EVALUATING THE IMPACT OF GATE STRATEGIES ON A CONTAINER TERMINAL'S ROADSIDE NETWORK USING MICROSIMULATION: THE PORT NEWARK/ELIZABETH CASE STUDY

By

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ABSTRACT OF THE THESIS

Evaluating the Impact of Gate Strategies on a Container Terminal's Roadside Network

Using Microsimulation: The Port Newark/Elizabeth Case Study

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Intermodal Marine Container Terminals (IMCTs) are experiencing consistent growth in container volumes and are under pressure to come up with strategies to increase their capacity to accommodate the increasing demand. In addition to the deterioration of the performance of terminal and drayage operations, the environmental effect from idling trucks has been starting to emerge as a serious problem. Different solutions have been proposed to address the issue and reduce the amount of externalities from drayage operations including new technologies, operational strategies and financial mechanisms.

The purpose of this thesis is to develop a simulation model capable of modeling a number of different gate strategies, using real world data, and evaluate the possible benefits that different operational improvements may have in reducing congestion in the vicinity of the terminals. For the purpose of the thesis the Port of Newark/Elizabeth in New York and New Jersey was selected to evaluate the roadside impacts of the two most common operational strategies (a gate appointment system and extended gate hours) using dynamic microsimulation. Several demand shifting scenarios were tested for a base year and future years and an extensive sensitivity analysis was performed based on the output of these simulations. Results from the sensitivity analysis were used to determine the percentage of truck demand that would theoretically need to be shifted to off peak weekday or weekend hours in order to maintain an efficient level of service on the roadway network at the Port Newark/Elizabeth for each simulated year.

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CHAPTER 1 INTRODUCTION

1.1 Problem Statement

Intermodal Marine Container Terminals (IMCTs) are experiencing consistent growth in container volumes. Even with the recent downturn in economic conditions, forecasts are estimating that freight volumes will continue to increase and will result in substantial increases in congestion both at the seaside and the landside of the terminals. IMCTs are under pressure to come up with strategies to increase their capacity to accommodate the increasing demand. One of the major factors contributing to the congestion problem is that the terminal gates, where trucks enter and exit the terminal to deliver or pick-up a container, are only open during certain hours on weekdays (due in part to union agreements), although operations within the terminal carry on 24/7. Consequently, trucks are forced to pick-up and deliver containers during specific hours of the day, resulting in high demand over certain periods. This phenomenon has led to inefficient gate operations that can spill traffic over to the surrounding roadway network causing serious safety, environmental and traffic congestion problems. The problem of congestion also extends to the yard of the terminals where coupled with capacity issues, it can degrade the reliability and performance of carriers, shippers, and terminal operators. In addition to the deterioration of the performance of terminal and drayage operations, the environmental effect from idling trucks has been starting to emerge as a serious problem as truck emissions have been linked to health conditions including asthma, cancer and heart disease.

Different solutions have been proposed to address the issue and reduce the amount of externalities from drayage operations[1] (i.e. truck container pickup from or delivery to a seaport terminal with both the trip origin and destination in the same urban area) including new technologies, operational strategies and financial mechanisms. Due to the limited and very expensive right of way in the area surrounding IMCTs, low cost and quickly implementable approaches to address mobility constraints at IMCTs become more viable than physical capacity expansions. There is an ongoing discussion concerning the implementation of different operational strategies (e.g. gate appointment systems, extended hours of operations for terminal gates, and advanced technologies for gates and terminals) that may relieve the effects of congestion and potentially help improve air quality. The impact of gate strategies (either at the tactical or operational level) on drayage operation efficiency is not very well understood, and is an area where researchers and practitioners are becoming increasingly involved. A number of researchers have attempted to evaluate the effects of different types of gate strategies either through simulation modeling (Sgouridis and Angelides, 2002; Juang and Liu, 2004) or through before-and-after case studies of terminals where gate strategies have been implemented (Giuliano et al., 2006, 2007).

The purpose of this thesis is to develop a simulation model capable of modeling a number of different gate strategies, using real world data, and evaluate the possible benefits that different operational improvements may have in reducing congestion in the vicinity of the terminals. One issue with operational changes at a port is the large number

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[1] Truck container pickup from or delivery to a seaport terminal with both the trip origin and destination in the same urban area (Harrison et al. 2008) Harrison,R.,N. M. Hutson, J.West, J. Wilke. (2008). Characteristics of Drayage Operations at the Port of Houston. University of Texas, Austin, Southwest Region University Transportation Center.

of key stakeholders involved including shippers, port authorities, terminal workers, government agencies, distribution center operators, etc. Organizing and managing cooperation between these major players can become quite a complex, if not infeasible, task. In the work presented herein it is assumed that the different operational measures tested can be applied and thus any collaboration issues between the different stakeholders that may arise are not considered or discussed. Although, participation, collaboration, and coordination of the stakeholders of such a freight system is a very interesting topic, it is left as future research.

1.2 Research Objectives and Scope

In this thesis a model will be developed that will simulate the operations of the incoming and outgoing drayage trucks at a port. The proposed model will be used to implement and evaluate the effect of different gate strategies on the drayage operations and the reduction of roadway congestion produced by the drayage trucks. The proposed model will be a Dynamic Traffic Assignment (DTA) simulation model that will simulate passenger and truck traffic on the roadway network within the port area. DTA was chosen over static models as it is capable of providing more realistic estimates of traffic performance than traditional traffic analysis methods by simulating the performance of individual vehicles and incorporates the influence of traffic controls and roadway geometry. DTA models also have the advantage of providing detailed measurements of traffic elements critical in the evaluation of traffic network performance (Peeta and Ziliaskopoulos, 2002). Currently there are four (4) main software packages that can perform DTA simulation (VISTA, Paramics, VISSUM, TransCAD). All four packages were reviewed and the best software was selected as the implementation platform of the

DTA model. PTV America's Vissim was chosen to perform the DTA simulation based on its user-friendly interface, compatibility with Synchro files, and availability of an OD correction algorithm (Visum's TflowFuzzy Model).

The developed DTA simulation model will be assessed for its accuracy subject to the available data. This assessment will consist of two components: a) verification and b) validation. Verification will assess the correctness of the formal representation by performing consistency checks on statistics on key variables from several simulation runs. Validation will assess how realistic the modeling assumptions are, by comparing performance metrics (i.e. link volumes) obtained from model test runs, to their counterparts in the system under study (i.e. traffic counts).

For the purpose of the thesis the Port Newark/Elizabeth Marine Terminals area was selected to evaluate the roadside impacts of the two most common operational strategies (gate appointments and extended gate hours) using dynamic microsimulation. For the selected port two different gate strategies will be implemented using the simulation model: a) a gate appointment system and b) gate extended hours of operation. The first strategy is positively adopted by drayage operators as it guarantees quick turn-around time at the terminal. The latter strategy can only be successful if it is combined with different incentives to the drayage operators for using the gates at off peak (e.g. PierPass, reduced turn-around time). These strategies main objective is the reduction of the congestion at peak hour periods by evening out and controlling the demand at the gate side of the terminal while at the same time minimizing the stochasticity in the planning of the yard side operations (i.e. time and sequence of pick-up or delivery of containers arriving or leaving the terminal by truck). Both strategies are expected to reduce congestion and spread more evenly (within a 24-hour period) the production of air pollutant emissions from idling or slow moving trucks. Different scenarios of demand increase and gate extended hours of operation will be developed for a base year (2006) and three future years (2011, 2016, and 2021) and used as an input to the DTA model. Extending the hours of the gate operations will consist of serving demand on a 24-hour basis and over the weekend.

The scenarios that were implemented in this thesis include:

1. Do-nothing case
2. WD 70 (30% shift of truck demand to off-peak weekday hours)
3. WD 80 (20% shift of truck demand to off-peak weekday hours)
4. WE 80 (20% shift of truck demand to weekend hours)
5. WE 90 (10% shift of truck demand to weekend hours)

The second and third gate strategy portray the implementation of a gate appointment system that results in a shift of demand from the peak to the off peak periods of the day[2]. The latter two strategies portray the implementation of extended gate hours of operations, with the introduction of weekend service. After consultation with a number of the public and private stakeholders, it was concluded that these are the most likely and possible scenarios, if an appointment system and/or extended gate hours were implemented at the Port Newark/Elizabeth terminals to manage the demand patterns of truck arrivals at the terminal gates. Using results from the simulation, a sensitivity analysis was performed to identify the impact on truck travel times and delays on the roadside network in the vicinity of the terminals for each simulation year and the different demand scenarios.

[2] The same results may be obtained by the use of different pricing schemes similar to concept of variable tolls in passenger transportation

The sensitivity analysis was then used to determine the percentage of truck demand that would theoretically need to be shifted to off peak weekday or weekend hours in order to maintain an efficient level of service on the roadway network at the Port Newark/Elizabeth.

1.3 Thesis Organization

This thesis contains an extensive literature review that examines a number of technologies and operating systems that can be implemented at a container terminal to reduce truck traffic, congestion, wait times and queues. The strategies reviewed in detail and considered in the case study and sensitivity analysis include gate appointment systems, and extended gate hours.

Chapter 3 introduces the case study at the Port of Newark/Elizabeth Marine Terminals area along with data collection procedures, model calibration and overall methodology. All models used for this thesis are also reviewed in this chapter.

Chapter 4 exhaustively reviews the microsimulation model inputs and results from all of the demand and gate strategy scenarios. All scenarios are described in detail and a sensitivity analysis showing the impacts of all scenarios on the roadside network is then presented.

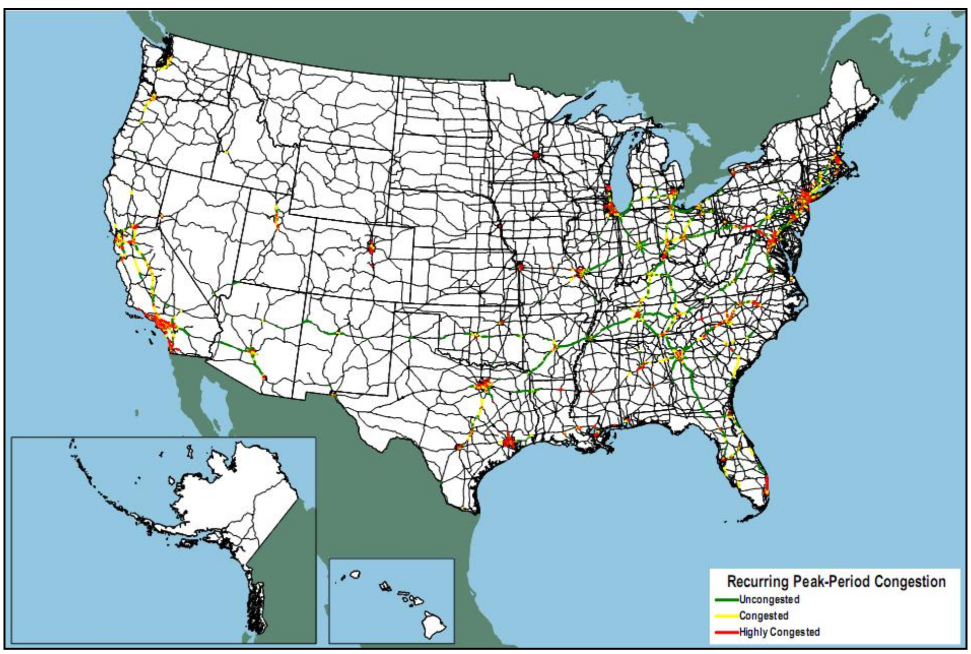
Chapter 5 summarizes the major findings of the results and suggests the most effective scenario for each simulated year (2006, 2011, 2016, and 2021).

CHAPTER 2 LITERATURE REVIEW

This literature review first looks at the increasing trends in international trade and the impact that growing container volumes have on intermodal terminals and their surrounding areas. Since the Port Newark/Elizabeth the site for the case study in this thesis, this chapter will look specifically at international trade trends and their impact on the port and road network in the New York Metropolitan Region. This chapter also reviews several technologies and operating systems that can be implemented at marine container terminals to alleviate truck traffic and congestion at container terminals. The case study in this thesis considers the two most common operational strategies, gate appointments and weekend gate hours. These strategies are reviewed in more detail and specific examples are given for each. The last section of this chapter describes a variety of automation technologies that can be used to compliment the implementation of certain operational strategies.

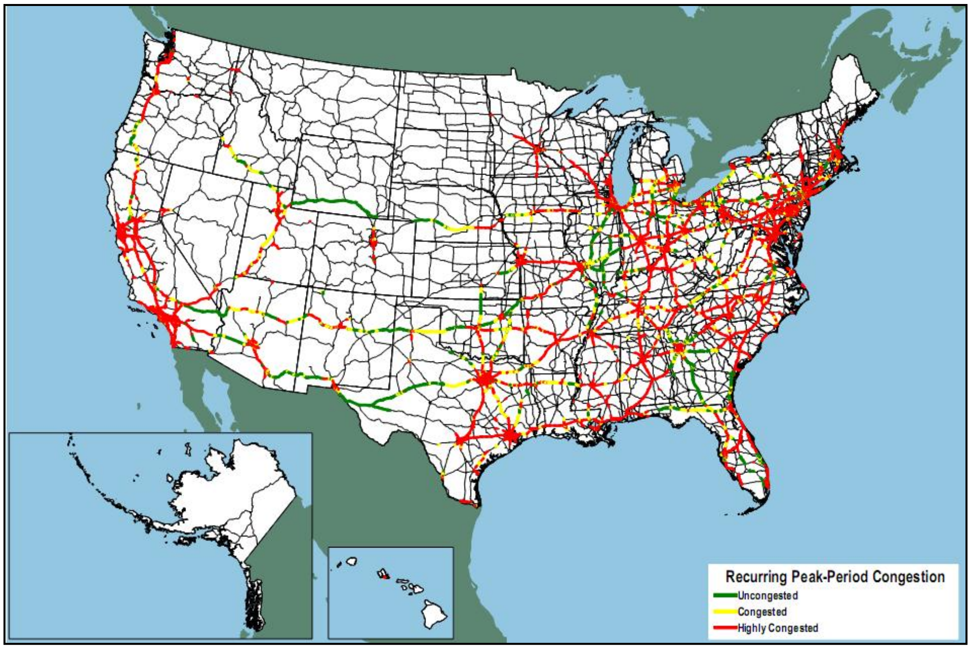
2.1 International Trade

Until 2009, intermodal marine container terminals had experienced constant growth in container volumes since widespread containerized trade began. Even with the downturn in freight volumes due to recent economic conditions, forecasts are that freight volumes will rebound and will increase dramatically by 2020, resulting in substantial increases in congestion. Demand for all modes of transportation carrying freight has increased over the last 25 years, especially for trucks that today carry approximately 60% of the domestic freight by weight and nearly 70% by value (Bureau of Transportation Statistics 2006). Projections indicate that by 2020, 80% of domestic freight by weight will be moved by trucks (Bureau of Transportation Statistics 2006). This increase of trade has impacted the roadway transportation systems of metropolitan areas, especially around the major generators (ports, airports, rail yards, and industrial areas) causing congestion, delays, and air and noise pollution (Bureau of Transportation Statistics 2006). Figure 2-1 and Figure 2-2 show the peak period congestion on high-volume truck portions of the National Highway System in the years 2002 and 2035, respectively. The figures show a significant amount of predicted congestion on these major freight corridors throughout the United States. The figures show congestion in areas that contain major freight hubs in the Northeast, along the west coast, and along the Gulf Coast is predicted to increase dramatically.



Source: (Office of Freight Managment and Operations, 2009)

Figure 2-1: Peak Period Congestion on High-Volume Truck Portions of the National Highway System: 2002



Source: (Office of Freight Managment and Operations, 2009)

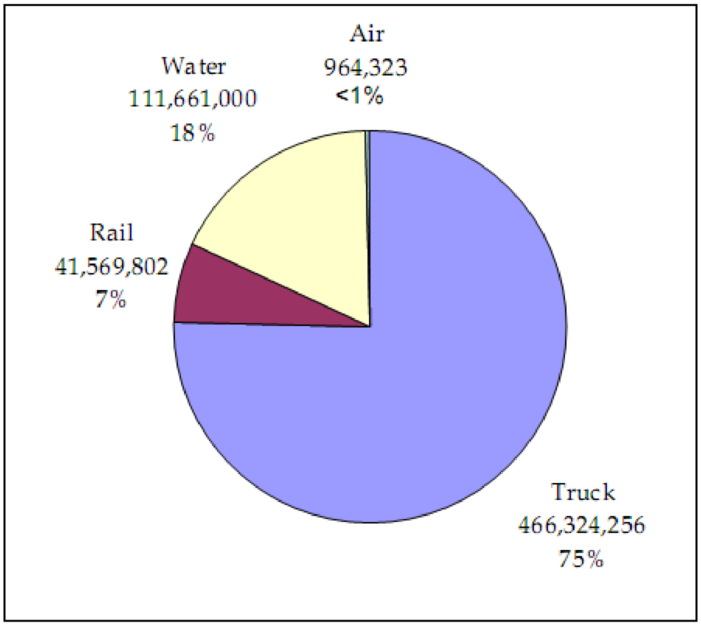
Figure 2-2: Peak Period Congestion on High-Volume Truck Portions of the National Highway System: 2035

2.1.1 Impacts to New Jersey Roadways

Significant and rapid growth in the number of people and markets to be served, coupled with ever-rising expectations about reliable and precise delivery times and an increasingly global economy, have created the heaviest demands on our freight delivery system ever (Parsons Brinckerhoff Quade and Douglas, Inc., 2007). The NJ Statewide Truck Model indicates that peak hour congestion will continue to grow at such a high rate that significant portion of the growth is expected to spread to the shoulders of the peak hours and extend both the morning and evening peak periods (Parsons Brinckerhoff Quade and Douglas, Inc., 2007). Although traffic is rapidly increasing there is still a significant amount of off-peak capacity on roadways that is currently underutilized, as trucks, mainly in response to customer needs and business practices, travel during the peak periods. Many businesses that utilize the trucking industry, such as shippers, warehouses and consignees, operate in and around the traditional passenger traffic peak periods. Package delivery companies (i.e., Federal Express, UPS, US Postal Service) have established their reputation on delivering packages during the morning peak periods and picking new packages during the evening peak (Parsons Brinckerhoff Quade and Douglas, Inc., 2007). Figure 2-3 shows the breakdown of freight flows by mode in short tons from the 2007 NJ Statewide Freight Plan. Approximately 75 percent of short ton freight is shipped by truck in New Jersey adding to the already congested metropolitan roadways during peak hours. Table 2-1 shows the estimated short ton weight broken down by mode and flow type. The table shows that the majority of goods are moved by truck. This is because a majority of the goods coming into the Port of New York and New Jersey are destined for locations within the region, which requires short haul truck trips.

Table 2-1: Breakdown of Flow Type by Mode on NJ Highways
Source: (Parsons Brinckerhoff Quade and Douglas, Inc., 2007)

Flow Type	Total	Estimated Weight (Short Tons)			
		Truck	Rail	Water	Air
Inbound	199,001,448	103,873,482	22,518,945	72,069,000	540,021
Outbound	164,661,920	117,584,251	10,974,367	35,679,000	424,302
Intrastate	131,015,146	126,807,290	294,856	3,913,000	0
Through	125,840,867	118,059,233	7,781,634	Unknown	Unknown
TOTAL	**620,519,381**	**466,324,256**	**41,569,802**	**111,661,000**	**964,323**



Source: (Parsons Brinckerhoff Quade and Douglas, Inc., 2007)

Figure 2-3: Estimated Statewide 2003 Freight Flows by Mode in Short Tons

2.2 Operational Strategies at Marine Container Terminals

Efficient gate operations are crucial to intermodal freight terminals since their impact is not isolated to the efficiency of the operations within the terminal but also extends to the road traffic on nearby freeways and access ramps. Inefficient gate operations can spill over to the surrounding roadway network causing serious safety and congestion problems, and degrading the reliability and performance of carriers, shippers, and terminal operators. Since intermodal freight terminals tend to be located in or near major cities, where right of way is limited and very expensive, implementing operational strategies to reduce the effect of the port truck related traffic to the surrounding roadway network becomes more important and more viable than physical capacity expansions. Among the gate operation strategies being considered to relieve the impacts of congestion and delay are gate appointment systems and extended weekday and weekend hours of operation for terminal gates.

2.2.1 Gate Appointment Strategies

Gate appointment is a truck reservation system that provides a certain number of reserved transactions during a specified time slot (usually one hour). Appointments are made by the use of the Internet or by phone. Modern distribution centers that are fully automated have appointment systems for trucks in use for pick up and drop off of cargo. An appointment system requires dedication of shippers, drayage operators, and terminal operators, in order to be effective (Bureau of Transportation Statistics, 2006). Gate appointment systems can be very effective in controlling the random arrival of trucks, modifying the peak hours of demand, minimizing congestion of idling trucks, and improving the utilization of the terminals' capacity (both at the delivery area and the storage yard). In order for a gate appointment to be successful, further strategies should be in place for processing the trucks arriving before or after their appointment time. Methods of processing arriving trucks with appointments differ from terminal to terminal, as shown by the current literature (Lord and Morais 2006). One way of processing trucks is to have dedicated lanes for trucks with appointments. Faster processing of trucks with appointments is assured if the conditions inside the terminal are well organized. Besides separate lanes, another method of processing trucks without appointments is to gather them all in a marshalling yard and service them according to a pre-determined pattern. This way all trucks with an appointment have priority (Theofanis et al. 2008). When there are no dedicated lanes for trucks with an appointment, the same queue can be used for all trucks, and trucks with appointments can be pulled out of line if the wait time exceeds a limit for trucks with appointments. To fully take advantage of an appointment system, terminal operations must also be organized, so that when a truck makes an appointment, containers are ready for pick up. To facilitate this objective containers can be reshuffled the day before, or when time is available, based on the appointment schedule so there are no delays at the interchange area of the terminal (i.e. area for pick-up and delivery of the containers by trucks).

2.2.1.1 California Assembly Bill AB 2650

In September 2002, California Assembly Bill AB 2650 was passed and became active in 2003. It presented regulations that required marine terminals to either: a) begin using appointment systems for trucks, b), extend the hours of operations for the pick-ups and deliveries by trucks, or c) find another way to reduce truck queues at the terminal gates (Giuliano and O'Brien 2007). This was the first bill in any US state aimed at port terminals, to lower congestion and air pollution. It included fines on marine terminal operators who allow heavy-duty trucks to idle for more than 30 minutes while waiting to enter the terminal.

2.2.1.2 Giuliano and O'Brien Study (2007)

The use of a gate appointment system at the port of Los Angeles and Long Beach was studied in California after the enactment of AB 2650. The appointment system was monitored over a 16-month period from January 2004 through June 2005 (Giuliano and O'Brien 2007). Prior to this, no data was available on terminal gate queues. During the study period trucking companies only made appointments 5-30% of the time, many appointments that were made were not met by the truckers, terminals were not always ready for the trucks with appointments and did not have special arrangements for trucks inside the terminal, so many trucks waited as long inside the gate as they had waited outside the gate before the appointment system.

2.2.1.3 Metrans Transportation Center Study (2008)

A second publication from Metrans Transportation Center (Giuliano et al. 2008) gave broader explanation on the extent of survey and interviews performed in California terminals from January 2004 through June 2005. Research was limited by lack of data, since the private sector typically does not share data, and data is usually available just for the state or region level. Data and information varied from terminal to terminal, and terminals are not required to share data with the public. An identified problem was that containers at the terminal were not ready for pick up by a truck with an appointment. Average queue length at observed terminals ranged from 5 to 26 minutes, and maximum was up to 122 minutes (Giuliano et al. 2008). The Air District in California stated that in 2004 AB 2650 contributed to annual reduction of emissions by 30%. The overall conclusion is that if marine terminal operators used appointment systems, emissions and noise would be reduced, overall terminal operations improved, and truckers would benefit from better operations.

2.2.1.4 Lord and Morais Study (2006)

The Transportation Development Center of Canada published a study in 2006 (Lord and Morais 2006) that reviewed current practices and strategies used at North American ports, to speed up handling of cargo, in order to reduce congestion and idling of trucks at the gate (Lord and Morais 2006). Information for the project was assembled in a literature review and survey of ports, followed by on-site visits and interviews. The report concentrated on the twelve largest North American ports by highest annual transiting container volumes (TEUs per year), and by availabilty of automated technologies.

The use of appointment systems at observed ports was mainly successful, and dependent on factors producing congestion. The major problem at the ports with no mandatory appointment system is that the truck drivers largely ignored it. The main reason given for not using appointment systems was difficulty for truck drivers to set up an appointment 24 hours in advance, mainly because of the other transactions scheduled that day. There is also the uncertainty of road congestion on a given day, and number of trips planned for one day. When an appointment was made, some drivers also failed to keep appointment times. The findings of the report indicate that appointment systems must be flexible to be successful. This means that they must (Lord and Morais 2006): "

- Handle cancellations
- Re-assign reserved time that has been canceled
- Agree to appointments that are made during the day, not just 24 hours ahead of time
- Decline or discourage double/triple appointments for the same container
- Fines for missed reservations
- Allow one hour window for trucks to show up
- Operate based on container appointment (not truck appointment)
- Allow for reservation by phone" (Lord and Morais 2006).

The researchers conclude that one of the best ways to improve terminal efficiency is by the use of gate appointment systems and they documented the necessary components to establish a good such system in Canada. They found that in order for improvements to take place at Canadian ports there has to be a detailed strategy in place, which includes policies and regulations, air quality mitigation programs, infrastructure improvements, and new port information systems and technologies (Lord and Morais 2006). Close coordination of all stakeholders is necessary for succesful operations.

