan, Terry, “Corps backs 50-foot channels,” The Journal of Commerce, September 10th, 1999.

Brennan, Terry, “Sea-Land to open gates through lunch hour”, Journal of Commerce, September 27, 1999.

Bridge, Sarah, "Exterior Furnishing", Container Management, May 1996.

Buffum, Jay, “Port Facilities Face a Plethora of Exposures,” National Underwriter (Property & Casualty/Risk & Benefits Management), May 22, 1995, 10-11.

Button, Peter, "The Role of Information Technology in Terminal Design Planning and Operations", Terminal Conference, Paper # 28, New Orleans, Dec. 7-9, 1994.

Carruthers, Robert, "Pacific Pacesetters", Port Development International, April 1996.
Cerwonka, Richard M, "Terminal Automation System", Terminal Conference, Paper # 31, New Orleans, Dec. 7-9, 1994.
Chung, Young-Gyo, "A Simulation Analysis for a Transportation-Based Container Handling Facility," Computers & Industrial Engineering, 1988, 113-125.
Colville, Erik E., "The Basics of Equipping Transfer Stations," World Wastes, Apr. 1994, 34-40.
Damas, Phillip, "Big, Bigger, Biggest", American Shipper, July 96.
D'hondt, Erik, "Automation of a Straddle Carrier Operation", Terminal Conference, Paper # 21, New Orleans, Dec. 7-9, 1994.
DiBenedetto, Wiliam, "Inventor hopes to put robots on the docks unloading boxes", Journal of Commerce, Dec. 2, 1996.
Eakland, Peter B. and Marc Roddin, "Strategic Assessment for the 1994 Update of the San Francisco Bay Area Seaport Plan," Terminal Conference, Paper # 15, New Orleans, Dec. 7-9, 1994.
Economic Impact of the Port Industry on the New York-New Jersey Metropolitan Region, Economic Division, Office of Economic and Policy Analysis, The Port of NY & NJ, various issues.
Eddy, Art, "Capital Investing Is Ports' Strategy of Attractiveness," Handling & Shipping Management, Sept. 86, 36-46.
Fossey, John, "Speed Merchant", Containerization International, March 1999.
Frazier, Clark, Carl D. Martland, and Bahar Norris, "Analysis of Intermodal Terminal Highway Access to Economic Activities Centers", Terminal Conference, Paper # 25, New Orleans, Dec. 7-9, 1994.
Freudmann, Aviva, "Demand is catching up to container supply", The Journal of Commerce, Special Report, September 22, 1999.
Gasparro, Michael G., "POLA's On-Dock Rail Terminal: The Intermodal Container Terminal of the Future", Terminal Conference, Paper # 35, New Orleans, Dec. 7-9, 1994.
Griffiths, Dylan, "Under Pressure", Container Management, May 1996.
Gring, Jim, "A Journey Through the Past." Port of Baltimore Magazine, Oct. 1990.
Hall, Paul, "The Port of Baltimore: Strategies to Remain Commutative in the Area of Deregulation in the Transportation Industry," Thesis.
Haynes, K.E., Y.M. Hsing, R.R. Stough, "Regional Port Dynamics in the Global Economy: The Case of Kaohsiung, Taiwan", Maritime Policy and Management, January-March 1997, Volume 24, # 1.
Hayuth, Yehuda, "The Overweight Container Problem and International Intermodal Transportation," Transportation Journal, Winter 94, 18-28.
Institute of Traffic Engineers, Planning Hand Book
James, Mike, "The Why, When, and How of Upgrading Crane Systems," Plant Engineering, 1988.