2.2.2 Extended Gate Hours

In addition to a gate appointment system, the strategy of extending the hours of operations of the gates is another way to manage the demand patterns of truck arrivals and avoid high concentration during peak hour periods. Both strategies can exist in isolation or can be implemented together and complement each other. The latter strategy allows the demand for processing containers to be spread out throughout the evening, night, and even on weekends. This reduces the likelihood of congestion occurring during peak hours. There are three main issues that affect the successful implementation of this strategy: a) providing incentives to drayage operators to encourage them to utilize the extended hours of gate operations, b) adjustment of hours and pay of workers at the terminal (Giuliano and O'Brien 2007), and c) the ability of delivery locations to accommodate the truckers that pick-up containers during the extended hours of gate operations. Peak hour surcharges are an option to encourage traffic in off-peak hours. The improved truck turn times within the terminal and increased credibility of the terminal operator in keeping the promised truck turn times, could also facilitate the successful implementation of this strategy.

2.2.2.1 PierPASS OffPeak Program

This section summarizes the PierPASS OffPeak Program that has been in place at the San Pedro Bay Ports (Los Angeles and Long Beach) since July 2005. PierPass was implemented to achieve the following goals:

- Reduce peak-period congestion

- Improve terminal operating efficiencies
- Reduce truck wait and idle times
- Improve air quality
- Lessen community impacts

In 2004 there was an increase in container volume at the San Pedro Bay ports (Los Angeles and Long Beach) of approximately 12 percent, exceeding the expected increase of 5 percent (Federal Highway Administration, 2009). The unexpected increase caused major backups and delays at all ends of the international supply chain as the port systems reached capacity. The Ports at San Pedro Bay are the top two ports in the United States in terms of TEUs and produce a significant amount of truck traffic during port operating hours (Office of Freight Managment and Operations, 2009). The increase in container volume added to an already congested roadside network in the LA metro area caused major concern from port operators, politicians, and the community. Capacity had to be added to the system somehow to alleviate congestion, however adding infrastructure capacity would be a huge investment, take too much time to complete, and cause widespread community opposition (Federal Highway Administration, 2009). The search for an operational solution yielded the PierPASS OffPeak Program which extended gate hours at the ports increasing their capacity.

U.S. west coast ports typically operate at a productivity of around 5,000 TEUs per acre per year, which is significantly less than the productivity of Asian ports that handle more than 16,000 TEUs per acre per year (Federal Highway Administration, 2009). Due to current labor contracts U.S. terminals only operate for single shifts per day. Asian terminals on the other hand typically work all day shifts. The restricted operating hours at U.S. terminals is a major factor impacting the productivity of U.S. terminals.

To increase terminal capacity the San Pedro Bay ports implemented the PierPASS OffPeak program. This program offers off-peak (night and weekend) gate operating hours. The program provides an incentive for cargo owners and their carriers to move cargo at night-time periods and on weekends as a way of reducing truck traffic during peak periods throughout the day on major highways around the Ports, alleviating Port congestion and reducing air quality impacts from high peak-period truck traffic volumes (Federal Highway Administration, 2009). The program is based on a market incentive approach, where all loaded containers entering or exiting the marine terminals at the ports by truck during the day time shifts (Monday through Friday, 3:00 am to 6:00 p.m.) are charged a Traffic Mitigation Fee (TMF). Before the implementation of the OffPeak program in July 2005, marine container terminal gates at the San Pedro Bay ports were operating mainly during the day time shift (Monday through Friday between 8:00 a.m. and 5:00 p.m.). When the OffPeak program was set in place, all the marine container terminals at the two ports created the following off-peak gate shifts: (Monday through Thursday 6:00 p.m. to 3:00 a.m.) and (Saturday 8:00 a.m. to 6:00 p.m.) (Federal Highway Administration, 2009). One of the major problems reported in that study was the increased demand during the last hour that the port gates operated (between 5:00 and 6:00 p.m.). Higher numbers of trucks at gates was also reported at ports during the 6:00 p.m. and 10:00 p.m. time period, which resulted in gate capacity problems. Analysis of truck traffic on the nearby freeway I-710 indicated that there was no major change in truck traffic volumes from daytime peak to nighttime traffic. Therefore the OffPeak Program did not have major impacts on reducing congestion on roadways. The recommendation was that the congestion problems could be solved with the use of the OffPeak Program in combination with different strategies, like pricing strategies and appointment systems, and that this combined approach should be used if a similar program is implemented at other ports.

2.3 Automation Technologies

Although automation technologies are not considered in this thesis, a brief presentation of the available technology is presented. Use of these technologies may support and compliment the implementation of the gate strategies.

Growth of freight and containerized traffic around the world has influenced industries to use new and advanced automation technologies for management and operating technologies and systems at intermodal terminals. Use of these systems increases gate productivity and overall truck turn time through the terminal. Automated identification and container tracking is also very important for security issues. New technologies use Terminal Operation Systems (TOS), which manage every component of the terminals' operations. Many companies offer TOS services, but most of them use specific functions of terminal operations. Every individual terminal is different and each must decide which technologies to implement within their TOS to maximize operational efficiency and security.

Technologies used at the terminal gates are:

- *Optical Character recognition (OCR)* used to automatically identify containers, chassis information and truck plates at entry and exit gates, with the use of cameras and scanners (Ioannou P. A., 2008).

- *Global Positioning System (GPS)* used to identify container position anywhere within a terminal
- *Radio Frequency Identification Device (RFID)* wirelessly transmits object location by radio waves. This system is used to track trucks, containers and cargo at terminals. It can also pass information at marine terminals from one piece of equipment to another (Ioannou P. A., 2008).
- *Closed-Circuit Television Camera* used to monitor traffic and terminal activities and gates.
- *Bar Code Readers and Mounted Data Collection Computer* used to identify containers at gates and anywhere else at terminals.
- *Real-Time Location Systems (RTLS)* used to track and identify location of trucks and containers in real time using simple, inexpensive tags attached to containers and devices that receive wireless signals from these tags. They are used to improve terminal gate congestion and help terminal operators manage movements more efficiently. RTLS can also combine information on queues and traffic delays with terminals and delivery scheduling (Ioannou P. A., 2008).

The following section describes components of TOSs available for use in the market that can help improve the terminals' gate operations.

2.3.1 Automatic Gate Systems

Automatic Gate Systems (AGSs) help establish a connection at gate terminals between trucks and terminal operators. Truck handling at the terminal gates is controlled by the Gate Operating System (GOS). In order to process the collected data, communication needs to be established between the customer's advanced Gate Operating

System and the terminals application or usually Terminal Operating System (TOS) (COSMOS, 2008). AGSs use camera portals and optical recognition to read the number on the container, search the billing file to see whose cargo it is, and determine where it needs to go. Drivers can be identified with fingerprints of the first two fingers on the left hand, increasing security and accountability. Workers, therefore, will not need to be on the ground checking in drivers.

2.3.2 Pacific Gateway Portal

Pacific Gateway Portal (PGP) is a port user information system in a web-based form, operated by the Port of Vancouver. The information available on PGP includes container status, vessel activity, and real time video images from both the port terminal side and also truck and driver identification. This system also has an option of an appointment system for trucks and dangerous goods applications. A truck appointment system is in use at all three terminals within the Port of Vancouver, and is very successful. In order to make appointments, truck companies use the terminal's web page. Appointments are matched with transactions determined by the terminal on the basis of capacities of terminal. Dedicated lanes are in use for trucks with an appointment (Pacific Gateway Portal 2008). An approved Truck Licensing System (TLS) License is required by any party wishing to access Port of Vancouver's property for the purposes of draying marine containers to or from any of the terminals under the jurisdiction of Port Metro Vancouver. Trucks without a TLS license are not allowed to access Port Metro Vancouver property (Pacific Gateway Portal, 2008). Truckers also have to be in line at the gate entrance at least 15 minutes before expiration of their reservation time. If trucks arrive late they are required to go to the line for trucks with no reservation, or they will need new reservation. There is no fee to use the reservation system, but there is a fee to use the web portal.

2.3.3 SynchroMet

SynchroMet offers a virtual container yard service, which is used at the Port of Oakland as an on-line service. It integrates ocean carriers' with motor carriers' information through a virtual container yard (VCY) to perform mutually beneficial congestion management, reduce costs and ease port and public road congestion. The SynchroMet service, accessed through the Internet at www.synchromet.com, is where inbound containers can be posted as empty street-turn opportunities and matched in real time with equipment needs to cover export bookings (SynchroMet 2009). SynchroMet reduces empty truck miles and waiting time at local marine terminals, which has a positive impact on the local environment.

2.3.4 SeaLink

SeaLink provides trucking companies serving the port of New York and New Jersey access to the regions highway system, helping them move cargo to their final destinations. SeaLink is a uniform truck driver identification system, which helps trucks move more efficiently through terminal gates. It uses ACES (Automated Cargo Expediting System) to send out information from truck drivers to terminal operators, which ensures more efficient flow of containers through the port (The Port Authority of NY &NJ, 2009).

2.3.5 eModal System

The eModal system applications focus on truck and marine terminal gate interfaces. The system is designed to improve efficiency and deal with the congestion at container terminals, so that it can reduce truck queuing and idling (eModal, 2009). eModal uses a common portal of container and export booking status information (US Environmental Protection Agency). eModal has information on detailed container status, vessel schedules, terminal locations, truck driver lists and other important terminal information. Trucking companies and terminal operators can also use eModal for a gate appointment system. Trucking companies use it to pre-approve their drivers for container pick up and drop off. When drivers are pre-approved eModal sends this information to terminals, which helps reduce the time drivers spend at gates. With the possibility to integrate all the processes online, eModal helps to speed up transactions at terminals. The only problem is that there needs to be greater usage of the system by trucking companies in order to fully realize the system benefits.

2.3.6 Edge Manager Auto Gate

Edge Manger Auto Gate is developed by NAVIS, a part of Zebra Enterprise solutions and it is one of the leading solutions for automated gate systems. Gate transactions are monitored with the use of different technologies like RFID, OCR, GPS positioning, reefer monitoring, e-seals and mobile computers (Zebra Enterprise Solutions, 2009). Truck drivers use a self service pedestal to check-in. Terminal inspectors use a mobile graphical interface for checking the cargo that comes to the terminal. Edge Manager Auto gate can be used with Navis Yard mangement or other Terminal Operating Systems, which provides easier and more integrated overall terminal operations.

2.3.7 NAVIS

NAVIS is an automated system that allows terminal operators to see what is happening in real time from terminal gate to rail or vessel, at their terminals yard. Paper based systems and bar code based systems at yards are not able to provide real time and up-to-date automated information. NAVIS yard management software includes capabilities for dock and yard management, gate scheduling and automation, security, container tracking and visibility of property (NAVIS, 2009). With the use of NAVIS customers are served better, operating cost of the terminal is lowered and capacity is increased.

2.3.8 COSMOS System

COSMOS System is a fully automated and integrated yard control and planning system for terminals and it includes a lot of different software that can be customized for different yards or terminals. It can help optimize and automate operations like yard and vessel planning, equipment control and tracking, gate administration, invoicing and management reporting. COSMOS uses already available components of an individual terminal to build the best possible terminal (COSMOS, 2008). COSMOS also provides gate control and container tracking capabilities. Software programs are linked so that a when container is checked at a gate, all the container information is used to plan activities inside of the yard. Every time the container is moved, the COSMOS system software is updated (Lord and Morais 2006).

2.3.9 Embarcadero System

Embarcadero (ESC) System is a full service provider to marine, rail and intermodal terminal operators, and it offers technology software and integration services.

ESC automates intermodal operations, providing integration of cargo handling and visibility inside and outside the terminal. Web based tools used by ESC are VoyagerTrack and webTAMS and they use Differential Global Positioning System (DPGS), and wireless local area networks (WLANS) to pinpoint the exact equipment position and provide real-time communication for the terminal operating software. ESC uses Premier Appointment System (PAS) that includes VoyagerTrack, and this allows truck companies to schedule arrival appointments at the gate. The other solution from ESC is smartGATE, which is an automated terminal access solution, and it provides centralized gate transactions. SmartGATE uses Optical Character Reader (OCR), RFID, and GPS technologies. A unique feature to SmartGATE is Intelligent Camera, a CCTV (Closed Circuit Television) that improves the accuracy of OCR, giving terminal operators better real time images. With the use of this system productivity of the gate terminal is improved, and the yard security and safety is greatly enhanced (Lord and Morais 2006).

2.3.10 CATOS System

CATOS system is a fully integrated TOS which is used in 72 container terminals worldwide (Total Soft Bank 2009). Most of the terminals that use CATOS are in Asia (Thailand, Taiwan, Malaysia and Vietnam) and they have been using it for more than 10 years. CATOS has the capability to use one database server for different terminals. CATOS system is integrated with different parts of the terminal system which provides better system optimization. CATOS system is interfaced with Gate Automation System, Gate Weighing Scale, Crane Automation and Monitoring System and RFID System.

2.3.11 Jade Master Terminal (JMT) System

Jade Master Terminal TOS is used in container terminals, rail company operations, bulk and general cargo operations, log marshalling and vessel scheduling. It has been used in New Zealand for past 15 years, in more than 15 terminals (Jade Logistics 2009). US and Austarlia have started to use Jade TOS recently. Jade TOS operates best in small or mid-sized terminlas. Jade is installed on every terminlas computer like any other program, and it makes technology for terminals systems. Jade can offer intergration for any part of terminla system from gate to vessel scheduling. New techologies like OCR, RFID, GPS can be used with Jade TOS, and this techologies can be added if terminal wants to use them.

2.4 Summary

Coordination between trucking companies and port intermodal terminals is essential for efficient terminal operations. Gates that are clogged can worsen terminal capacity and this creates not only an operational but also an environmental problem. For a tactical/operational level gate strategy system to be effective, a large percentage of trucks will have to use it, and there has to be some priority or benefit for trucks with appointments. Incentives are necessary to get trucking companies to buy into appointment systems and actually make appointments (and keep them). Incentives may also be needed for the terminals to use the systems effectively. Gate appointments are a more favored alternative than extended gate hours, since the cost is lower.

Gate appointment systems have the potential to dramatically improve operations inside the terminal as well as at the gate, and as a secondary result, reduce congestion on the roadway system, and therefore reduce harmful emissions in the neighboring communities. Of course, as freight shipping increases, there will be a point that limits the amount of trucks and containers that can physically be processed within the constraints of terminal boundaries, but there is certainly room for improvement now, before reaching that point. For extended gate hours, additional workers are required at off-peak times, but this is a viable option to increase throughput at terminals. It will require that additional workers be added, hours and pay contracts be adjusted and associated businesses buy-in, but there is potential for greater amounts of container movement without the need to expand terminals.

Increased efficiency at intermodal port terminals due to any or all of the strategies discussed in this section can affect the overall transportation community and all other types of intermodal transportation by allowing more containers to be shipped, and moved more quickly away from the ports, onto the other forms of transportation, and to their final destinations. Appointment systems and extended hours, as well as the managing technologies can be used by other modes experiencing congestion and air quality concerns to increase efficiency, thereby lowering congestion and emissions. The key to developing effective gate appointment systems is to ensure participation from all key stakeholders.

CHAPTER 3 MODEL AND METHODOLOGY

3.1 Introduction

As mentioned in Chapter 1 the goal of this thesis is to evaluate the impacts of two gate strategies on the LOS of the roadside network in the vicinity of a container terminal using traffic microsimulation. The Port Newark/Elizabeth in New Jersey was selected as the study area due to the accessibility to the site and the availability of data. An extensive sensitivity analysis on current and future-year scenarios was performed to compare the impacts of the different gate strategies to truck travel times and delays and to determine the most efficient parameters of each gate strategy for each future year. Appointment systems and extended gate hours were the two operational strategies considered in the simulations and sensitivity analysis since they are the most commonly implemented in practice and discussed in the literature. Simulations were performed for the base (2006) and future years (2011, 2016, 2021, and 2025). All scenarios are described at the beginning of Chapter 4. A traffic microsimulation software package, Vissim (PTV America, 2009), was used to build the DTA model and perform all the simulation scenarios.

This chapter describes in detail the area of study, models, and methodology used to perform the simulation study for the Port Newark/Elizabeth roadside network. Section 3.2 describes the location and layout of the port along with the location of the major terminals within the port and the major access roads of the port. Section 3.3 overviews the software used to build and calibrate the traffic simulation model and perform all the simulation scenarios. The final section (3.4) describes the data collection, methodology, and model calibration and validation procedures.

3.2 Overview of Port Newark/Elizabeth Marine Terminals Area

3.2.1 Location

The Port Newark/Elizabeth Marine Terminals are located within the cities of Elizabeth and Newark in New Jersey, along the Newark Bay in the Newark – New York Metropolitan area. Figure 3-1 shows the location of the marine terminal. The port is bordered to the east by the Newark Bay, to the north by I-78 and to the west by I-95 (The New Jersey Turnpike). The Newark International Airport is also located to the west of the port, separated by the New Jersey Turnpike.

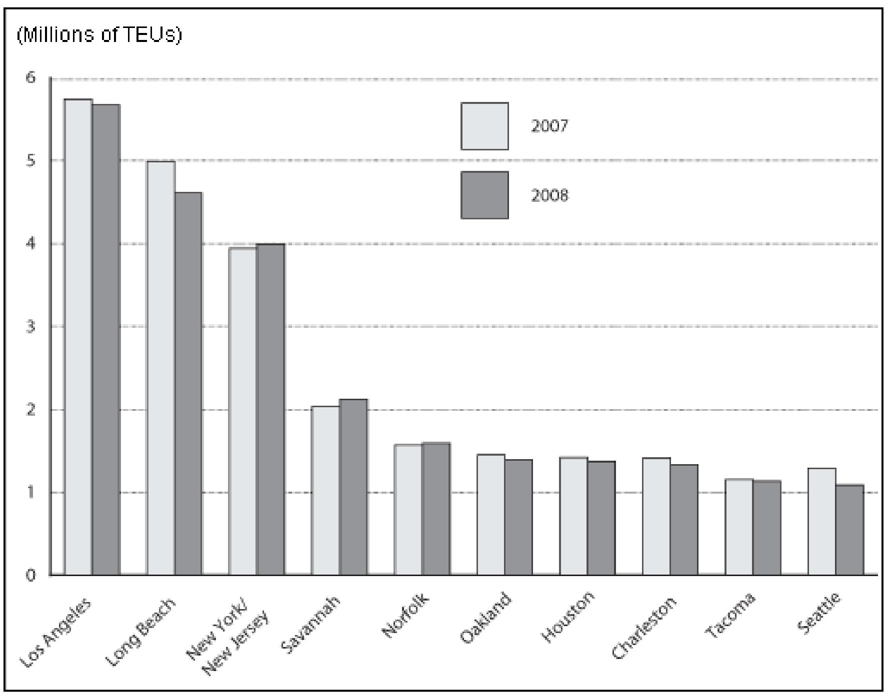
Source: (The Port Authority of New York and New Jersey, 2007)

Figure 3-1: Location of Port Newark/Elizabeth

3.2.2 Port Newark/Elizabeth Freight Statistics

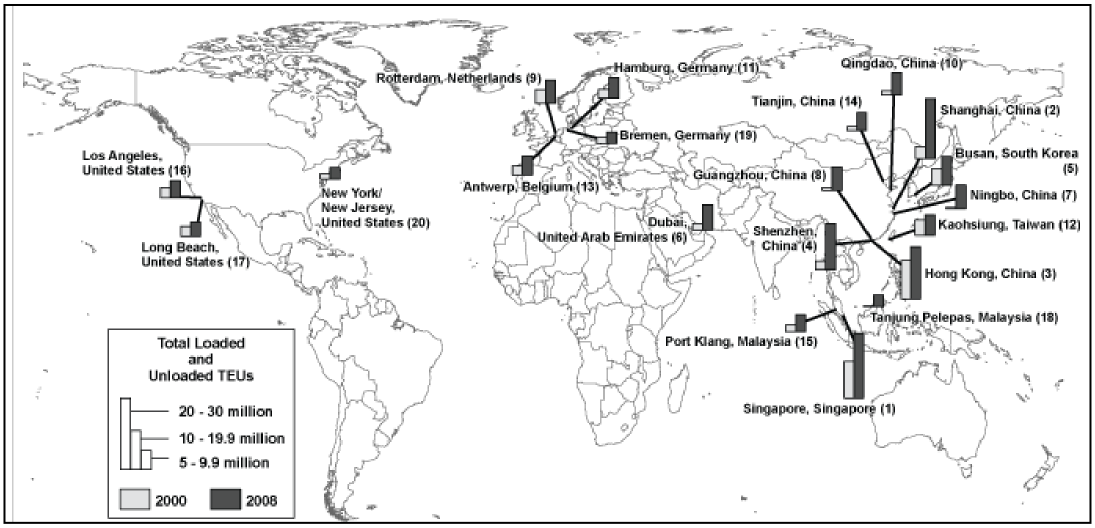
The Port Newark/Elizabeth is one of the busiest ports in the country and the world. Figure 3-2 shows the number of twenty-foot equivalent units (TEUs) handled at the top 10 United States ports in 2007 and 2008. The Port of New York and New Jersey (PONYNJ) is the third busiest port in the country behind Los Angeles, CA and Long

Beach, CA. Port Newark/Elizabeth, on the New Jersey side of the PONYNJ handles the majority of the PONYNJ container traffic. The New York / New Jersey port handled approximately 3.94 million TEUs in 2007 and approximately 3.99 million TEUs in 2008 (Bureau of Transportation Statistics, 2009). Figure 3-3 shows a thematic map representing the top 20 container terminals in the world. PONYNJ, one of three US ports to make the list, ranks twentieth (Bureau of Transportation Statistics, 2009). The Port is located among heavily traveled corridors in a major metropolitan area. Increasing freight traffic during peak travel hours will only cause more congestion in the area, eventually contributing to significant delays on roads that are already nearing capacity.



Source: (Bureau of Transportation Statistics, 2009)

Figure 3-2: Maritime Container Cargo Handled at Top 10 U.S. Container Ports



Source: (Bureau of Transportation Statistics, 2009)

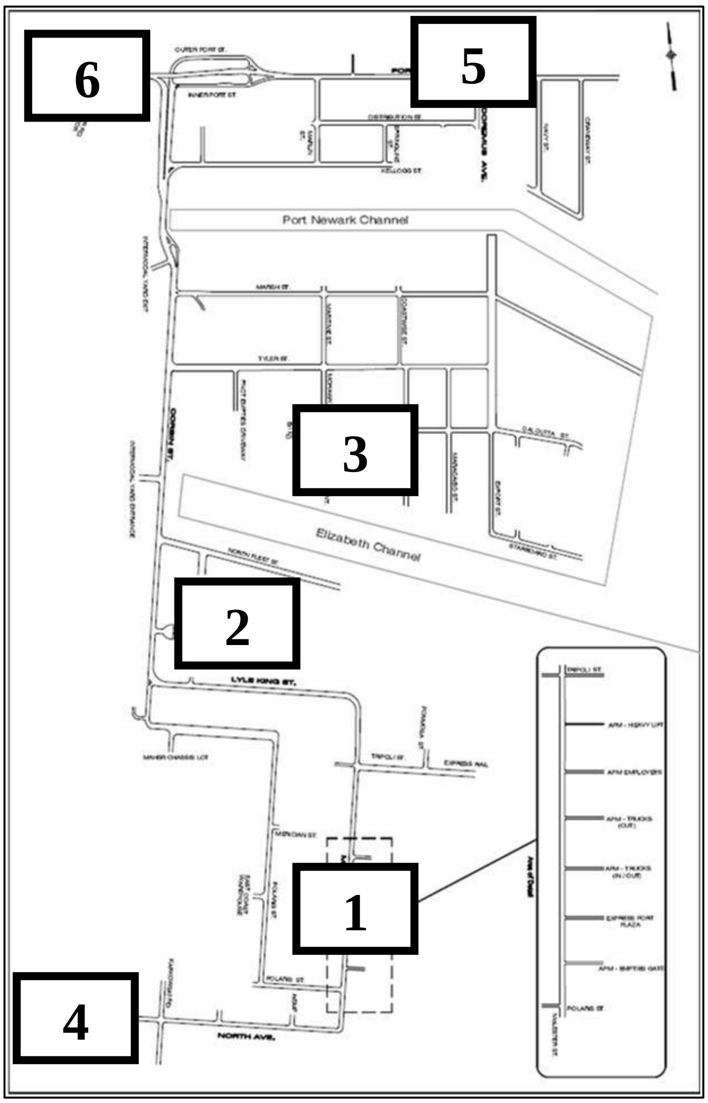
Figure 3-3: Top 20 World Container Ports

3.2.3 Terminals and Access Roads

The roadside network of the Port Newark/Elizabeth is not a complex network, with three major access roads, three major terminal entrances and one main road that runs through the network in the north-south direction (Corbin Street/McLester Street). APM, Maher, and the Port Newark Container Terminal (PNCT) are the three major container terminals operating in the port. Access to these terminals and the rest of the Port areas is provided by North Avenue at the southern end of the network, along with Doremus Avenue and Port Street both on the northern end of the port network. North Avenue is accessible from the New Jersey Turnpike Exit-13 and Route 9. Port Street is accessible from I-78, Route 1 and Route 9. Doremus Avenue is accessible via New Jersey Turnpike Exit-15 a couple miles north of the port. Figure 3-4 shows the layout of the Port Newark/Elizabeth Marine Terminals. In this figure, the location of the three major container terminals (APM, Maher, and PNCT) can be seen along with the location of the three access roads into the port. Table 3-1 shows the index numbers used to locate the major access roads and container terminals in Figure 3-4. This index only represents the locations of the terminals and access roads in this particular section and does not correspond to the traffic generating zones of the port that are defined later in this thesis.

Table 3-1: Index of Key Areas in Port Road Network

Name	Index
APM Terminal	1
Maher Terminal	2
PNCT	3
North Avenue	4
Doremus Avenue	5
Port St	6



Source: (The Port Authority of New York and New Jersey, 2007)

Figure 3-4: Port Newark/Elizabeth Roadside Network

3.2.3.1 Terminals at Port Newark/Elizabeth

This section provides a brief overview and description of the three major container terminals at the port; APM Terminal, Maher Terminal and Port Newark Container Terminal.

3.2.3.2 APM Terminal

APM Terminal is located on McLester Street toward the southern end of the port road network. The closest access road to APM Terminal is North Avenue just to the south of the container terminal's main entrance. APM's Port Elizabeth terminal is their largest container terminal on the east coast of North America. The terminal covers 350 acres, 15 Ship-to-Shore cranes, 6000 feet of wharf, three deep-water berths, on-dock rail, and AQI/CBP inspection capabilities (APM Terminals, 2010).

3.2.3.3 Maher Terminal

Maher Terminal is located on Corbin Street in the center of the port road network. To the north of the terminal's main entrance are the Doremus Avenue and Port Street access roads. To the south of the terminal, a little over 1.5 miles, is the North Avenue access road. Maher has developed North America's largest marine container terminal in the Port Newark/Elizabeth. The terminal covers 445 acres, 16 cranes, 10,128 ft of ship berth and offers the only cooperative chassis pool in the port (Maher Terminals LLC, 2010).

3.2.3.4 Port Newark Container Terminal

The Port Newark Container Terminal is located on Corbin Street north of Maher Terminal. Just north of PNCT are Doremus Avenue and Port Street, which are the closed access roads to the container terminal. PNCT covers 180 acres, 4,400 ft in berth length, 335 reefer plugs and has daily intermodal connecting service with CSX (Port Newark Container Terminal, 2010).

3.2.3.5 Access Roads to Port Newark/Elizabeth Marine Terminals

As mentioned in the previous section the three access points into the port roadside network are North Avenue, Port Street and Doremus Avenue. These roads connect the port to and from Interstate 95 (New Jersey Turnpike), Interstate 78 and Routes 1 and 9 which are all major travel corridors in the area. Table 3-2 shows the distances to and from the terminals and a point of entrance/exit of the major highways around the port via the three access highways. Figure 3-5 through Figure 3-13 show the mapped routes corresponding to Table 3-2.

Table 3-2: Distances Between Major Highways and Terminals via Access Roads

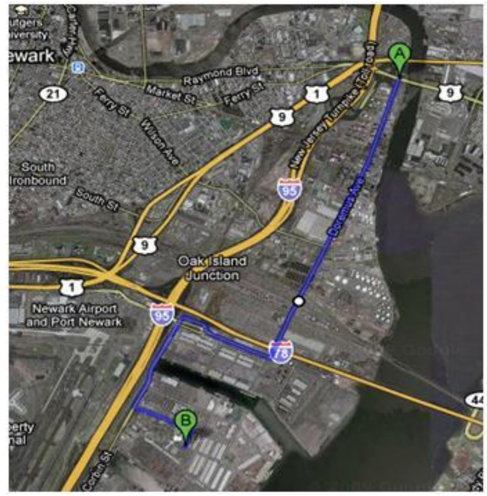
From/To (Miles) **Via**	APM	Maher	PNCT
NJTP Exit 13 via North Avenue	1.1	2.3	3.8
NJTP Exit 15 via Doremus Avenue	6	4.8	4.6
I-78, US-9, US-1 via Port St	4	2.7	2.4

Source: Google Maps

Figure 3-5: Route between NJTP Exit 15 and APM via Doremus Ave

Source: Google Maps

Figure 3-6: Route between NJTP Exit 15 and Maher via Doremus Ave



Source: Google Maps

Figure 3-7: Route between NJTP Exit 15 and PNCT via Doremus Ave

Source: Google Maps

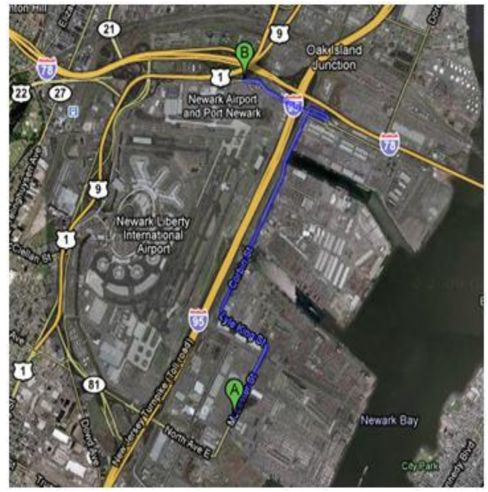
Figure 3-8: Route between NJTP Exit 13 and APM via North Ave

Source: Google Maps

Figure 3-9: Route between NJTP Exit 15 and Maher via North Ave

Source: Google Maps

Figure 3-10: Route between NJTP Exit 13 and PNCT via North Ave

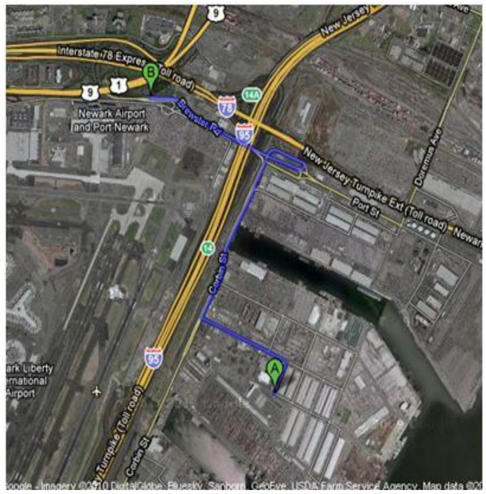


Source: Google Maps

Figure 3-11: Route between I-78 and APM via Port St

Source: Google Maps

Figure 3-12: Route between I-78 and Maher via Port St



Source: Google Maps

Figure 3-13: Route between I-78 and PNCT via Port St

3.3 Available Data

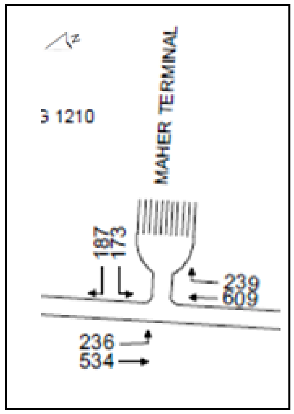
To efficiently and accurately simulate the Port roadside network in the micro-simulation program Vissim, current traffic count data is needed. Without count data a realistic simulation of the traffic conditions on the network is nearly impossible. Accurate and updated data allows for the calibration of the baseline Vissim model in order to simulate other scenarios to be compared to base case results. The sensitivity analysis performed in this case study requires a calibrated base model in order to effectively analyze the results of all other scenarios. The Port Authority of New York and New Jersey was able to provide a detailed traffic count report of the study area, the Port Newark/Elizabeth Comprehensive Traffic Study. This 2006 traffic study was the most recent available study. Therefore 2006 will be used as the base year in the sensitivity analysis. This section summarizes the data that was extracted from the traffic study and used in the calibration of the Vissim baseline model.

3.3.1 Traffic Counts

The 2006 traffic study provided turn count information at all intersections within the port roadside network for each peak period (7:00-8:00AM, 12:00-1:00PM, and 3:00-4:00PM). This data was key in the calibration of the Vissim model. Traffic count maps are shown in the Appedix.

Turn counts, link volumes, and productions and attractions for each defined zone were extracted from these maps. As the available maps only provided turn volumes, a small example is presented to explain how we obtained the link volumes and production and attractions. Figure 3-14 shows a small part of the network at the Maher Terminal (MT) truck entrance and exit for the AM period (7-8 am). In total 239 northbound and 236 southbound trucks are attracted (i.e. entering the terminal) and 187 northbound and 173 southbound trucks are produced (i.e. departing the terminal). Traffic volumes on the links leading to and from the Maher terminal can be calculated in the same manner. Northbound traffic from the Maher terminal is equal to: 187+609, northbound traffic to the Maher terminal is equal to: 609+239, southbound traffic to the Maher terminal is equal to: 534+236, and southbound traffic from the Maher terminal is 534+173. By aggregating turn counts in the same manner just described for all links and zones, link volumes and zone productions and attractions were determined.

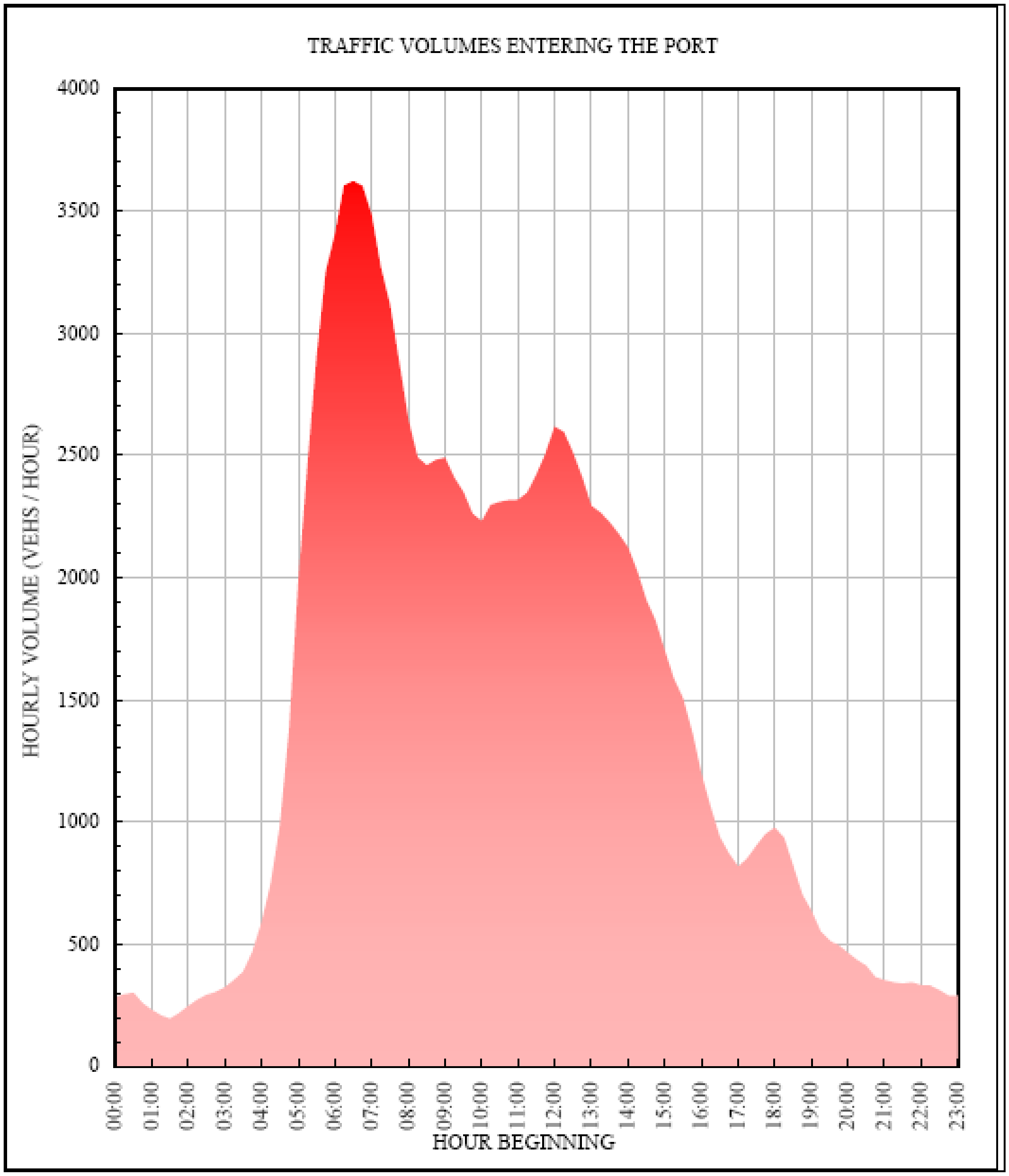
This data was used to calibrate the three peak hour origin-destination matrices using Visum's TFlowFuzzy model (described later in this chapter).



Source: (The Port Authority of New York and New Jersey, 2007)
Figure 3-14: Maher Terminal Gate Turn Counts

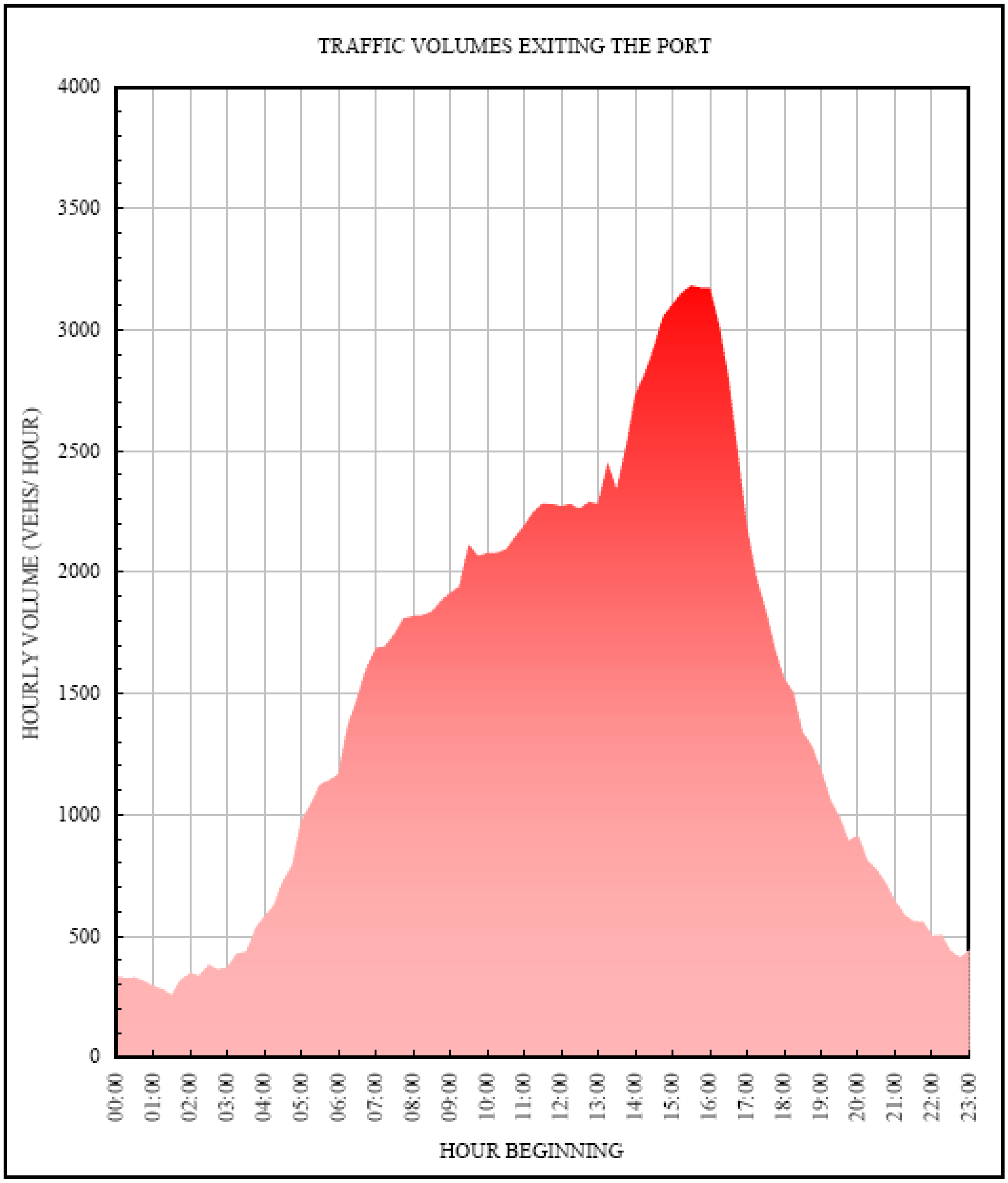
3.3.2 Entering and Exiting Volumes

Figure 3-15 shows the hourly traffic distribution entering the network on the three access highways on a typical weekday. Figure 3-16 shows the hourly traffic distribution exiting the network on one of the three access highways on a typical weekday. As discussed earlier in this chapter the three access highways are Doremus Avenue, North Avenue and Port Street. The figures clearly show the peak entering and exiting times on a typical weekday. In Figure 3-15, the peak entering volume occurs between 6:00-7:00 AM with nearly 3,600 vehicles are entering the network during that hour. In Figure 3-16, the peak exiting volume occurs between 3:00-4:00 PM with nearly 3,200 vehicles exiting the network during that hour. Since turn counts were only provided for the three peak periods of the day (7:00-8:00 AM, 12:00-1:00PM, and 3:00-4:00PM), the entering and exiting volumes were used to estimate the origin-destination matrices for the non-peak hours throughout the day. The traffic distributions were also used when analyzing the entering and exiting results from the baseline model to ensure calibration.



Source: (The Port Authority of New York and New Jersey, 2007)

Figure 3-15: Hourly Traffic Distribution Entering the Port (typical weekday)



Source: (The Port Authority of New York and New Jersey, 2007)

Figure 3-16: Hourly Traffic Distribution Exiting the Port (typical weekday)

3.3.3 Generated Truck and Automobile Traffic

Figure 3-17 through Figure 3-22 show the generated truck and vehicle traffic within the network during the peak periods of the day (7:00-8:00 AM, 12:00-1:00PM, and 3:00-4:00PM). Figure 3-17 shows the generated truck traffic during the AM peak hour (7:00-8:00AM) on a typical weekday. APM terminal generates approximately 450

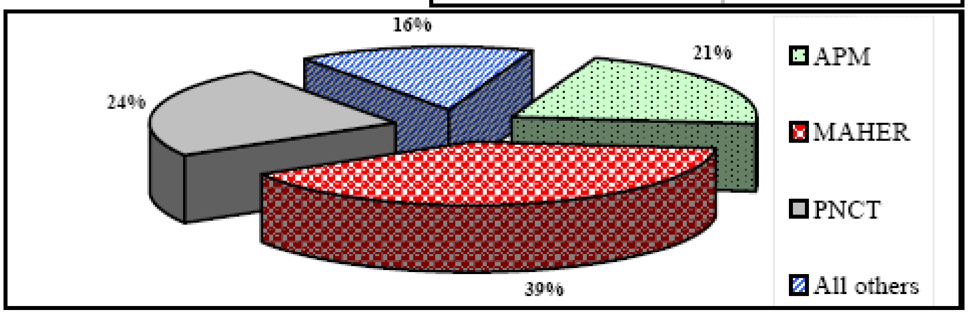
(21%) trucks, Maher terminals 840 (39%) trucks, PNCT 500 (24%) trucks, and all other facilities 330 (16%) trucks for a total of 2,120 trucks during the AM peak period. Figure 3-18 shows the generated truck traffic during the MD peak hour (12:00-1:00PM) on a typical weekday. APM terminal generates 560 (20%) trucks, Maher terminals 930 (34%) trucks, PNCT 594 (21%) trucks, and all other facilities 706 (25%) trucks for a total of 2,790 trucks during the MD peak period. Figure 3-19 shows the generated trucks traffic during the PM peak hour (3:00-4:00PM) on a typical weekday. APM terminal generates 400 (18%) trucks, Maher generates 760 (33%) trucks, PNCT 360 (16%), and all other facilities 760 (33%) trucks for a total of 2,280 trucks generated during the PM peak period.

Figure 3-20 shows the automobiles generated during the AM peak hour (7:00-8:00AM). APM generates 370 (12%) automobiles, Maher 500 (16%) automobiles, PNCT 230 (7%) automobiles, and all other facilities 1,980 (65%) automobiles for a total of 3,080 automobiles generated during the AM peak period. Figure 3-21 shows the automobiles generated during the MD peak hour (12:00-1:00PM). APM generates 240 (11%) automobiles, Maher 440 (21%) automobiles, PNCT 90 (4%) automobiles, and all other facilities 1,330 (64%) automobiles for a total of 2,100 automobiles generated during the MD peak hour. Figure 3-22 shows the automobiles generated during the PM peak hour (3:00-4:00PM). APM generates 250 (10%) automobiles, Maher 380 (15%) automobiles, PNCT 190 (7%) automobiles, and all other facilities 1,750 (68%) for a total of 2,570 vehicles during the PM peak hour.

These figures show that traffic generated from the three major terminals in the Port (APM, Maher, and PNCT) generate the majority of truck traffic traveling in the port throughout the day. Other facilities within the port area generate the majority of automobile traffic. This data was used to calibrate the productions and attractions to and from the major terminals throughout the day and the vehicle compositions input into Vissim for each hour.

AM PEAK HOUR (7:00-8:00 AM)

APM	MAHER	PNCT	All others
450	840	500	330
		TOTAL	2,120

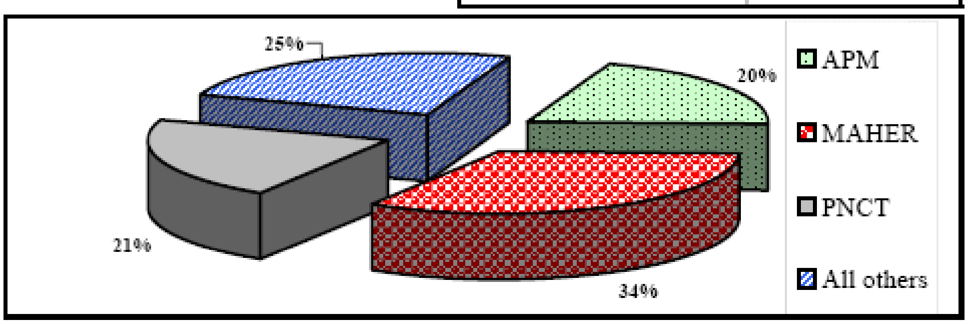


Source: (The Port Authority of New York and New Jersey, 2007)

Figure 3-17: Generated Truck Traffic – AM Peak YEAR 2006

MD PEAK HOUR (12:00-1:00 PM)

APM	MAHER	PNCT	All others
560	930	594	706
		TOTAL	2,790

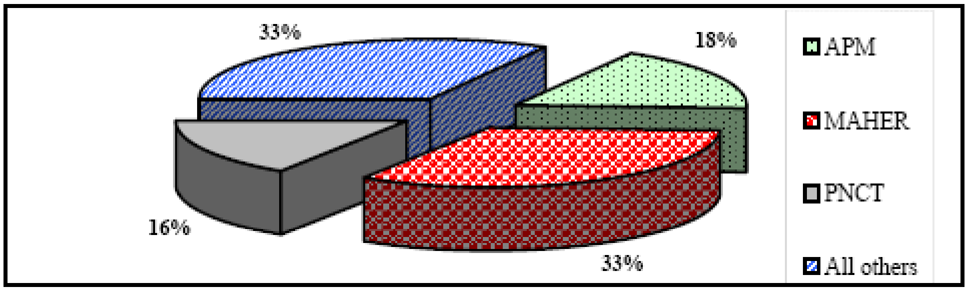


Source: (The Port Authority of New York and New Jersey, 2007)

Figure 3-18: Generated Truck Traffic – MD Peak YEAR 2006

PM PEAK HOUR (3:00-4:00 PM)

APM	MAHER	PNCT	All others
400	760	360	760
		TOTAL	2,280

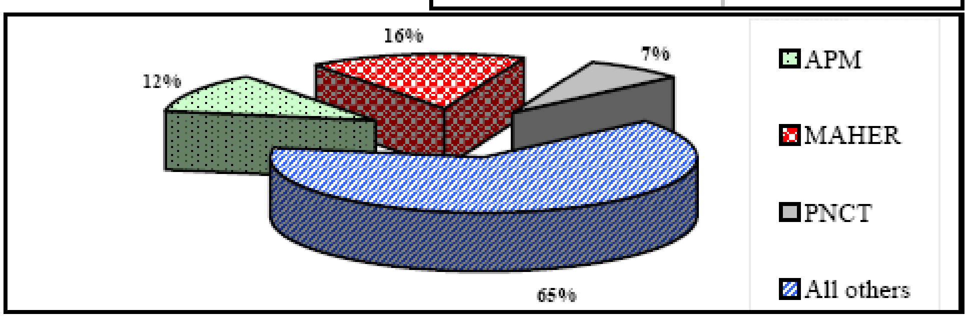


Source: (The Port Authority of New York and New Jersey, 2007)

Figure 3-19: Generated Truck Traffic – PM Peak YEAR 2006

AM PEAK HOUR (7:00-8:00 AM)

APM	MAHER	PNCT	All others
370	500	230	1,980
		TOTAL	3,080

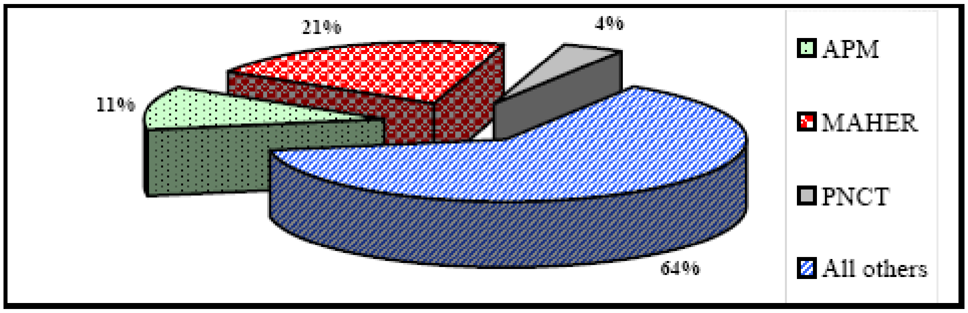


Source: (The Port Authority of New York and New Jersey, 2007)

Figure 3-20: Generated Automobile Traffic – AM Peak YEAR 2006

MD PEAK HOUR (12:00-1:00 PM)

APM	MAHER	PNCT	All others
240	440	90	1,330
		TOTAL	2,100

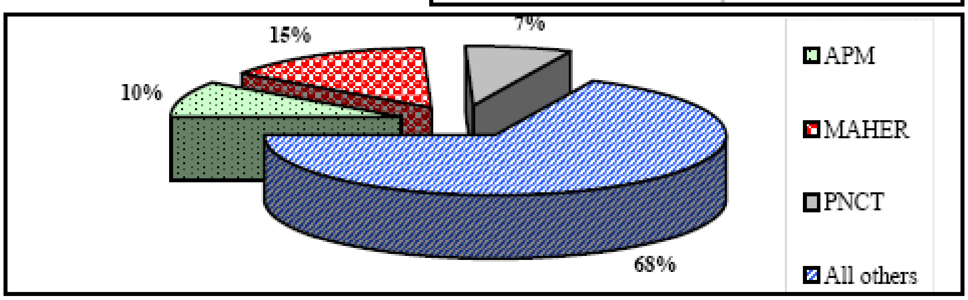


Source: (The Port Authority of New York and New Jersey, 2007)

Figure 3-21: Generated Automobile Traffic – MD Peak YEAR 2006

PM PEAK HOUR (3:00-4:00 PM)

APM	MAHER	PNCT	All others
250	380	190	1,750
		TOTAL	2,570



Source: (The Port Authority of New York and New Jersey, 2007)

Figure 3-22: Generated Automobile Traffic – PM Peak YEAR 2006

3.3.4 Synchro Files

The Port Authority of New York and New Jersey also provided Synchro files of the port roadside network. The Synchro files included the traffic count data along with the network signal timing plan for the three peak periods (7:00-8:00AM, 12:00-1:00PM, and 3:00-4:00PM). These files were imported into Visum and Vissim in order to derive the baseline origin-destination matrices and design the network for the 24-hour micro-simulations run in Vissim.