Jenkins, Robert C., “Seagrit: Wave of the Future?” Baltimore Sun, 3 March, C1.
Johnson, Bruce, “The East Coast Heats Up,” Container News, Jan. 1979.
Kelly, Daniel F., “Cargo’s Speeding Up: No More Sitting at the Dock,” International Business, July 1991, 46-49.
Kelly, Ken, "Equipment Location Systems - Providing Intermodal Terminal Operators with Information Accuracy", Terminal Conference, Paper # 14, New Orleans, Dec. 7-9, 1994.
Land Transportation Access to Ports and Marine Terminals, USDOT, FHA 1993.
Lotz, Donald, "Expansion of On-Dock Rail Facilities at the Port of New York and New Jersey", Terminal Conference, Paper # 29, New Orleans, Dec. 7-9, 1994.
MANNESMANN, "Automated transport systems AGVs for modern logistics", brochure, October, 1996.
Maryland Port Administration, “Lease Agreement for the Seagrit ICTF,” 1990.
Maryland Port Administration, Terminal Operations Report 1978, (Baltimore: Maryland Port Administration, 1978).
Miles, Gregory L., “The War of the Ports,” International Business, Mar. 1994, 70-74.
Muller, Gerhardt, Intermodal Freight Transportation, Eno Foundation, 1995.
New York - New Jersey Dredging Scenario Study, Final Report, Louis Berger & Associates, Inc., July 1996.
NJMT Cargo Activity report, various quarterly reports from 1991 to 1997.
Paaswell, Robert and D. Petretta, "Goods Movement Characteristics in the New York City Region", University Transportation Research Center, Region II, City University of New York, April 1993.
Palmer, J. Gordon, Michael Leue and Frederic R. Harris, "Simulation Modeling of Traffic Access for Port Planning," Terminal Conference, Paper # 18, New Orleans, Dec. 7-9, 1994.
Pielow, Colin, Guide to Port Entry 1995-96, Volume 2, Shipping Guides Ltd.
Platt, John, "Ohio's Approach to Intermodal Management and Planning", Conference on Intermodalism, New Orleans, Dec. 7-9, 1994.
Port of NY & NJ Oceanborne Foreign Trade Handbook 1994, The Port of NY & NJ, October, 1995.
Porter, Janet, "Amsterdam plans to double speed of handling boxships", Journal of Commerce, Nov. 27, 1996.
Prince, Theodore, "Paradigm Shift in the Intermodal Terminal Operations of Marine Containers", Terminal Conference, Paper # 4, New Orleans, Dec. 7-9, 1994.
REGGIANE "Terminal Module Technical Brief", September 1996.
Regional Economy: Review and Outlook for the NY-NJ Metropolitan Region, April 96.
Richardson, Paul F, Peninsula Study Phase II, Draft Report, May 1996,

Rijsenbrij, Joan C., "Automation: A Process Redesign", Terminal Conference, Paper # 30, New Orleans, Dec. 7-9, 1994.

Rogers, Paul, "New Cranes For Dundalk," Baltimore Sun, 9 Nov. 1973, B2

Ruriani, Deborah Catalano, "Matching Product and DC Capabilities," Distribution, Mar. 1991, 56-60.

Sheppard, Edward J., "Obstacles to Port Operation and Development: The Dredging Permit Process and Other Environmental Constraints," Terminal Conference, Paper # 3, New Orleans, Dec. 7-9, 1994.

Shields, Jonathan J., "An Innovative Planning and Control System for Maersk Pacific, Long Beach", Terminal Conference, Paper # 19, New Orleans, Dec. 7-9, 1994.

The Port Authority of New York & New Jersey Dredging Impact Study, Draft, Paul F. Richardson Associates, Inc., December 1994.

Transportation and Economic Development, Translink, Wisconsin Dept. of Transportation 1994.

van Hee, K.M., "Decision Support System for Container Terminal Planning," European Journal of Operational Research, March 1988, 262-272.

Vandeveer, David, "Intermodal Rail Facility Design for the Next Century," Terminal Conference, Paper # 8, New Orleans, Dec. 7-9, 1994.

Welch, Rupert, "With Intermodal Traffic in a Slump, Rail Carriers, Ports, and Motor Carriers Get Creative to Remain Competitive," World Trade, Nov. 95, p.42-8.

World Cargo News, various issues.

Yahalom, Shmuel, "Intermodal Productivity and Goal Movement; Phase I, Crane Performance," University Transportation Research Center, Region II, April 1997

Yaro, Robert D. and Tony Hiss, A Region at Risk: The Third Regional Plan for the New York-New Jersey-Connecticut Metropolitan Area, Regional Plan Association, Island Press, Washington. DC, 1996.

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