3.4 Tools and Models – Visum and Vissim

Two software programs were used to implement the sensitivity analysis for this research work, PTV America's Visum and Vissim. This section of the thesis describes the models and how they were used for the sensitivity analysis.

3.4.1 Visum

Visum is a macroscopic planning model used for transportation planning, travel demand modeling and network data management and is used worldwide for metropolitan, regional, statewide and national planning applications (PTV America, 2010). Visum integrates all relevant modes of transportation (i.e., car, car passenger, truck, bus, train, pedestrians and bicyclists) into one consistent network model and provides a variety of assignment procedures and 4-stage modeling components which include trip-end based as well as activity based approaches (PTV America, 2010). Although the essential component of the sensitivity analysis was the microsimulation capabilities of Vissim, the Visum program was used to derive origin-destination estimations which were used as input for the calibration of the base year model in Vissim. The T-Flow Fuzzy model within Vissim was utilized to estimate the origin-destination matrix based on turn counts, link volumes and productions and attractions which were all available from the Port Authority of New York and New Jersey's Comprehensive Traffic Study 2006. This process will be discussed in detail in following section.

3.4.2 Vissim

Vissim is a microscopic traffic, public transport, and pedestrian simulation software. It is one of the most powerful tools available for simulating multi-modal traffic flows, including cars, goods vehicles, buses, heavy rail, trams, LRT, motorcycles, bicycles and pedestrians (PTV America, 2010). Data can be reported for any time period and interval within that time period. Data can also be reported for any point-location in the network, for an intersection, along any path and/or for the entire network. Data can also be aggregated by mode or vehicle class which was very useful for this project, making the analysis of truck traffic much easier and reliable. Delay, speed, density, and travel time can be reported.

Vissim can assign vehicles to the network using one or a combination of three methods. The basis method assumes that traffic is stochastically distributed over fixed routes from user-definable start to end points. Dynamic routes allow traffic to be dynamically assigned to user-specified paths when special events occur. Dynamic Traffic Assignment (DTA) allows Vissim to assign traffic to the network using origin-destination matrices and travel cost stochastic assignment techniques (PTV America, 2010).

For the purpose of this project, the Dynamic Traffic Assignment module was used for all simulations. This allowed for 24-hour simulation based on count data provided by the Port Authority of New York and New Jersey. Origin-destination matrices were generated using the integrated demand model of Visum (TFlowFuzzy model) with its advanced matrix estimation and calibration functionality.

3.5 Model Calibration

In order to obtain accurate results from the model simulations, it is necessary that the model is calibrated using the actual traffic data provided by PANY/NJ. Running a 24-hour simulation using the dynamic assignment module in Vissim requires origin-destination matrices for each hour of the simulation. To derive these OD matrices based on the available data, Visum's Tflowfuzzy model was used. This model updates existing matrices based on user input data and defined convergence criteria. By using a dummy matrix and the available data from the 2006 Traffic Count Report, origin-destination matrices for the peak periods were created. The peak hour matrices and the daily traffic distributions were then used to derive non-peak OD matrices. The twenty four base demand matrices could then be input into Vissim to run the baseline (Year 2006) simulation. This section first describes the TFlowFuzzy model of Visum and the Dynamic Assignment model of Vissim which were essential components of this process. The procedures performed for the calibration of the model are then described in detail in this section of the thesis.

3.5.1 TFlowFuzzy Model

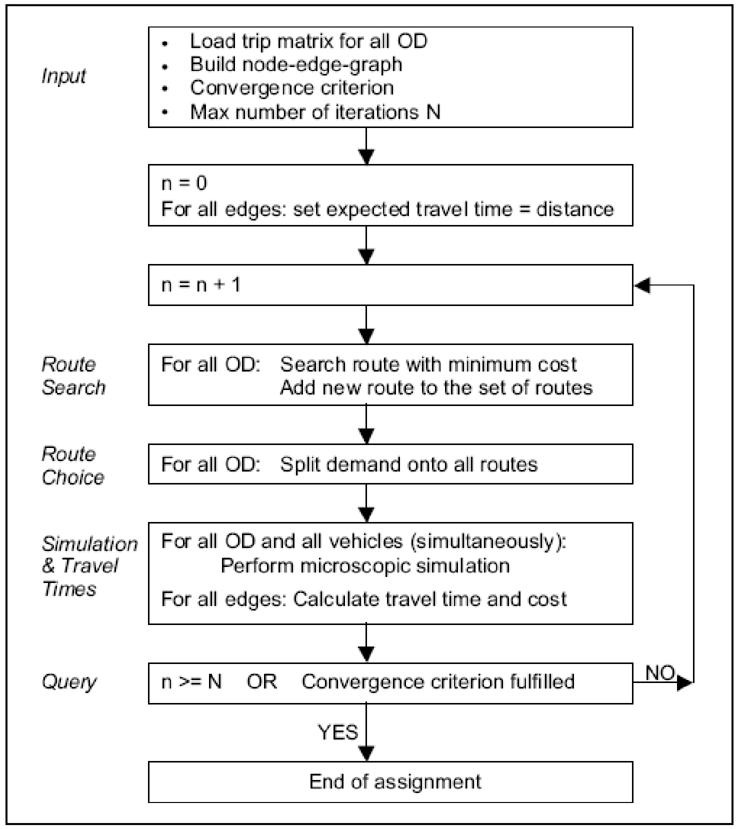
As discussed previously in this section the majority of the data that was collected for the Port Newark/Elizabeth Marine Terminals' roadside network came from the Port Authority of New York and New Jersey's 2006 Comprehensive Traffic Study. The data included turn counts for a large majority of intersections within the network during peak hours (7:00-8:00 AM, 12:00-1:00 PM and 3:00-4:00 PM). From the turn count data, link volumes, and productions and attractions to and from defined zones were calculated. Origin-destination matrices are required as the demands input for the dynamic assignment module in Vissim. Therefore, the OD matrices had to be derived from the data in the PANYNJ Traffic Report. Deriving an accurate origin-destination matrix from count data is not trivial and a computer algorithm designed specifically for this task is usually needed. Visum's TFlowFuzzy model has the capabilities to derive an origin-destination matrix based on user input data. This model was used to derive the base case origin-destination matrices that were input into Vissim's dynamic assignment model.

Since the 1980s, matrix correction/update techniques have been used to produce a current travel demand matrix from an earlier travel demand matrix using current traffic count values (PTV America, 2009). Based on research by Van Zuylen/Willumsen, Bosserhoff and Rosinowski which focuses on matrices for private transport, PTV America extended the application of these techniques to public transport. The TFlowFuzzy model works by adjusting a current matrix to match the user input data, allowing the origin-destination matrix to be calibrated based on actual count data from the Port (turn counts, link volumes, and zone productions/attractions). Section 3.5.4 shows the calibration procedures and results of the TFlowFuzzy model.

3.5.2 Dynamic Assignment

The Dynamic Assignment module of Vissim is designed to model the route choice behavior of drivers, and eliminates the need to model the network with static routes. This allows origin-destination matrices to be used as demand input. In Vissim the assignment is calculated dynamically over time by an iterated application of the microscopic traffic flow simulation with selected convergence criteria (PTV America, 2009). The convergence criteria for each simulation performed for the sensitivity analysis will be discussed later in this chapter. The static assignment method is commonly used as standard practice in transportation planning. Static assignment means that travel demand and the network are static or constant throughout the duration of the simulation. However, in real life scenarios travel demand and roadway network conditions change throughout the day; for example traffic signals, lane closures, or increased demand during peak travel periods. In order to capture the changes that occur on the traffic network throughout the simulation the dynamic assignment method is used. In each simulation drivers choose their routes based on the travel cost of routes in the previous simulations. This is known as the driver "learning process". First, routes from all origins to all destinations must be found by the drivers. Vissim assumes that not everybody uses the best route but that less attractive routes are used as well, although by a small percentage of drivers. Therefore, not only the best routes must be known for each origin-destination relation but a set of all routes. During the iterated simulations Vissim builds and stores a growing archive of routes from which the drivers choose. In order for drivers to base their route choice, each route must be assigned some value to rank the routes. Vissim computes a generalized cost for each route, which is a combination of distance, travel time and other costs such as tolls, etc. The distance and cost are defined directly in the network, but the travel time may change during every simulation. The computed generalized cost values are store so that the route choice model in the next simulation can use these values. The choice of one route out of a set of possible routes is a special case of the more general problem called "discrete choice modeling". Given a set of routes and their generalized costs, the percentages of the drivers that choose each route is computed. Vissim uses a variant of the Logit model to handle route choice (PTV

America, 2009). Figure 3-23 shows a flow chart of Vissim's dynamic assignment model that was just discussed.



Source: (PTV America, 2009)

Figure 3-23: Vissim Dynamic Assignment Flow Chart

3.5.3 Defining Traffic Generation Zones

The first step in creating and calibrating the model was to theoretically define traffic generation zones within the Port Newark/Elizabeth based on logical assumptions. As mentioned previously in the thesis there are three access roads into the network: Doremus Avenue, North Avenue and Port Street. There are also three major terminals located within the network: APM terminal, Maher terminal, and the Port Newark Container Terminal. Figure 3-24 shows the Port roadside network along with the zones that were defined as the main trip generation zones. These 12 selected zones were used in all origin-destination matrices throughout the procedures of this project. Table 3.3 is an index table of the 12 zones. For the remainder of the thesis, each zone always corresponds to its specific index number shown in the table.

Zones 1 through 7 are the major traffic generators of the port roadside network consisting of the three access roads, the three major container terminals, and the Maher Chassis Depot. According to the Port Authority's Comprehensive 2006 Traffic Study it was assumed that 60% of the trucks, originating at any of the three access highways or the warehouses on the southern end of North Ave, traveled directly to the Maher Terminal, bypassing the Maher Chassis Depot to pickup an empty chassis. The remaining 40% percent of truck traffic entering the Maher Terminal, from the external roadway network, traveled first to the Maher Chassis Depot to pick-up an empty chassis and then traveled to Maher's main terminal on Corbin Street. Conversely, 40% percent of the truck traffic exiting the main terminal initially traveled to the Maher Chassis Depot to drop-off an empty chassis. Then, this truck traffic exited the Port via any of the three access highways. The remaining 60% percent, originating at the Maher Terminal, bypasses the Maher Chassis Depot and traveled any of the three access highways or the warehouses on the southern end of North Ave (The Port Authority of New York and New Jersey, 2007). Since the Maher Chassis Depot generates a significant amount of traffic it was crucial to include it in the calibration of the network as a zone in the origin-destination matrix.

Although Zones 1 through 7 generate a majority of traffic throughout the day, they do not account for all traffic traveling through the network. Therefore it was essential to include smaller traffic generating zones. Zones 8 through 12 do not generate as much traffic, however including these zones in the origin-destination matrix allowed the matrix calibration to be more accurate and realistic. As described in the previous section, the TFlowFuzzy matrix correction model works by updating an existing matrix based on user defined variables. In this case the available data calculated from the traffic report included turn counts, link volumes, and productions and attractions. Without Zones 8 through 12 it would be impossible for the TFlowFuzzy model to correct the matrix and still have an acceptable percent error. Including these strategically placed zones allowed traffic to travel to all areas of the Port roadside network, and not just between Zones 1 through 7. Zones 8 through 12 include the Fed Ex warehouse, the break bulk north of PNCT, the PNCT intermodal rail area, the East Coast Warehouse and Meridian Street area.

Table 3-3: Origin-Destination Zone Index

Zone Name	Index
Port Street	1
Doremus Avenue	2
Port Newark Container Terminal	3
APM terminal	4
Maher Chassis Depot	5
Maher Container Terminal	6
North Avenue	7
Fed Ex	8
Break Bulk Area	9
Port Newark Container Terminal Intermodal Rail Area	10
East Coast Warehouse	11
Meridian Street	12

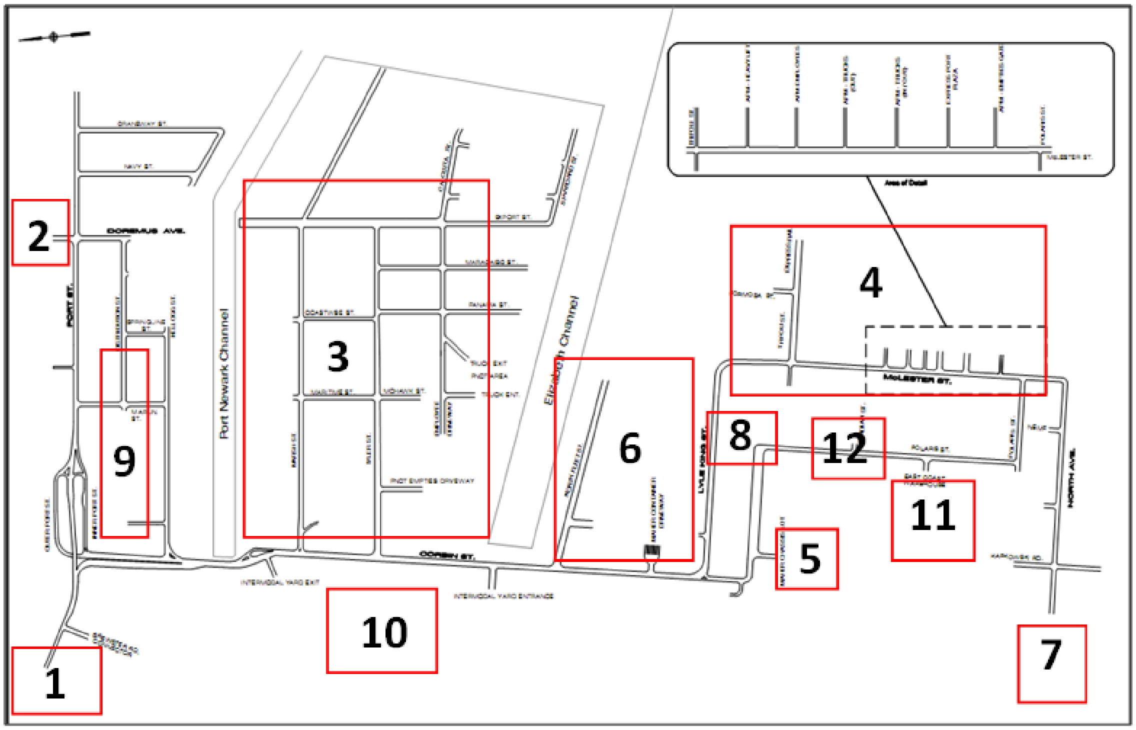


Figure 3-24: Defined Traffic Generation Zones in Port Newark/Elizabeth

3.5.4 Visum and the TFlowFuzzy Model

Once the traffic generation zones were defined, the origin-destination matrix calibration process could begin. Multiple attempts at deriving an OD matrix by hand using data from the traffic report failed. The data used included entering and exiting volumes, production and attractions volumes, percent breakdowns for access roads, and percent breakdowns by vehicle type entering at each access road. Even with this amount of data it was not possible to derive an accurate origin-destination matrix by hand. Each attempt at using these matrices as the travel demand in Vissim's Dynamic Assignment model was unsuccessful. During the simulations the network would become unrealistically congested and delay and travel times would exponentially increase throughout the day after the first peak period of the simulation. Numerous variables were tweaked to determine if something was wrong with the actual network and not the OD matrix, however none of the changes resulted in a more realistic simulation. In order to continue with the calibration another method to derive an origin-destination matrix was needed.

The Synchro file of the network provided by the Port Authority of New York and New Jersey was imported into PTV America's Visum and included the actual layout of the roads, accurate signals and timings and embedded count data for the three peak periods of the day (7-8AM, 12-1PM, and 3-4PM). Once imported into Visum some small manipulations were made in order to run the TFlowFuzzy Matrix correction model. First zones and centroid connectors had to be created for the 12 defined zones. Then the embedded turn counts, link volumes and productions and attractions data from Synchro were all linked to the matrix correction model within Visum.

As described previously, the TFlowFuzzy model updates an existing matrix based on turn counts, link volumes, and productions and attractions from the defined zones. In this case, all three of these data sets were taken from the Port Authority of New York and New Jersey 2006 Traffic Study. Since there was no existing origin-destination matrix available for the Port Newark/Elizabeth roadside network a dummy matrix had to be created for all three peak hours. The dummy matrix consisted of twelve rows and twelve columns (12 by 12), one for each of the 12 defined traffic generating zones. Values greater than zero were input into all matrix cells besides those cells representing internal zone trips. This was necessary because a non-zero number indicates to the model that that specific matrix cell needs to be updated. After the dummy matrix was created, it was input into the Visum network as the travel demand file for the corresponding peak hour. Since the Synchro file from PANYNJ contained separate data for each peak hour, the TFlowFuzzy Model was run three times using the separate data, creating three base origin-destination matrices, the 7-8AM base matrix, the 12-1PM base matrix, and the 3-4PM base matrix. The non-peak hour matrices were not derived using the TFlowFuzzy matrix since there was no available turn data for these hours. The procedure used to derive the non-peak hour ODs is described later in this chapter.

The next step in the origin-destination matrix calibration was to define tolerance limits for the variables (turn counts, link volumes, and productions and attractions). In other words, the number of vehicles plus or minus the number in the defined data set multiplied by a tolerance factor. The tolerance of the turn counts was defined as the number of actual vehicles from the data plus or minus 10 percent of the same number of vehicles. The tolerance of the link volumes was defined as the actual number of vehicles from the data plus or minus 10 percent of the same number of vehicles. And the tolerance on the productions and attractions was the number of actual productions/attractions from the data plus or minus 30 vehicles. The following tolerances were used for the TFlowFuzzy Model for all three peak periods:

Tolerance (Turn Count) = Turn Count ± 0.1*Turn Count

Tolerance (Link Volume) = Link Volume ± 0.1*Link Volume

Tolerance (Productions) = Productions ± 30 vehicles

Tolerance (Attractions) = Attractions ± 30 vehicles

After completing all of the preparation steps, the TFlowFuzzy Model can be implemented. The model first runs a static assignment using the dummy matrix in order to place vehicles on the network, basically creating a dummy assignment. The defined tolerances for turn counts, link volumes, and productions and attractions are then turned on and the model runs through an iterative process of multiple static assignments until the variables are all within the defined tolerances. Regression analysis can then validate the origin-destination matrix that was produced from the last static assignment in the iteration.

Figure 3-25 through Figure 3-33 show charts with the regression analysis applied for all three variables during all three time periods. In these charts the data from the Port Authority 2006 Traffic Study were compared with the variable values output from the TFlowFuzzy Model in Visum. Table 3-4 shows a summary of regression equations and R^2 values for these figures. The R^2 values range between 0.9552 at the lowest for the PM Turn Count and 0.9988 at the highest for the AM Productions. Since the R^2 values only drop as low as 0.9552, the regression analysis indicates that the model output is very accurate compared with the data from the report. Therefore, the origin-destination matrices produced from the TFlowFuzzy matrix that correspond to the regression attributes in were output from Visum to be used as the base origin-destination matrices for the Vissim micro-simulation process. The 7-8AM, 12-1PM, and 3-4PM matrices that were produced from the TFlowFuzzy Model in Visum are attached in the Appendix.

Table 3-4: Regression Analysis: Productions/Attractions, Link Volumes, Turn Counts

Figure	Variable	Time Period	Regression Equation	R^2 Value
Figure 3-25	Productions	7AM-8AM	$y = 1.0099x - 3.3486$	0.9988
	Attractions	7AM-8AM	$y = 0.9849x + 3.0861$	0.9985
Figure 3-26	Link Volume	7AM-8AM	$y = 1.0062x + 2.822$	0.9778
Figure 3-27	Turn Counts	7AM-8AM	$y = 0.9826 - 0.6962$	0.9813
Figure 3-28	Productions	12PM-1PM	$y = 1.0023x + 4.5756$	0.9962
	Attractions	12PM-1PM	$y = 0.9897x + 2.0055$	0.9938
Figure 3-29	Link Volume	12PM-1PM	$y = 0.9688 + 2.504$	0.9476
Figure 3-30	Turn Count	12PM-1PM	$y = 0.9757x + 0.9409$	0.9815
Figure 3-31	Productions	3PM-4PM	$y = 1x + 11.182$	0.9985
	Attractions	3PM-4PM	$y = 0.9848 - 21.388$	0.9992
Figure 3-32	Link Volume	3PM-4PM	$y = 0.9678 + 1.556$	0.9678
Figure 3-33	Turn Count	3PM-4PM	$y = 0.9132 + 16.826$	0.9552

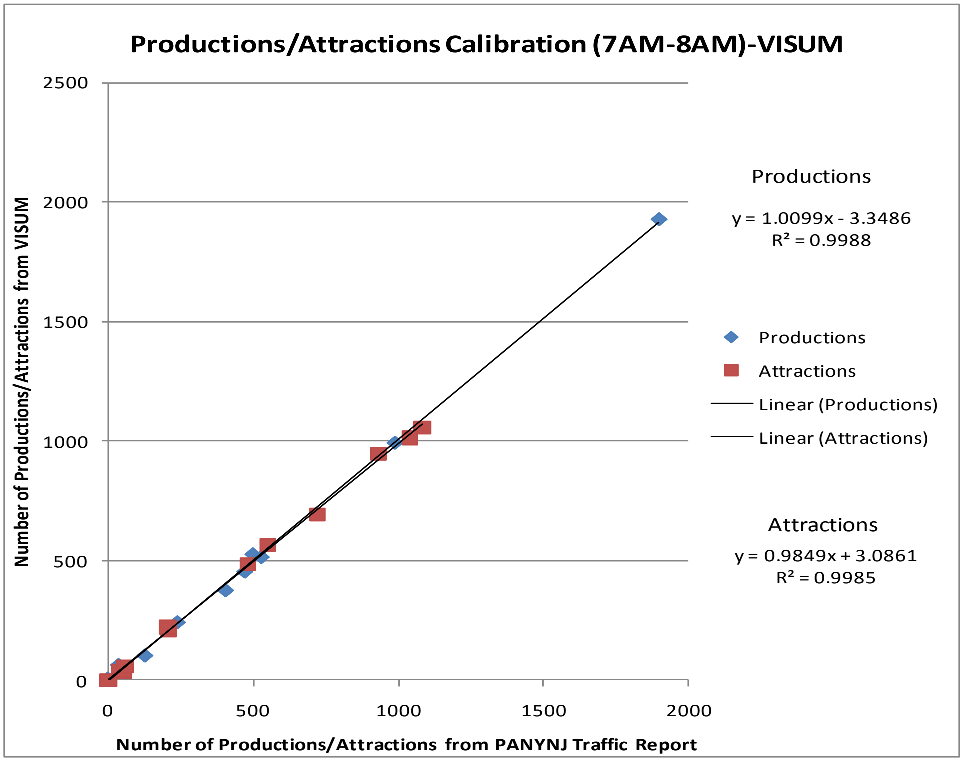


Figure 3-25: Calibration of Productions/Attractions in Visum (7-8AM)

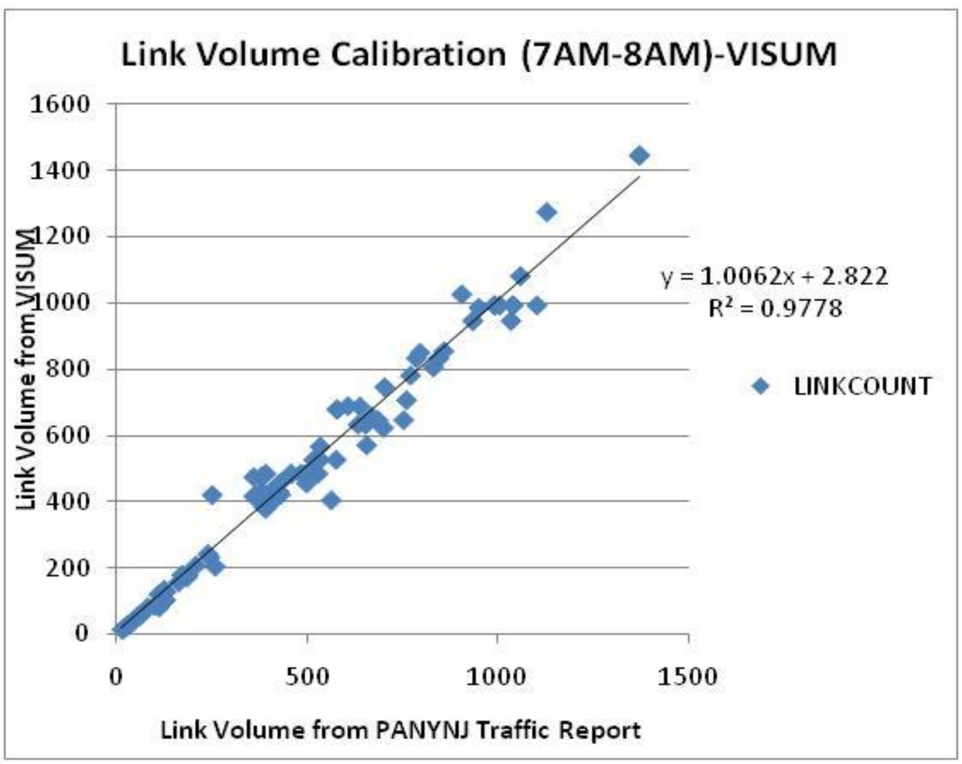


Figure 3-26: Calibration of Link Volumes in Visum (7-8AM)

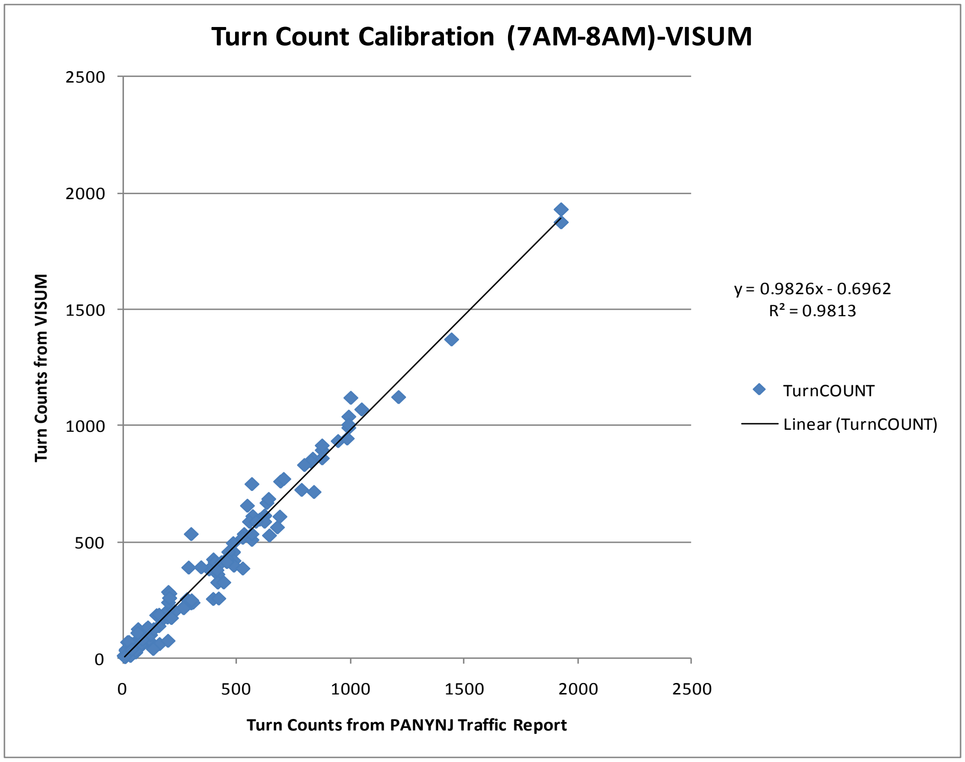


Figure 3-27: Calibration of Turn Counts in Visum (7-8AM)

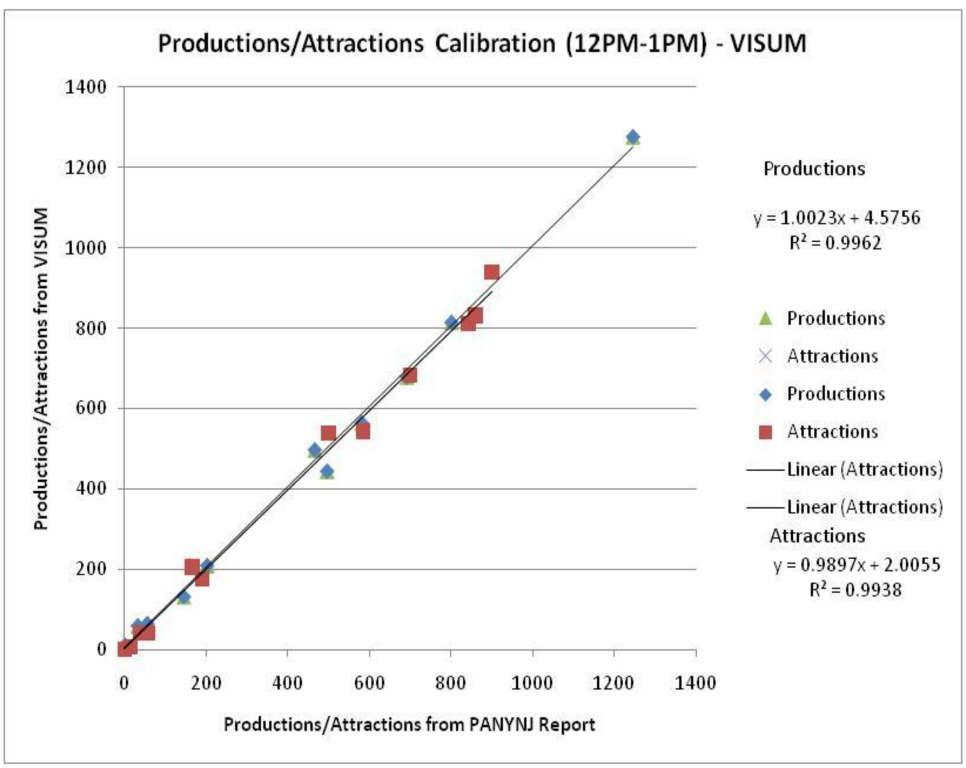


Figure 3-28: Calibration of Productions/Attractions in Visum (12-1PM)

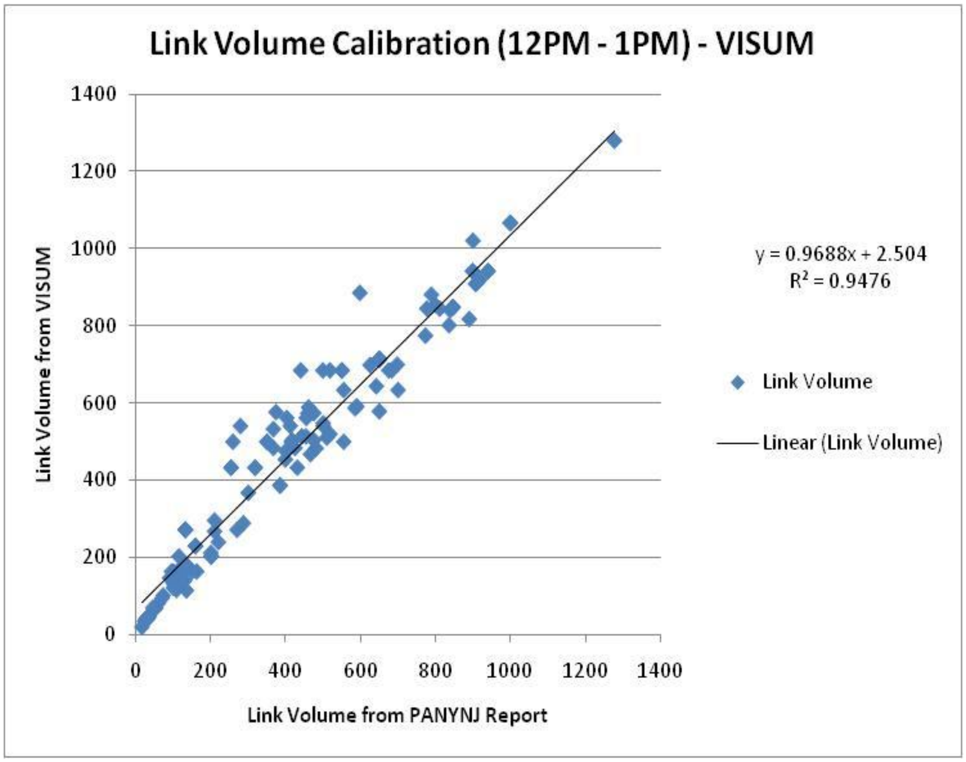


Figure 3-29: Calibration of Link Volumes in Visum (12-1PM)

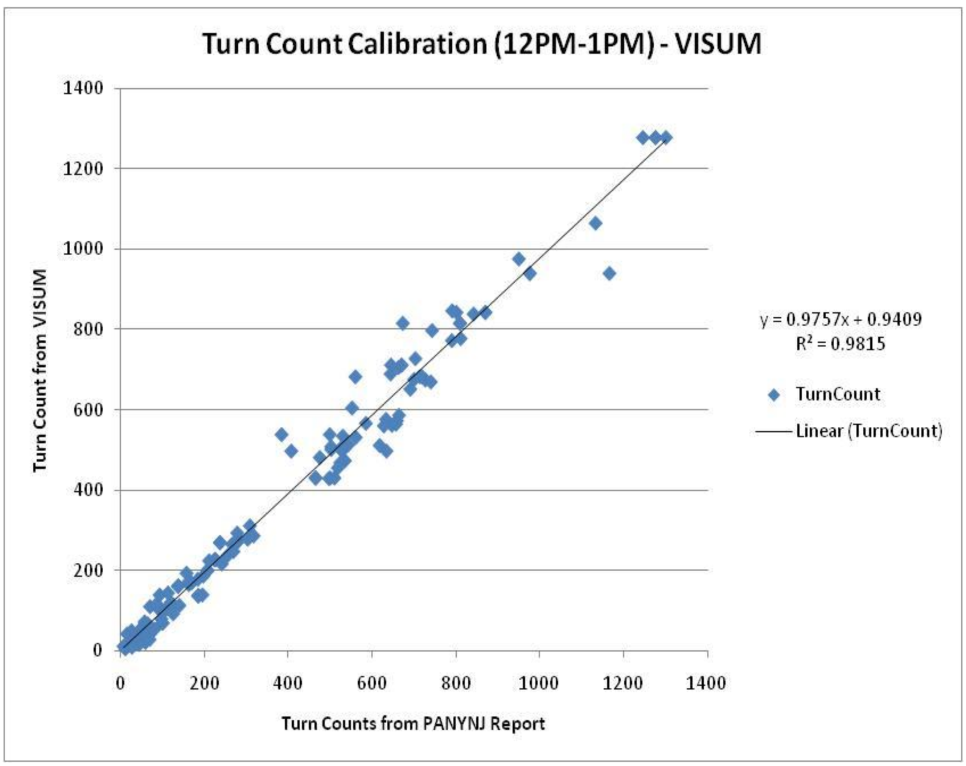


Figure 3-30: Calibration of Turn Counts in Visum (12-1PM)

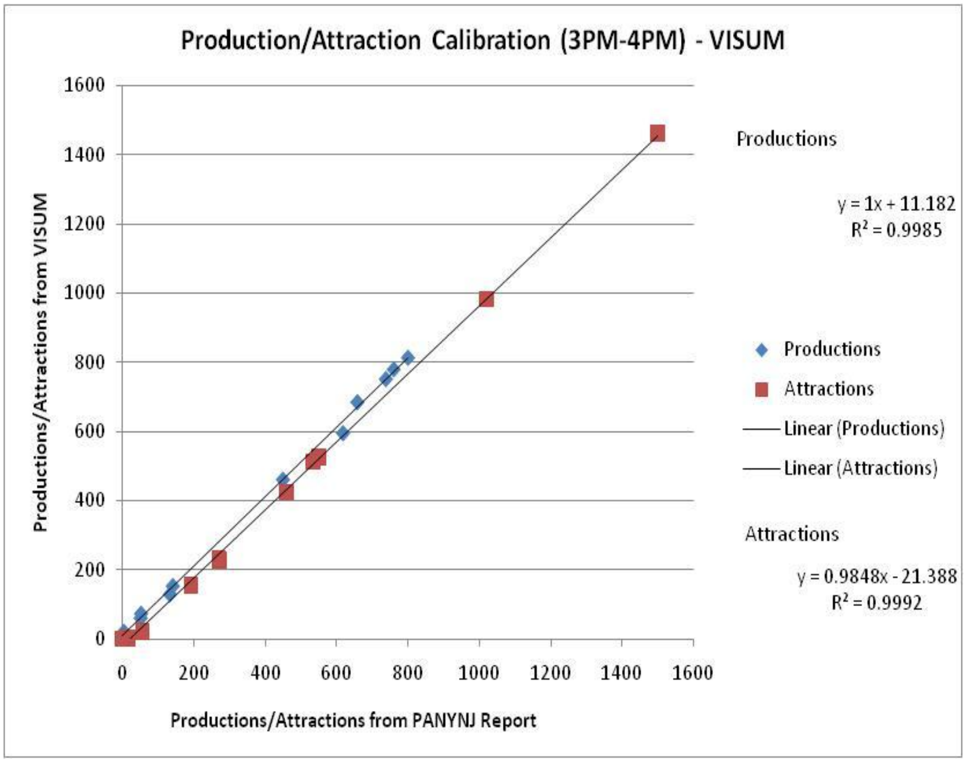


Figure 3-31: Calibration of Productions/Attractions in Visum (3-4PM)

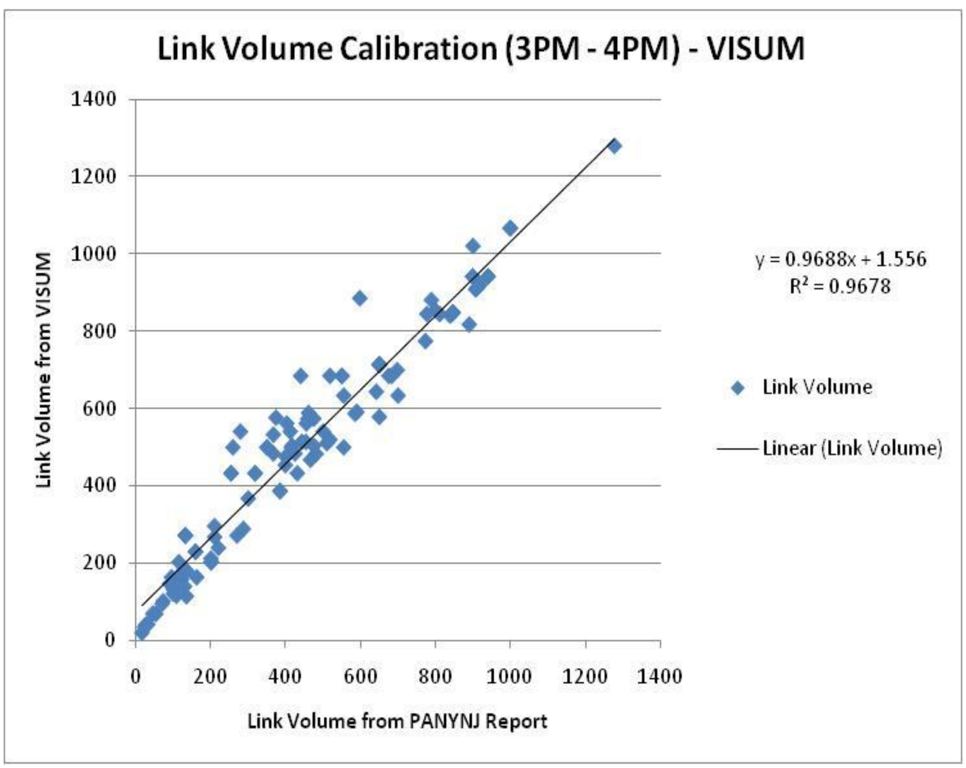


Figure 3-32: Calibration of Link Volumes in Visum (3-4PM)

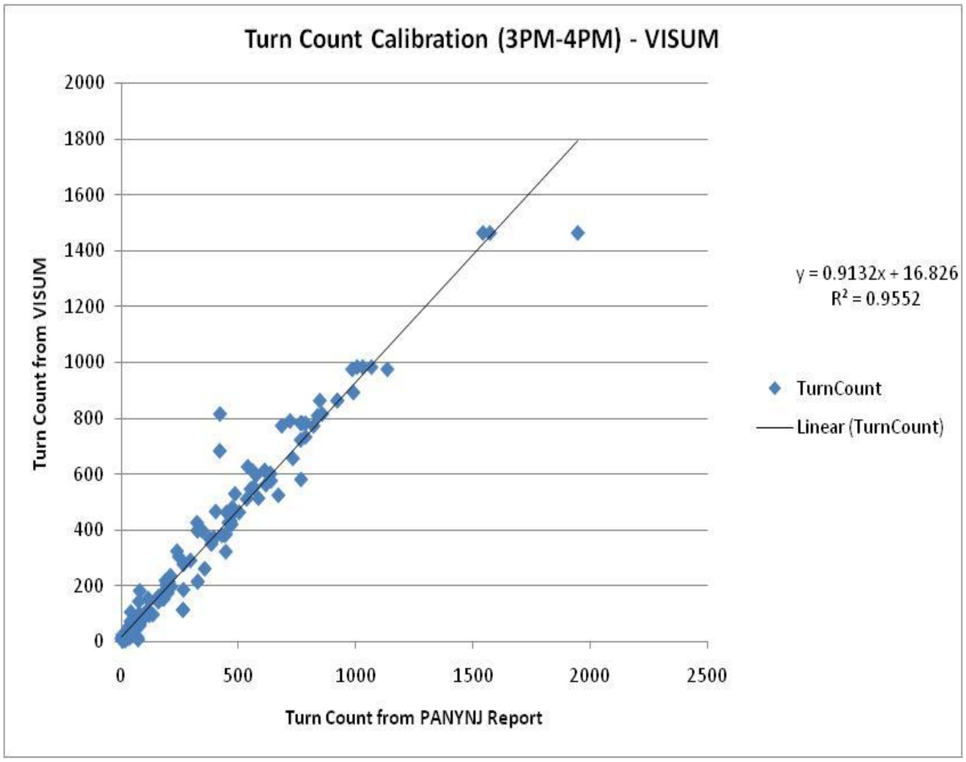


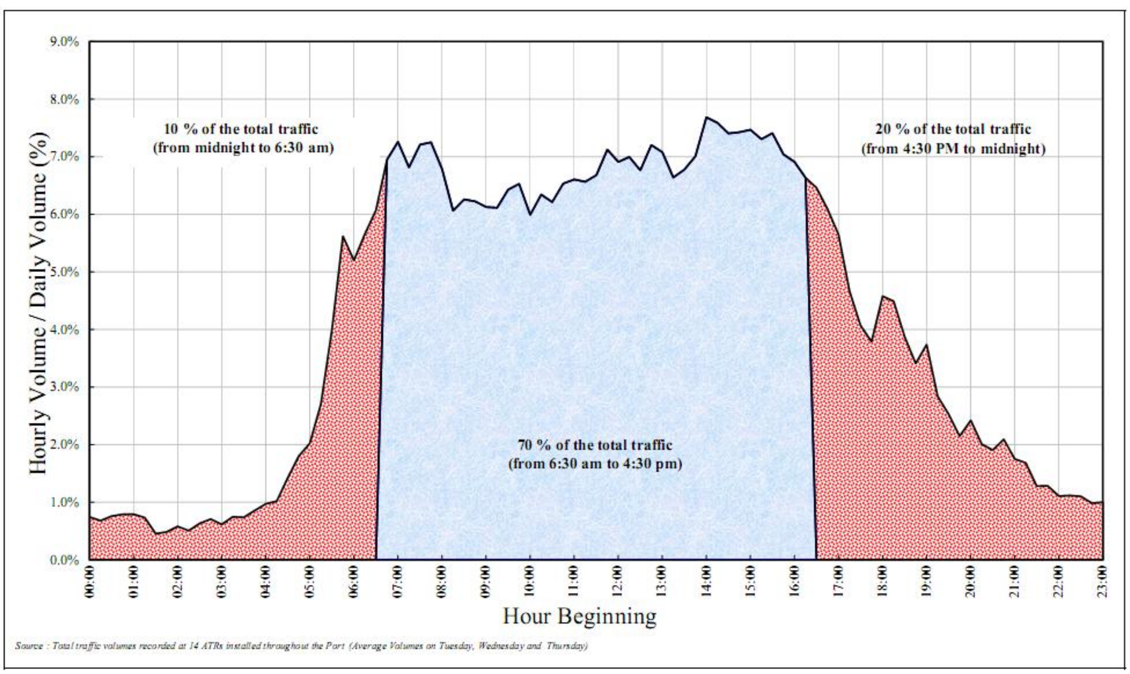
Figure 3-33: Calibration of Turn Counts in Visum (3-4PM)

3.5.5 Calibration of the Vissim Microsimulation Model

For all scenarios, the Vissim Dynamic Assignment Module was used to run 24-hour simulations with the derived travel demands and traffic compositions. The traffic demand patterns and traffic compositions are described in the next chapter for each scenario. The results produced for each scenario are average truck travel time to and from the terminals and access roads, delay per truck, and overall truck delay. This chapter details the model validation process by comparing the output from Visum and Vissim to the PANYNJ report.

As stated before, it was necessary to use origin-destination matrices as the travel demand input when running Vissim's Dynamic Assignment module. For that reason, Visum was used to derive origin-destination matrices for the peak periods instead of running a static assignment in Vissim with the count data from the Port Authority.

However, since a 24-hour simulation produces a more detailed and accurate assessment of the model, origin-destination matrices were needed for all 24 hours of the simulation. The 21 non-peak hour origin-destination matrices had to be derived based on the three peak hour OD matrices that were produced using Visum's TFlowFuzzy Model along with data from the Port Authority report. The report showed the hourly traffic distribution on the Port roadside network by hour of the day along with a breakdown of percentage of cars and trucks. Figure 3-34 shows the hourly traffic distribution on the network throughout a typical weekday and Figure 3-35 shows the auto and truck demand profiles for the 2006 base case based on the data provided by the PANYNJ traffic study. Table 3-5 shows the breakdown of autos and trucks on the network throughout the day. Using this data along with the peak hour origin-destination matrices from Visum, the non-peak OD matrices and the traffic compositions for each matrix were derived.



Source: (The Port Authority of New York and New Jersey, 2007)

Figure 3-34: Hourly Traffic Volume on Port Network

Table 3-5: Breakdown of Vehicles (Cars vs. Trucks) 2006

Hour	Total Veh	% Total	Truck Total	Auto Total	% Truck	% Car
0	600	0.87%	0	600	0%	100%
1	550	0.80%	0	550	0%	100%
2	550	0.80%	0	550	0%	100%
3	650	0.95%	0	650	0%	100%
4	1200	1.75%	0	1200	0%	100%
5	3000	4.37%	0	3000	0%	100%
6	4550	6.62%	1593	2957	35%	65%
7	5200	7.57%	2120	3080	41%	59%
8	4500	6.55%	2344	2156	52%	48%
9	4400	6.40%	2456	1944	56%	44%
10	4300	6.26%	2568	1732	60%	40%
11	4500	6.55%	2680	1820	60%	40%
12	4900	7.13%	2790	2110	57%	43%
13	4600	6.70%	2620	1980	57%	43%
14	4800	6.99%	2450	2350	51%	49%
15	4800	6.99%	2280	2520	48%	53%
16	4400	6.40%	2280	2120	52%	48%
17	3000	4.37%	836	2164	28%	72%
18	2450	3.57%	0	2450	0%	100%
19	1800	2.62%	0	1800	0%	100%
20	1350	1.97%	0	1350	0%	100%
21	1050	1.53%	0	1050	0%	100%
22	850	1.24%	0	850	0%	100%
23	700	1.02%	0	700	0%	100%

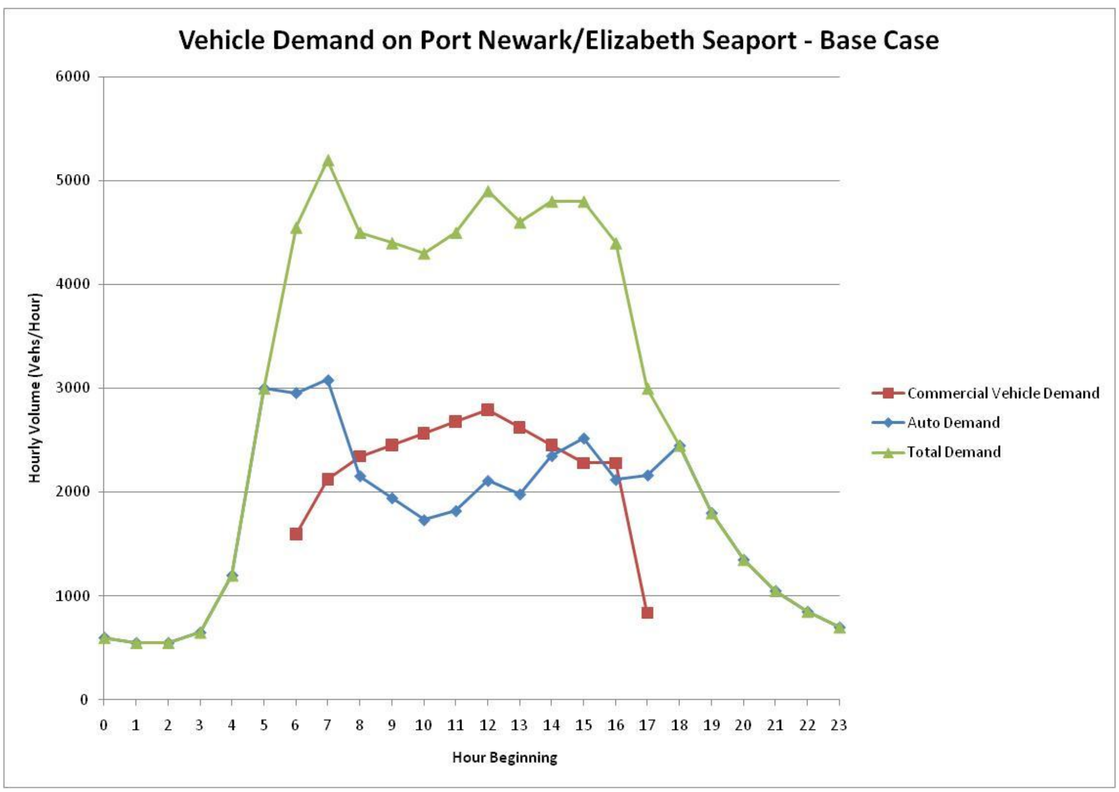


Figure 3-35: Network Vehicle Demand Base Case - 2006

3.5.5.1 Productions and Attractions Validation

Once the origin-destination matrices and the traffic compositions were calculated and input into the Vissim model, the base case simulation could be tested. The following figures show a comparison of the productions and attractions from Visum, Vissim and the PANYNJ report. These figures validate the transition of the data from the report into Visum and then into Vissim. For all 12 defined OD zones, the productions and attractions from the report, Visum, and Vissim are similar and no significant changes that would indicate inconsistencies in the transfer procedures are present. Figure 3-36, Figure 3-37, and Figure 3-38 show a comparison for the productions from the PANYNJ traffic report, Visum, and Vissim for the 7:00-8:00AM. 12:00-1:00PM, and 3:00-4:00PM peak periods. The zone numbers correspond to those defined earlier in this chapter. Zones 1 through 7 are the major traffic generators including the three major access roads (Port Street, Doremus Avenue, North Avenue), the three major terminals (APM, Maher, PNCT) and the Maher Chassis Depot. The figures show a smooth transition of the data from the report into Visum where the TFlowFuzzy model derived an OD matrix, and then into Vissim where the micro-simulation was run. Similarly Figure 3-39, Figure 3-40, Figure 3-41 show the calibration of attractions for the 12 define zones. These figures also show a smooth transition of the data from the PANYNJ report into Visum and then into Vissim. The calibration of productions and attractions for the base case scenario validates the travel demand generated by each major travel zone.

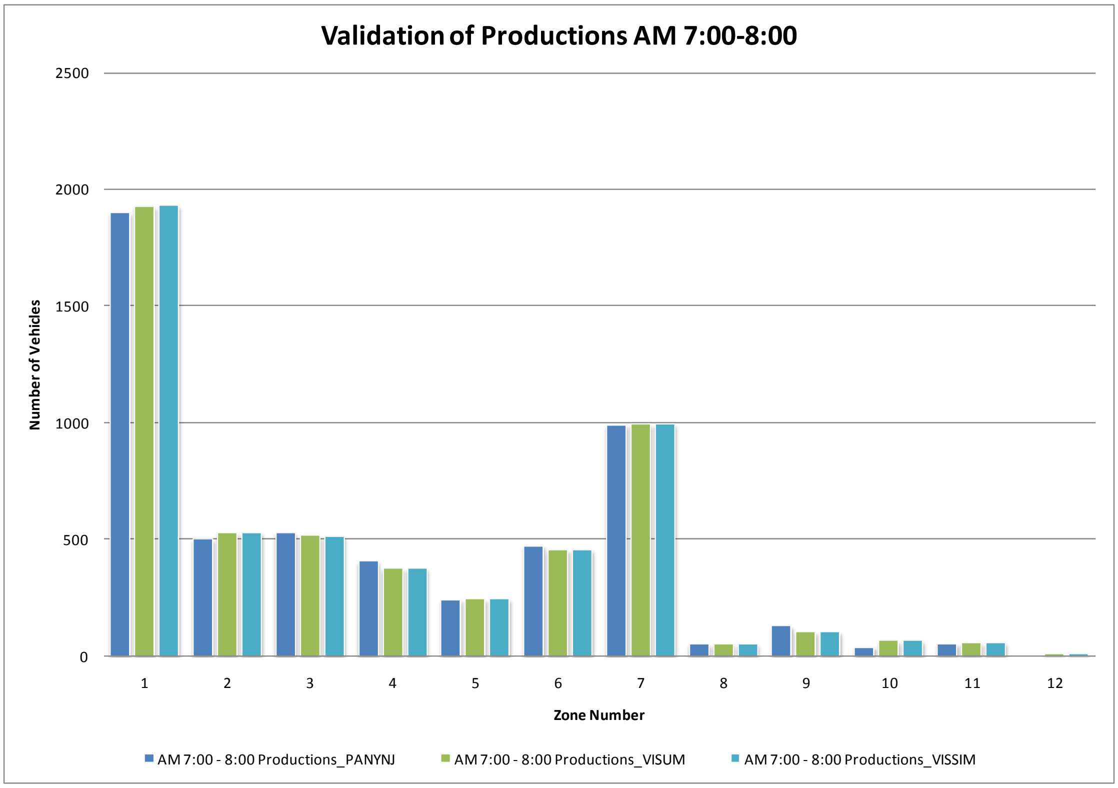


Figure 3-36: Validation of Productions (7-8AM)

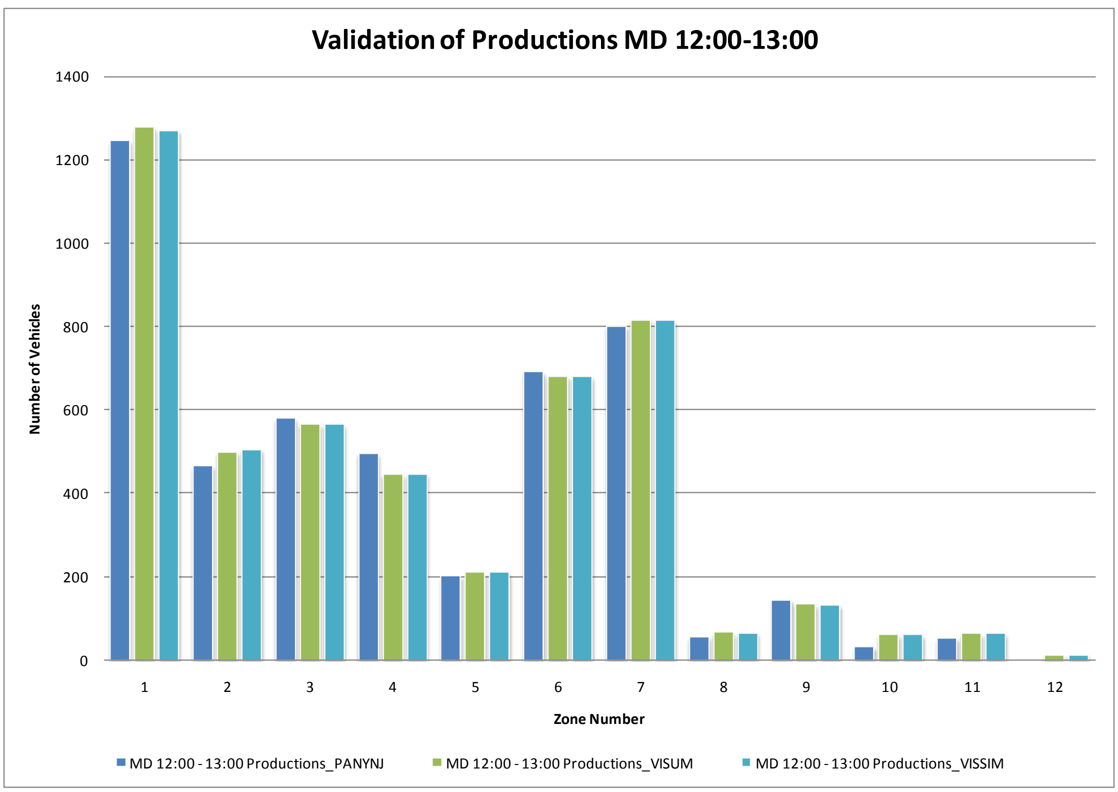


Figure 3-37: Validation of Productions (12-1PM)

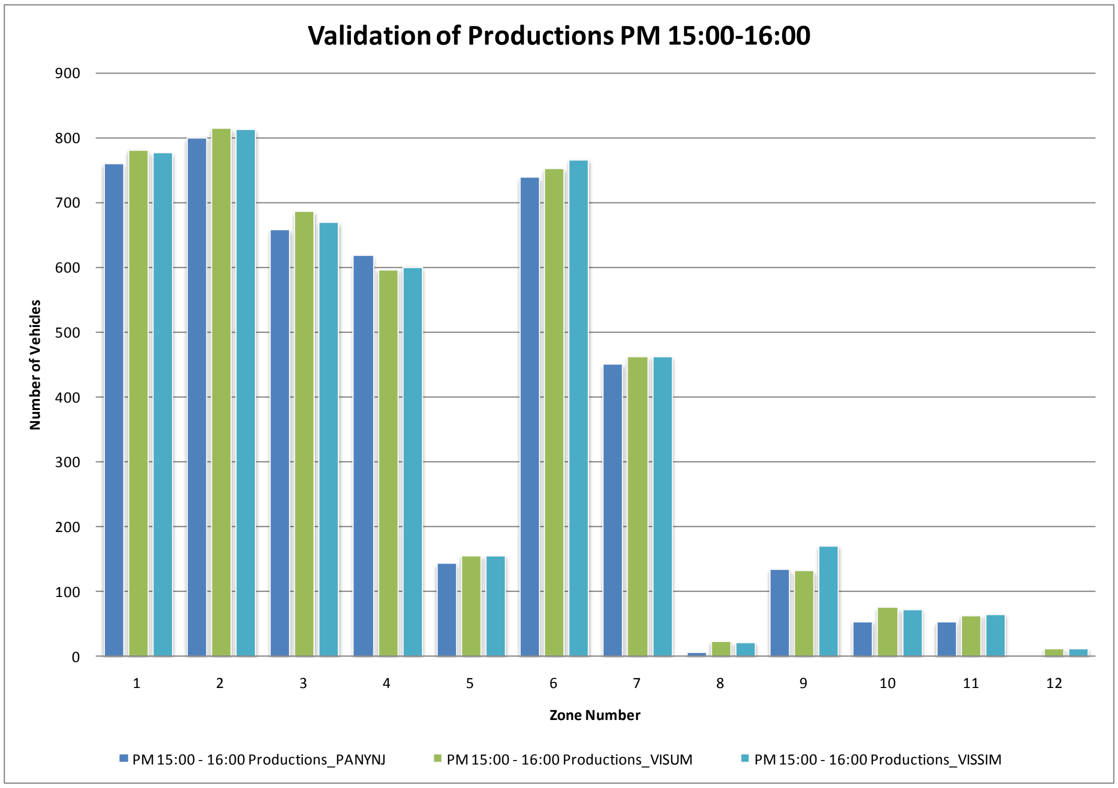


Figure 3-38: Validation of Productions (3-4PM)

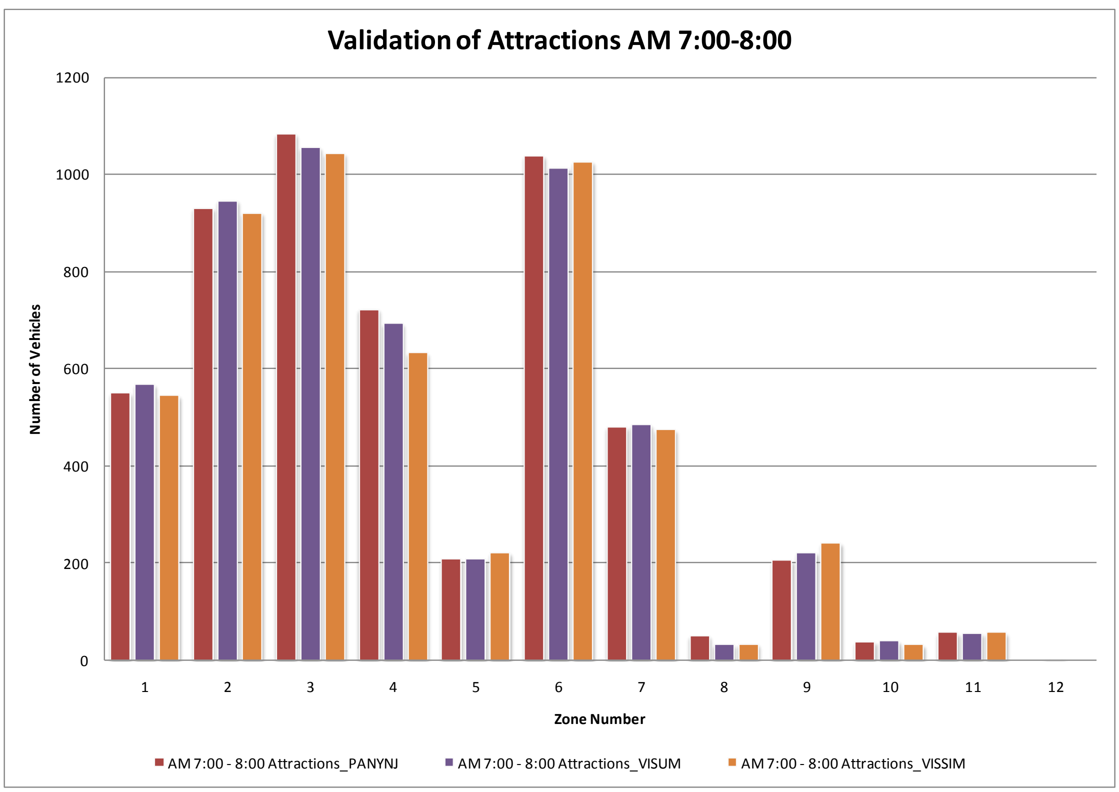


Figure 3-39: Validation of Attractions (7-8AM)

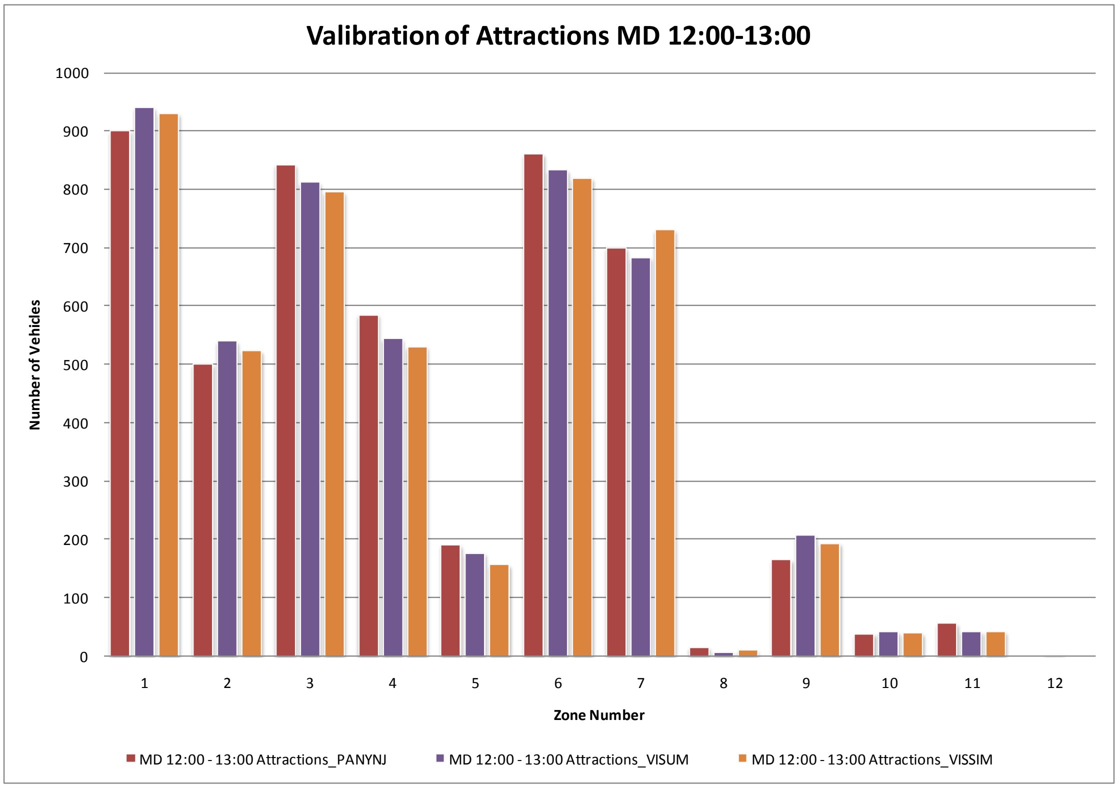


Figure 3-40: Validation of Attractions (12-1PM)

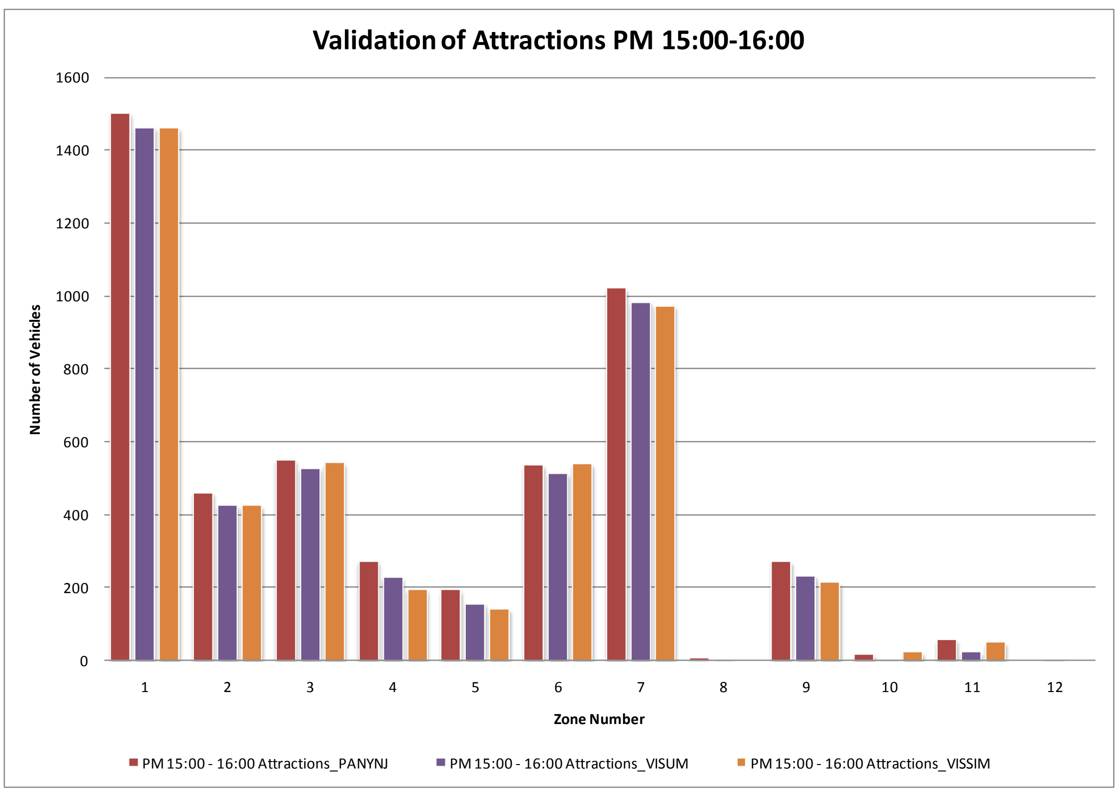


Figure 3-41: Validation of Attractions (3-4PM)

3.5.5.2 Travel Time Validation

Travel times to and from the three access roads and the three major terminals were also compared to validate the base case simulation. Time checks were performed at the Port Newark/Elizabeth Marine Terminals during the data collection process. Times were reported on three separate typical weekdays. The first time check was on a Tuesday (7/7/2009), the second time check was one week later on a Wednesday (7/15/2009), and the third time check was another week later on a Thursday (7/23/2009). The test vehicle followed a truck on each pass to ensure a realistic truck travel speed. Recorded times measured for specific paths from each week were averaged together. The following truck travel paths were recorded each week.

- Doremus Avenue to APM / APM to Doremus Avenue
- Doremus Avenue to Maher / Maher to Doremus Avenue
- Doremus Avenue to PNCT / PNCT to Doremus Avenue
- North Avenue to APM / APM to North Avenue
- North Avenue to Maher / Maher to North Avenue
- North Avenue to PNCT / PNCT to North Avenue
- Port Street to APM / APM to Port Street
- Port Street to Maher / Maher to Port Street
- Port Street to PNCT / PNCT to Port Street

Table 3-6 shows the measured travel times that were recorded at the Port. Travel time measurement sections were created in Vissim corresponding to the listed travel paths above in order to compare actual truck travel times and simulated truck travel times.

Table 3-6: Measured Truck Travel Times

Average Measured Truck Travel Times (Minutes)				
Route Index	Hour	7:00-8:00	12:00-13:00	15:00-16:00
	From North Ave			
1	to APM Truck Gate	1.75	2.00	2.00
2	to Maher Truck Gate	4.25	4.50	5.00
3	to PNCT (between Marsh St and Tyler St)	7.00	7.25	7.25
	From Port St			
4	to APM Truck Gate	8.75	8.25	8.00
5	to Maher Truck Gate	5.00	4.50	4.50
6	to PNCT (between Marsh St and Tyler St)	2.75	2.50	2.50
	From Doremus Ave			
7	to APM Truck Gate	8.75	8.42	8.50
8	to Maher Truck Gate	6.50	5.50	5.17
9	to PNCT (between Marsh St and Tyler St)	4.25	3.75	3.50
	To North Ave			
10	from APM Truck Gate	2.00	2.10	2.30
11	from Maher Truck Gate	4.32	4.35	5.45
12	from PNCT (between Marsh St and Tyler St)	6.23	7.05	7.3
	To Port St			
13	from APM Truck Gate	9.1	9	7.89
14	from Maher Truck Gate	4.58	4.75	4.75
15	from PNCT (between Marsh St and Tyler St)	3	2.13	2.78
	To Doremus Ave			
16	from APM Truck Gate	3.93	8.75	9
17	from Maher Truck Gate	6.54	5.5	5.23
18	from PNCT (between Marsh St and Tyler St)	3.9	4.23	3.56

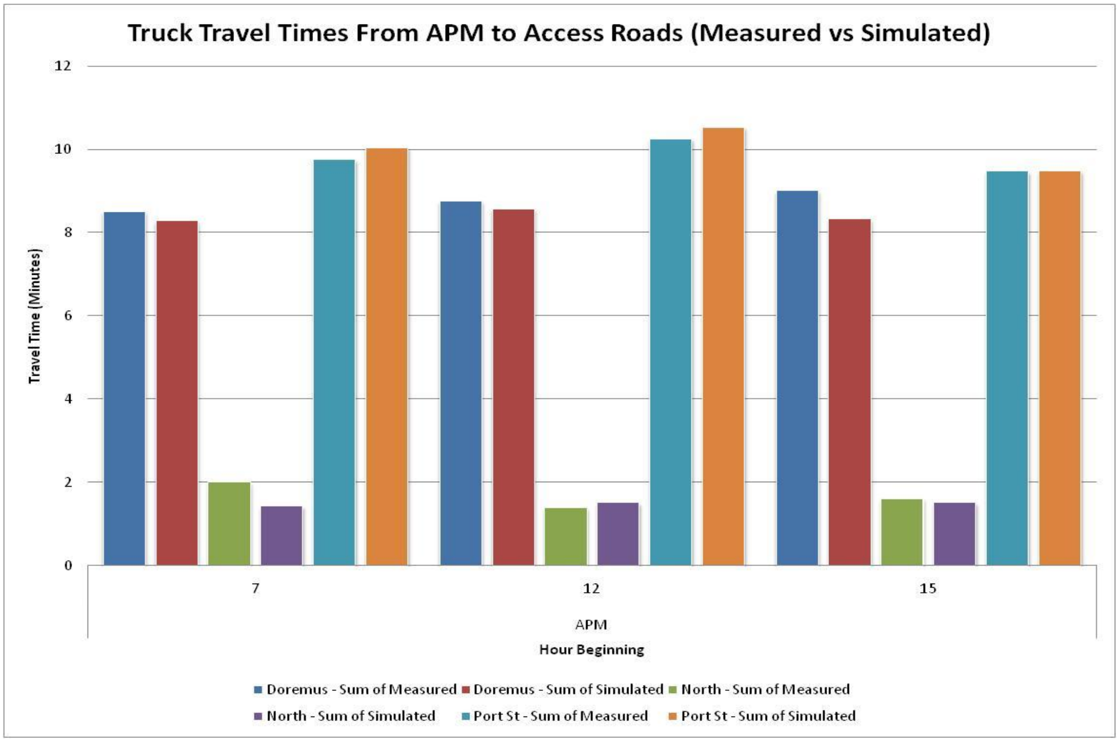


Figure 3-42: Truck Travel Times From APM to Access Roads (Measured vs. Simulated) Base Case-2006

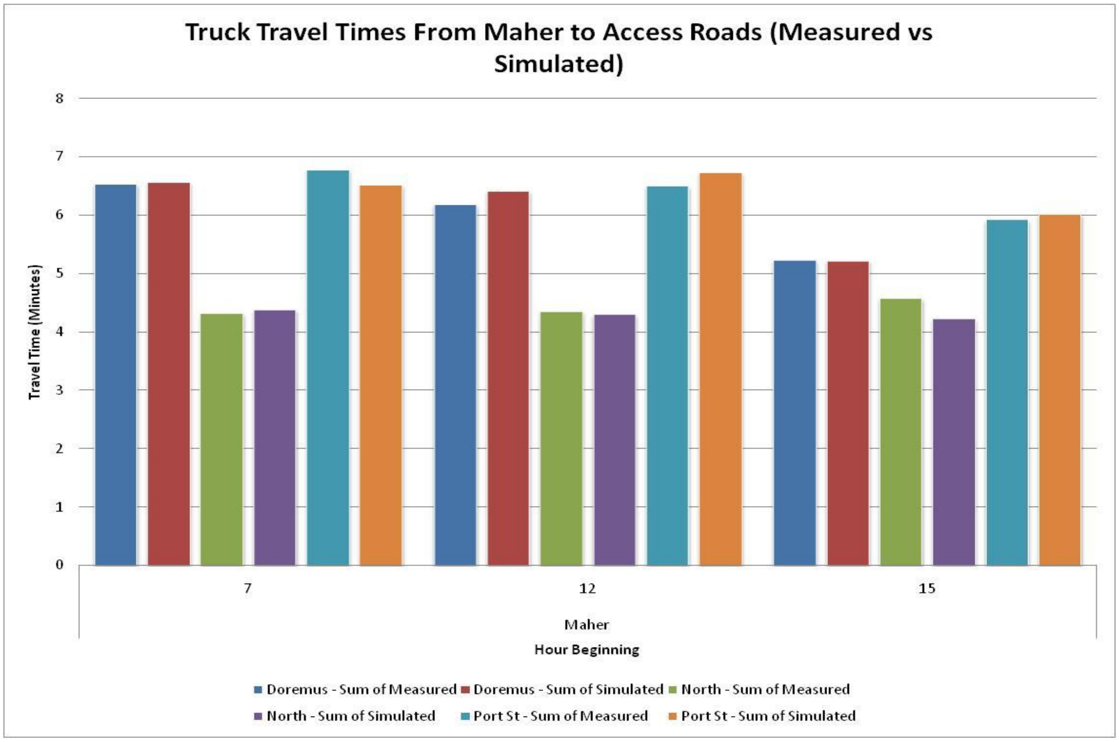


Figure 3-43: Truck Travel Times From Maher to Access Roads (Measured vs. Simulated) Base Case-2006

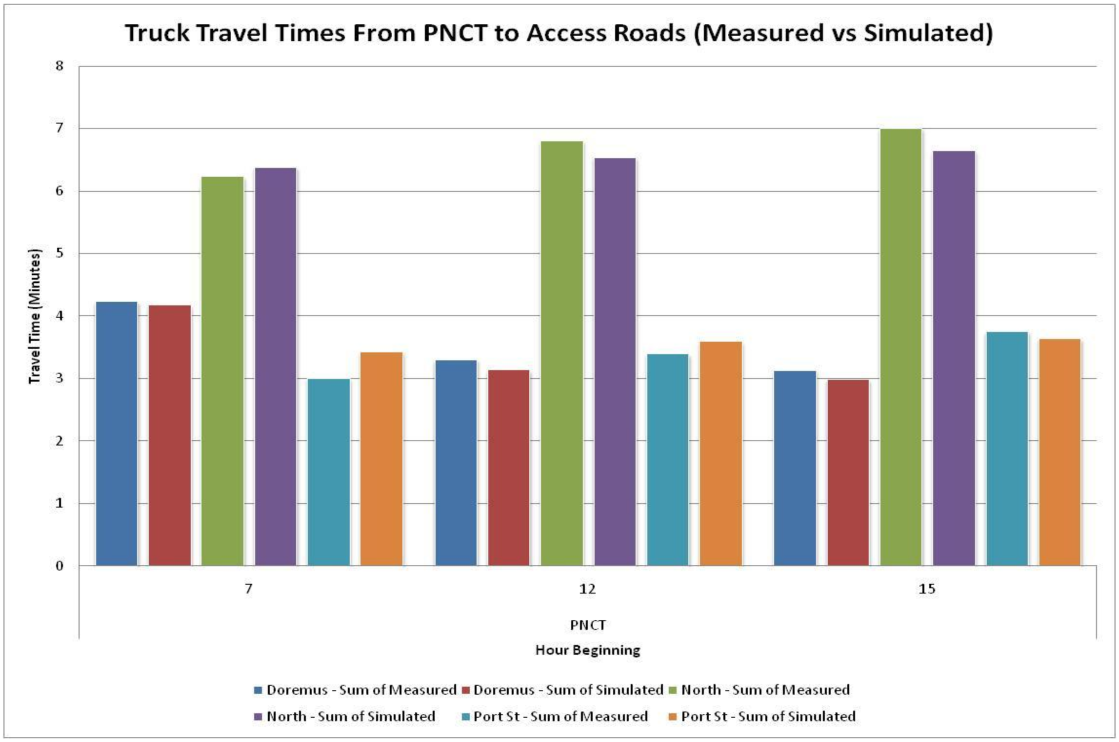


Figure 3-44: Truck Travel Times From PNCT to Access Roads (Measured vs. Simulated) Base Case-2006

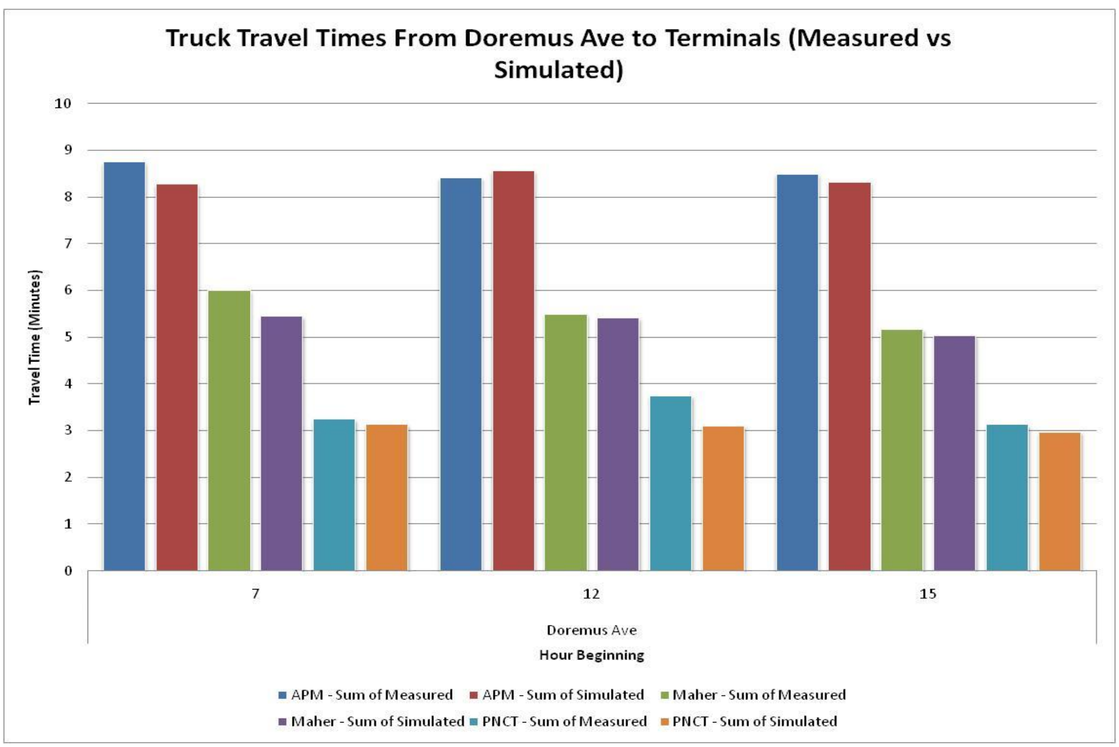


Figure 3-45: Truck Travel Times From Doremus to Terminals (Measured vs. Simulated) Base Case-2006

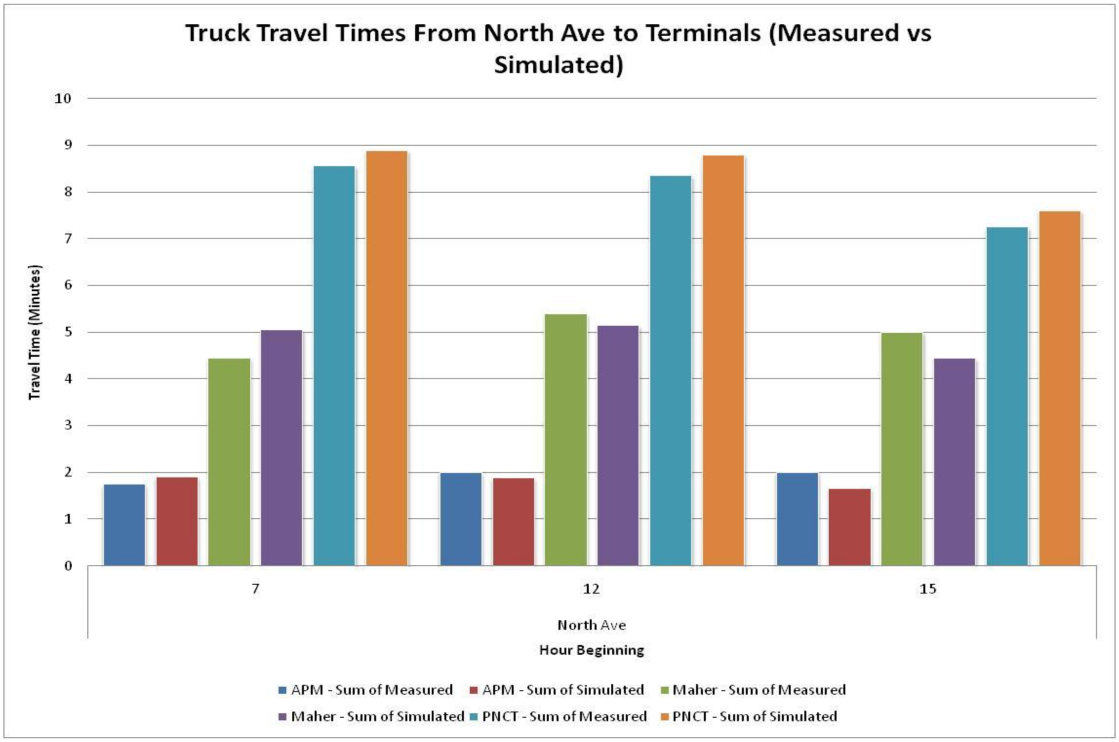


Figure 3-46: Truck Travel Times From North Ave to Terminals (Measured vs. Simulated) Base Case-2006

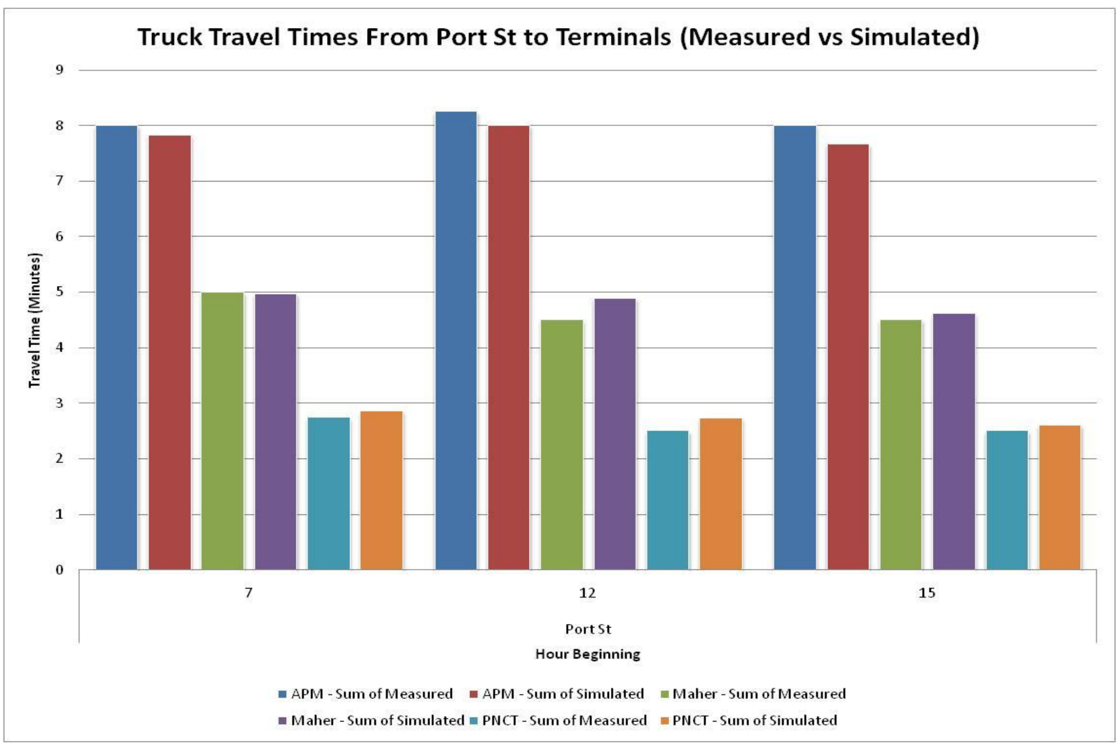


Figure 3-47: Truck Travel Times From Port St to Terminals (Measured vs. Simulated) Base Case-2006

CHAPTER 4 SCENARIOS AND RESULTS

The case study's sensitivity analysis will focus on two operational strategies: gate appointment systems and extended gate hours. These two gate strategies are the most commonly used methods to control the demand patterns of commercial vehicles. The first strategy is positively adopted by drayage operators as it guarantees quick turn-around time at the terminal. The latter strategy can only be successful if it is combined with different incentives to the drayage operators for using the gates at off peak (e.g. PierPass, reduced turn-around time). These strategies main objective is the reduction of the congestion at peak hour periods by evening out and controlling the demand at the gate side of the terminal while at the same time minimizing the stochasticity in the planning of the yard side operations (i.e. time and sequence of pick-up or delivery of containers arriving or leaving the terminal by truck). Both strategies are expected to reduce congestion and spread more evenly (within a 24-hour period) the production of air pollutant emissions from idling or slow moving trucks.

In order to incorporate these strategies into the Vissim DTA simulations, generalizations were made regarding the way gate appointment systems and extended gate hours would control the truck demand at the Port Newark/Elizabeth Marine Terminals. It is assumed that the most likely scenarios resulting from implementing either a gate appointment system, extended gate hours, or both at the Port are as follows:

1. Do-nothing case
2. WD 70: 30 percent of commercial demand is shifted to the morning and night shifts (12am-6am and 6pm-12am)

3. WD 80: 20 percent of commercial demand is shifted to the morning and night shifts (12am-6am and 6pm-12am)
4. WE 80: 20 percent of commercial demand is shifted to weekend hours
5. WE 90: 10 percent of commercial demand is shifted to weekend hours

These four scenarios were created in Vissim and compared against "Do-Nothing" scenarios for simulation years 2006, 2011, 2016, and 2021. This chapter of the thesis presents an extensive sensitivity analysis based on the results from each simulation performed in Vissim. Each section reviews all scenarios simulated and presents the total vehicle demand input, the commercial demand input, and the results including truck travel times and total truck delays.

Assumptions about the increase in truck and auto traffic were made based on the PANYNJ 2006 Traffic Study. For each year after 2006, it is assumed that auto traffic increases approximately 2 percent and truck traffic increases approximately 5 percent (The Port Authority of New York and New Jersey, 2007). These per year auto and truck increases are used for all future year scenarios that were simulated (2011, 2016 and 2021). Vissim's Dynamic Assignment Module, described in the previous chapter, was used to run all 24-hour simulations. The base case scenario was calibrated using the data from the PANYNJ 2006 Traffic Study.

4.1 2006 Scenarios

This section presents the results from the 2006 base year simulations. Scenarios simulated for 2006 include the base case or "Do-Nothing", WD_70, WD_80, WE_80, and WE_90. The 2006 base case is the calibrated simulation described in the previous chapter and results from this scenario are used as the baseline for this analysis.

4.1.1 Total Vehicle Demand

Figure 4-1 shows the total demand for the five different scenarios including “Do-Nothing”, WD_70, WD_80, WE_80, and WE_90 for the 2006 base year. The demand in this figure includes both commercial vehicles and private automobiles. The total vehicle demand for the “Do-Nothing” case correlates to the total demand given in the PANYNJ 2006 Traffic Study. In the morning period, total hourly volume peaks at 5,200 vehicles per hour. The midday peak volume for the base case is around 5,000 vehicles per hour and the afternoon peak volume is approximately 4,900 vehicles per hour. As the figure shows, for scenario WD_70, 30 percent of commercial vehicle traffic is moved from the time the terminal gates are open (6am-6pm) and shifted to the morning and night shifts on weekdays. Similarly WD _80 shifts 20 percent of commercial vehicle traffic from the period of 6am-6pm to the morning and night shifts. WE_80 and WE_90 shifted 20 percent and 10 percent of commercial traffic to weekend hours, respectively. The figure shows the hourly volumes in the morning, midday, and afternoon peaks decreasing for each respective scenario. These demand shifts can be obtained by implementing gate appointments and extended gate hours at the Port Newark/Elizabeth, reducing peak hour truck arrivals by shifting those arrivals to non-congested periods.

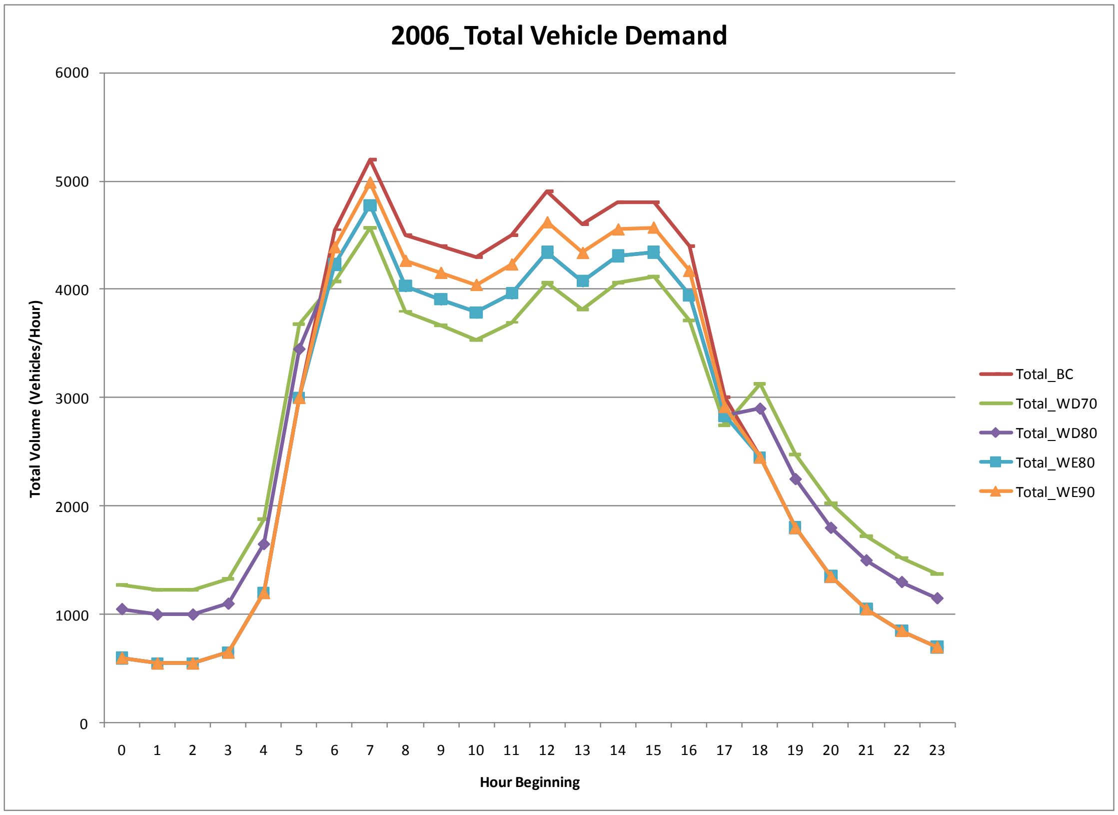


Figure 4-1: Total Vehicle Demand for all 2006 Scenarios

4.1.2 Commercial Vehicle Demand

Figure 4-2 more effectively shows the shifts in commercial vehicles for each 2006 scenario. Currently, terminal gates at the Port Newark/Elizabeth Marine Terminals are only open from 6am-6pm therefore the base case demand pattern shows truck volume beginning around 6am at around 1600 trucks/hours, eventually peaking during midday at approximately 2800 trucks/hour and slowly reducing towards the end of the work day. Similarly, the commercial vehicle demand pattern for WE_80 and WE_90 only span between 6am-6pm since the demand is shifted to weekend hours for these scenarios. The figure shows that for WD_70 and WD_80 the demand was shifted uniformly to the morning and night shifts for each respective scenario. Since the number of commercial vehicles that were shifted to the morning and night work shifts was not significant enough to affect the level of service on the port road network, it was assumed that these demands could be distributed uniformly rather than randomly as shown in the figure below.

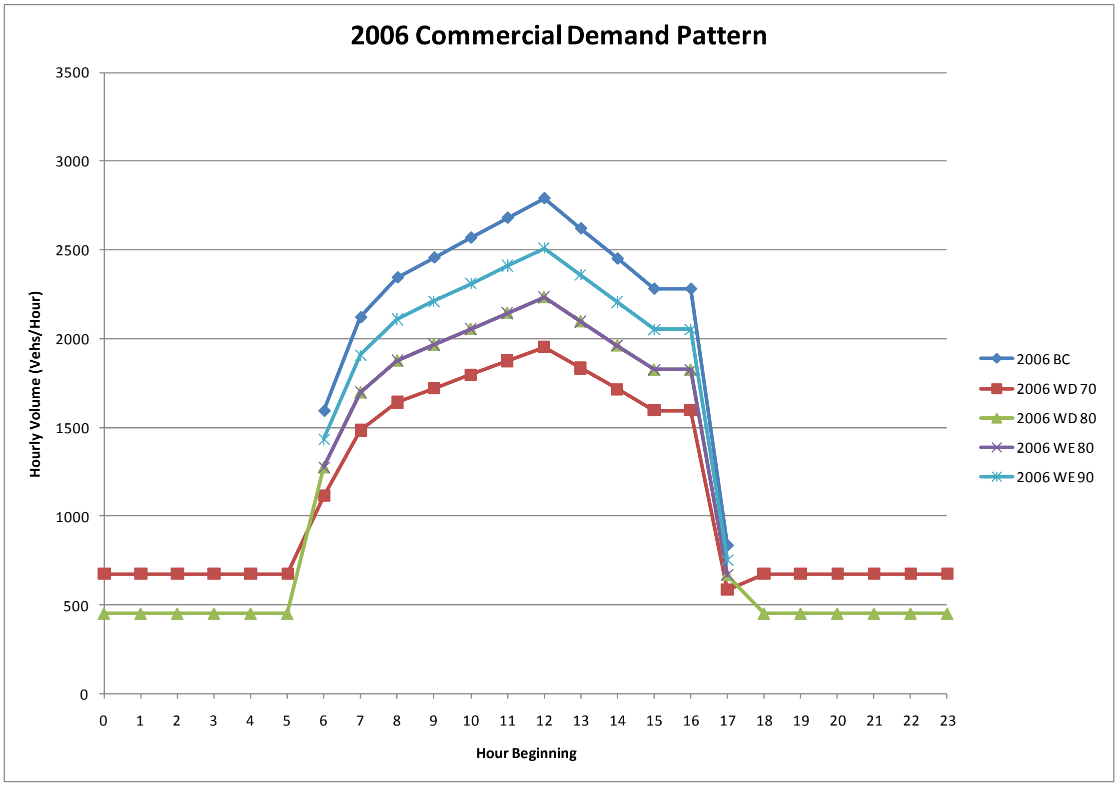


Figure 4-2: Total Commercial Vehicle Demand 2006 (All Scenarios)

4.1.3 Average Truck Travel Times

Figure 4-3 shows the average truck travel times output by VISSIM for each hour of the simulation and for all scenarios for the 2006 simulation year. Average truck travel times on the Port roadside network peak between 7AM and 8AM reaching approximately 7 minutes. Truck travel times average 6 minutes during the midday peak hour and slightly over 6 minutes in the PM peak hour. There is very little variance in average truck travel times when comparing all demand shifting scenarios. This indicates that the network level of service is sufficient in the 2006 base case simulation, and shifting demand to off peak hours does not have a significant impact on truck travel times for the simulation year 2006.

Although field observations[3] have shown that truck queues are present during peak hours at all three major terminal gates (APM, Maher, and PNCT), these queues are not large enough to impact the traffic on the roadside network. Field observations also confirm that there is very little delay throughout the day at the Port given the current conditions, confirming the insignificant changes in average travel times due to demand shifts on the network. However, the network is on the cusp of reaching capacity and an increase in truck queues at the gate has the potential to spill over onto the roadside network causing significant delays in future years if nothing is done to accommodate the increasing truck traffic.

[3] Field observations at the Port of Newark / Elizabeth were conducted on numerous occasions throughout 2009 and 2010.

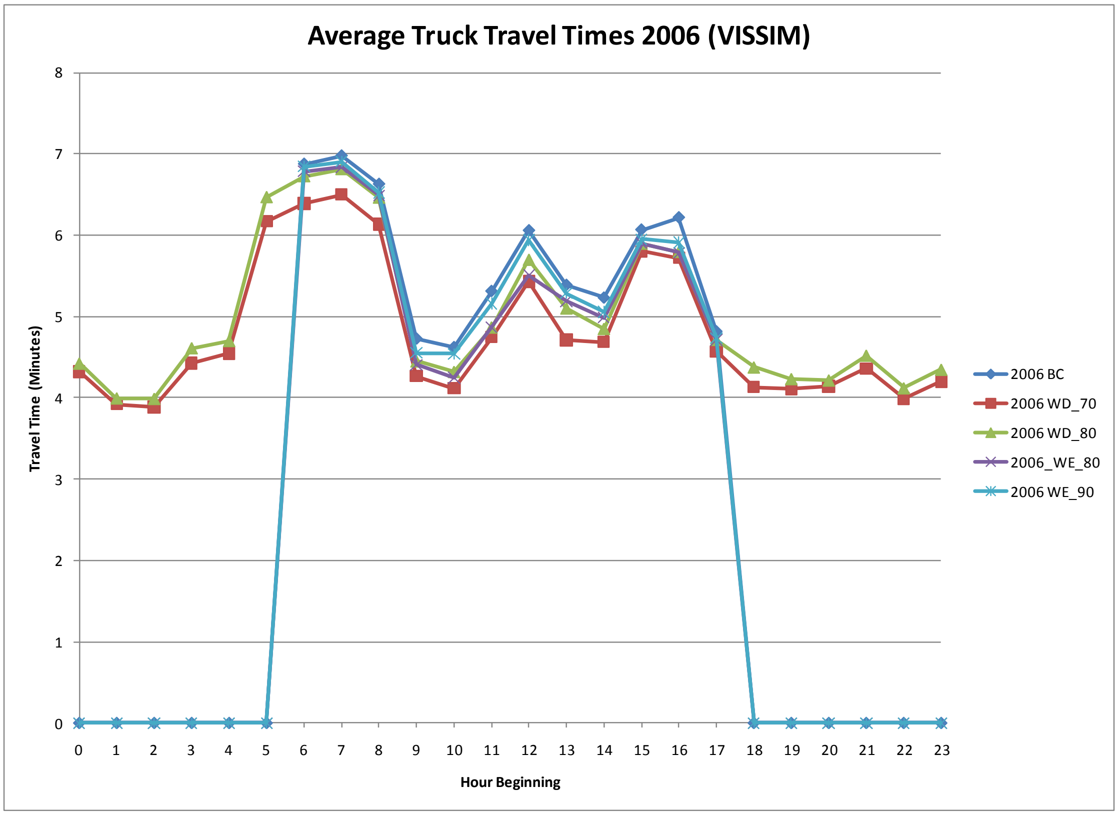


Figure 4-3: Average Truck Travel Times 2006 (All Scenarios)

4.1.4 Average Delay

Average delay is estimated by taking the difference of the average truck travel time and the free flow truck travel time for each hour of the simulation. This is travel delay and does not include delay at the terminal gates. Figure 4-4 shows the average delay per truck output by VISSIM for each hour of the simulation and for all scenarios for the 2006 simulation year. Although a difference for each scenario can be seen in the figure, the delay is not significant for the base case or any demand shifting scenario. This also correlates to the field observations mentioned in the previous section. There was minimal delay observed at the Port, with the majority of trucks traveling at the posted speed limit from the access roads to the container terminals. The figure does show a slight but insignificant decrease in delay per truck when demand is shifted to off-peak hours or weekends. As mentioned in the previous section, increasing queues at the terminal gates have the potential to spill over onto the roadside network, causing the level of service on to severely drop, in turn exponentially increasing truck delay on the network. As the demand increases for future year scenarios, more significant improvements from the demand shifts are seen.

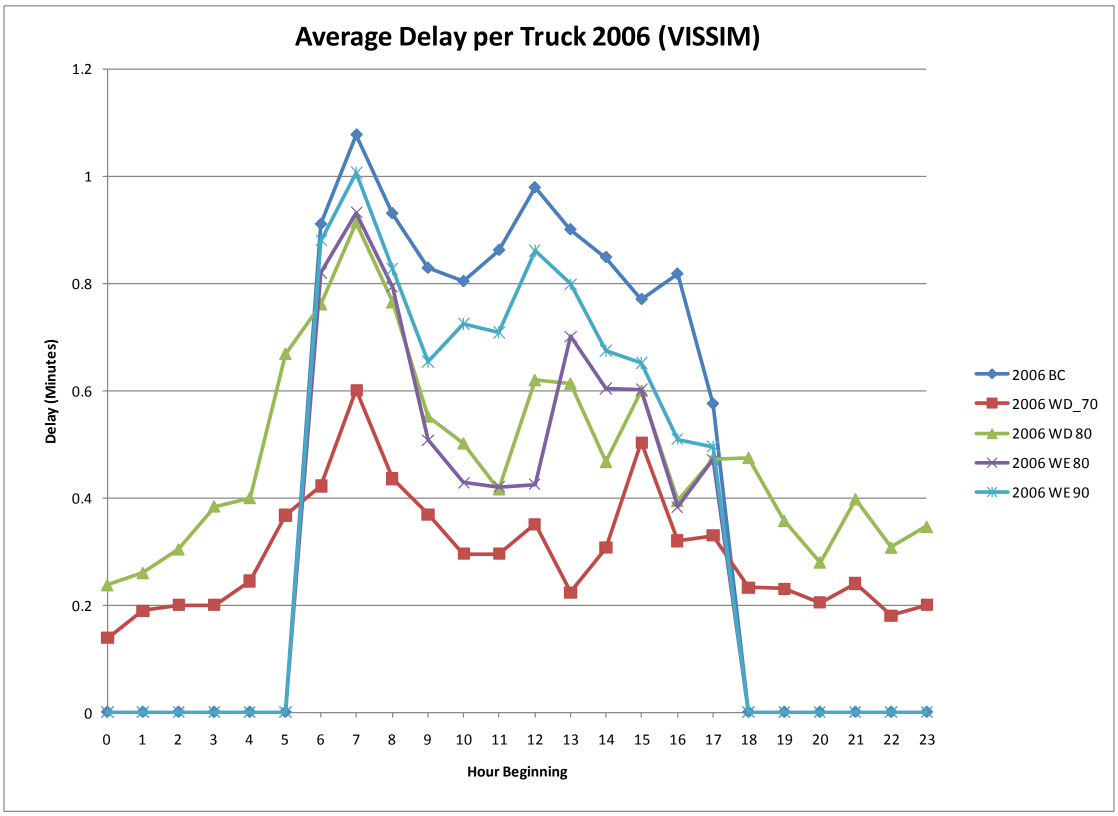


Figure 4-4: Average Delay per Truck 2006 (All Scenarios)

4.2 2011 Scenarios

This section presents the results from the 2011 simulations. Scenarios simulated for 2011 include the base case or "Do-Nothing", WD_70, WD_80, WE_80, and WE_90. A number of adjustments were made to the Vissim network in order for the simulations to output realistic results. This was the case since infrastructure improvements were completed on the Port roadside network between 2006, when the Synchro file containing the Port network was created, and presently in 2010. These improvements allowed higher volumes to enter and exit the port roadside network without significant impacts to the level of service and productivity at the Port. Therefore, the 2011 results presented in this section show only minor increases in average truck travel times and delay from the 2006 results. The updated Vissim network file used for the 2011 simulations was also used for the 2016 and 2021 simulations.

4.2.1 Total Vehicle Demand

Figure 4-5 shows the total demand for the five different scenarios including “Do-Nothing”, WD_70, WD_80, WE_80, and WE_90 for the 2011 base year. The demand in this figure includes both commercial vehicles and private automobiles. In the AM period, total hourly volume peaks at 6,000 vehicles per hour. The midday peak volume for the base case is around 5,800 vehicles per hour and the afternoon peak volume is approximately 5,600 vehicles per hour. As the figure shows, for scenario WD_70, 30 percent of commercial vehicle traffic is moved from the time the terminal gates are open (6am-6pm) and shifted to the morning and night shifts on weekdays. Similarly WD _80 shifts 20 percent of commercial vehicle traffic from the period of 6am-6pm to the morning and night shifts. WE_80 and WE_90 shifted 20 percent and 10 percent of commercial traffic to weekend hours, respectively. The figure shows the hourly volumes in the morning, midday, and afternoon peaks decreasing for each respective scenario. Also shown in the figure is the increase in vehicle demand from the previous 2006 base year demand profile. As previously stated, it was assumed that commercial truck demand increased at a rate of 5 percent per year and automobile traffic increased at a rate of 2 percent per year.

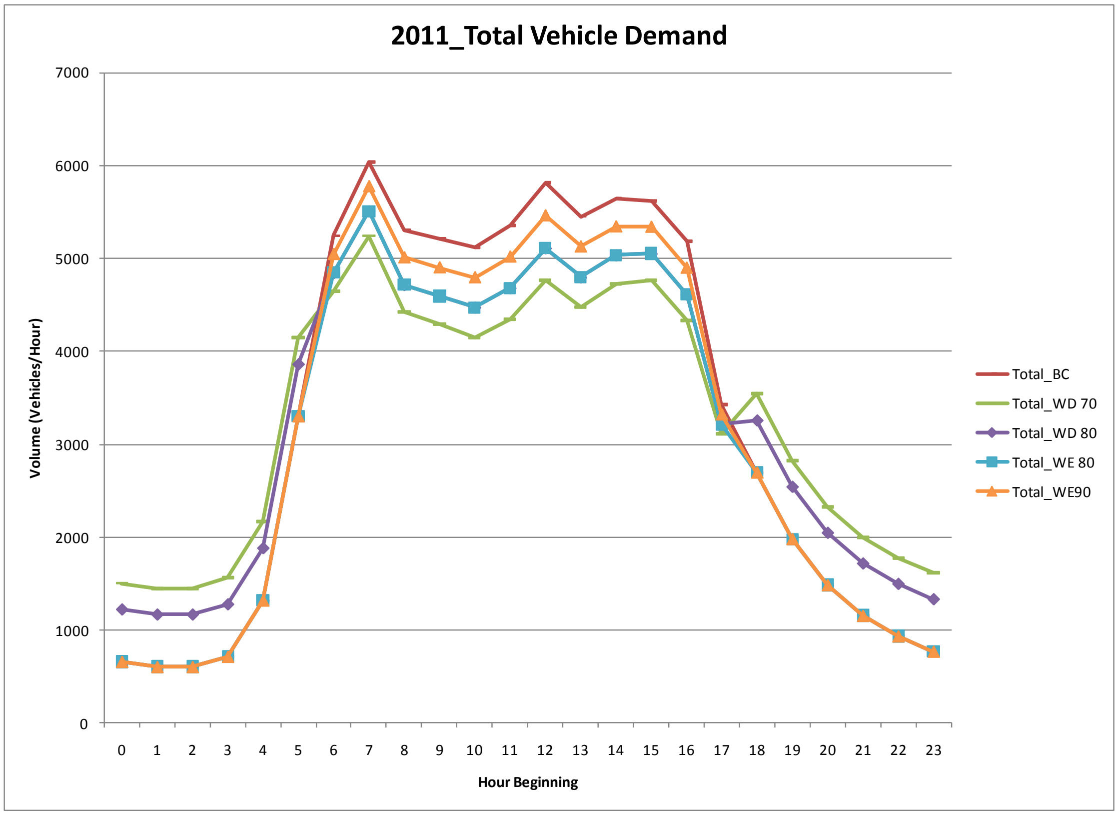


Figure 4-5: Total Vehicle Demand for all 2011 Scenarios

4.2.2 Commercial Vehicle Demand

Figure 4-6 more effectively shows the shifts in commercial vehicles for each 2011 scenario. Currently, terminal gates at the Port Newark/Elizabeth Marine Terminals are only open from 6am-6pm therefore the base case demand pattern shows truck volume beginning around 6am at around 2000 trucks/hours, eventually peaking during midday at approximately 3500 trucks/hour. Similarly, the commercial vehicle demand pattern for WE_80 and WE_90 only span between 6am-6pm since the demand is shifted to weekend hours for these scenarios. The figure shows that for WD_70 and WD_80 the demand was shifted uniformly to the morning and night shifts for each respective scenario. Since the number of commercial vehicles that were shifted to the morning and night work shifts was not significant enough to affect the level of service on the port road network, it was assumed that these demands could be distributed uniformly rather than randomly as shown in the figure below.

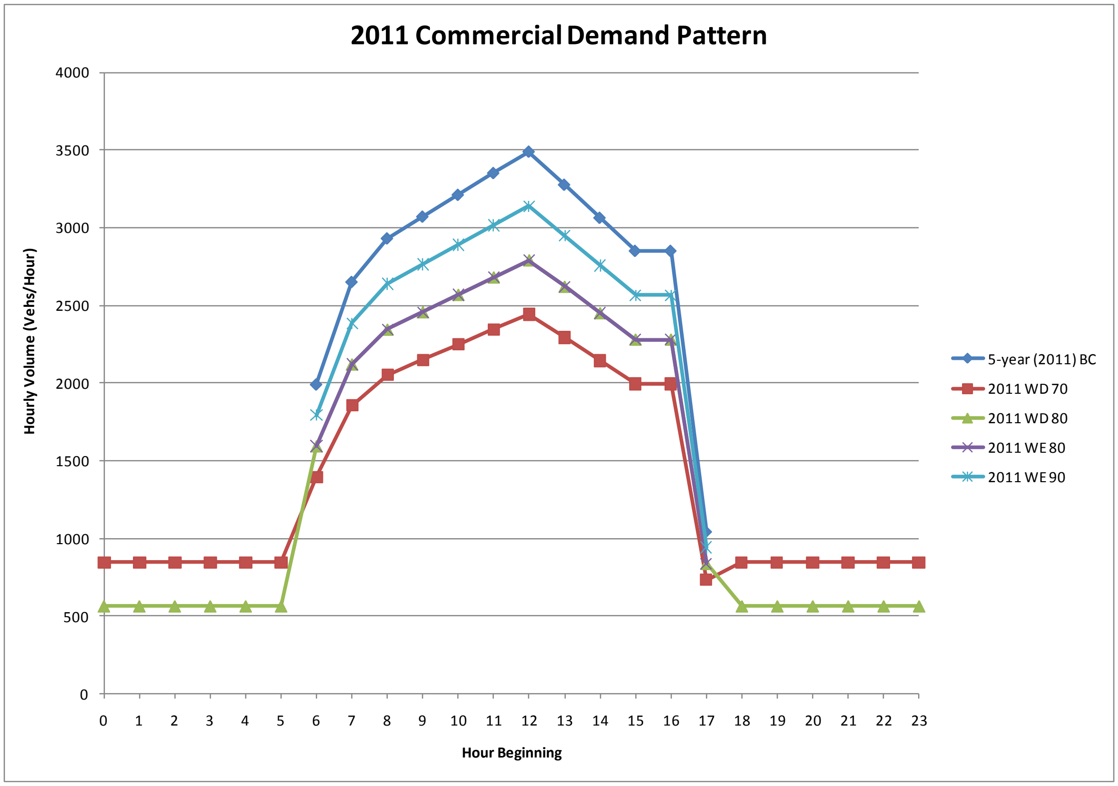


Figure 4-6: Commercial Demand Pattern 2011 (All Scenarios)

4.2.3 Average Truck Travel Times

Figure 4-7 shows the average truck travel times output by VISSIM for each hour of the simulation and for all scenarios for the 2011 simulation year. Average truck travel times on the Port roadside network peak between 7AM and 8AM reaching approximately 8 minutes, only 1 minute higher than the average truck travel time during the same hour in 2006. Truck travel times average 7 minutes during the midday peak hour and slightly over 7 minutes in the PM peak hour. Similar to the average truck travel time results for 2006, there is very little variance when comparing all demand shifting scenarios. However, the figure does show that for the 2011 simulations the WD_70 scenario has more of an impact on truck travel times. This scenario reduces average truck travel times approximately 1 minute for all three peak hours of the simulation. This indicates that the increases in vehicle demand are beginning to impact the roadside networks level of service, however not at a very significant level. Without the infrastructure improvements that were built between 2006 and 2010 (discussed above) travel times for the 2011 simulations would have been much higher and the demand shifting scenarios would show greater impacts in reducing average truck travel times.

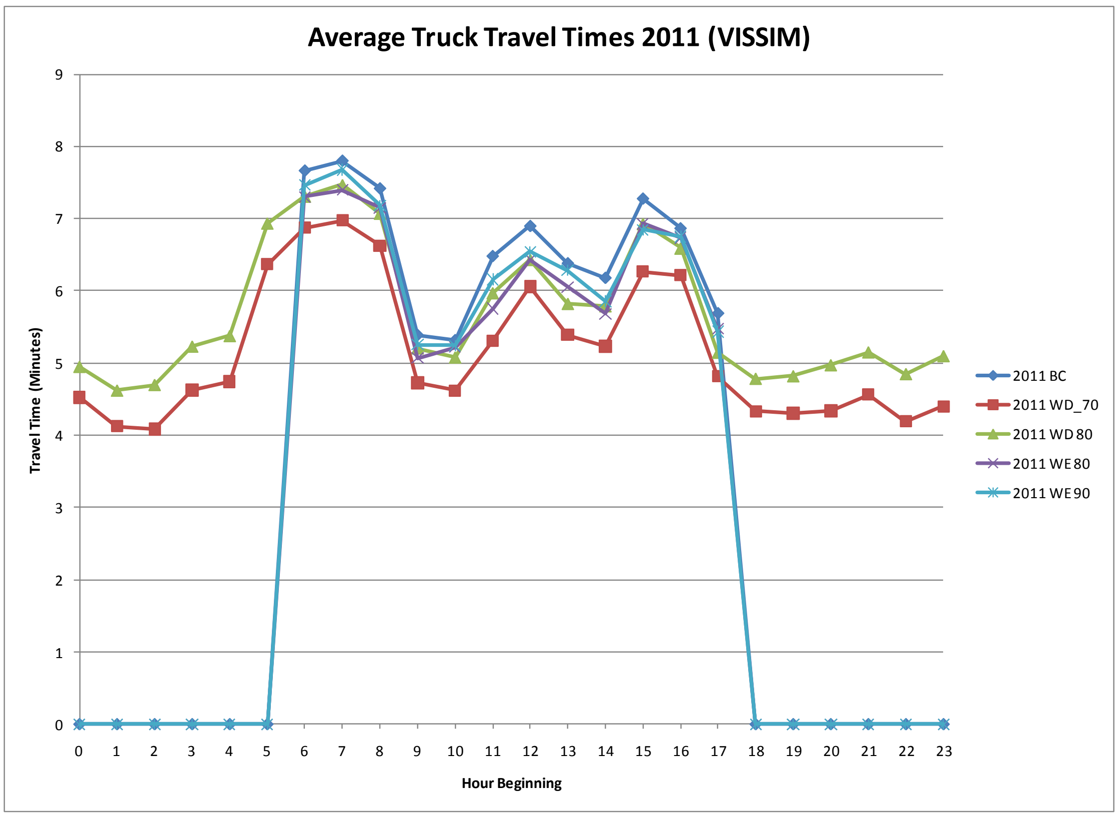


Figure 4-7: Average Truck Travel Times 2011 (All Scenarios)

4.2.4 Average Delay

Average delay is estimated by taking the difference of the average truck travel time and the free flow truck travel time for each hour of the simulation. This is travel delay and does not include delay at the terminal gates. Figure 4-8 shows the average delay per truck output by VISSIM for each hour of the simulation and for all scenarios for the 2011 simulation year. Although a difference for each scenario can be seen in the figure, the delay is not significant for the base case or any demand shifting scenario. Average delay per truck has slightly increased from the 2006 to the 2011 simulations, peaking during midday around 2 minutes of delay per truck on the roadside network before reaching the queue at the terminal gate. As mentioned previously, although there is a significant increase in vehicle demand from 2006 to 2011, additional capacity was added to the Port roadside network (also built into Vissim network for 2011, 2016 and 2021). The additional capacity was able to handle the increase in demand therefore no significant increases in average truck travel time or average delay were seen. This also correlates to the field observations mentioned in the previous section.

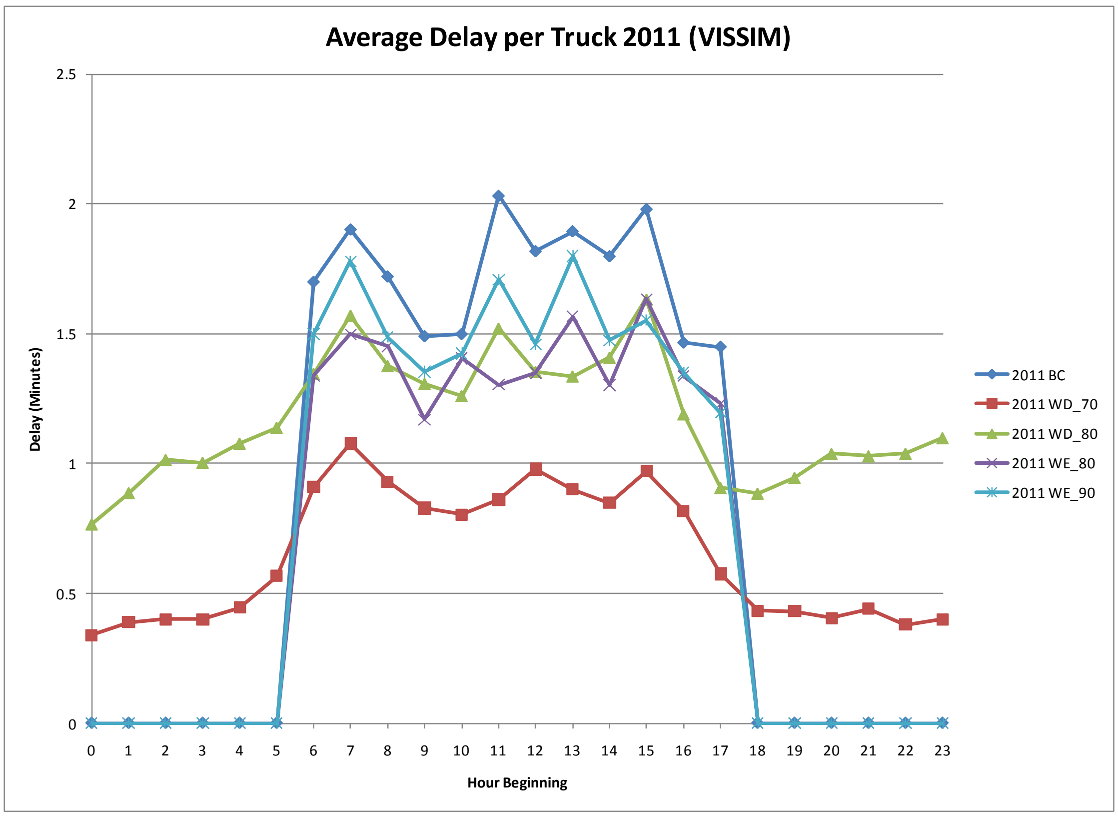


Figure 4-8: Average Delay per Truck 2011 (All Scenarios)

4.3 2016 Scenarios

This section presents the results from the 2016 simulations. Scenarios simulated for 2016 include the base case or "Do-Nothing", WD_70, WD_80, WE_80, and WE_90. The Vissim network used for the 2011 simulations was used for the 2016 and 2021 simulations, due to the complexity and uncertainty of projects planned to be completed by these dates. Therefore more significant impacts to travel time and delay are seen in the results of the 2016 simulations. No additional infrastructure has been provided to handle the increase in vehicle demand. This section reviews 2016 total vehicle demand, commercial demand, average truck travel time and average delay per truck, and compares how each demand shifting scenario impacts the Port's roadside conditions.

4.3.1 Total Vehicle Demand

Figure 4-9 shows the total demand for the five different scenarios including "Do-Nothing", WD_70, WD_80, WE_80, and WE_90 for the 2016 base year. The demand in this figure includes both commercial vehicles and private automobiles. In the AM period, total hourly volume peaks at 7,000 vehicles per hour. The midday peak volume for the base case is around 6,800 vehicles per hour and the afternoon peak volume is approximately 6,500 vehicles per hour. As the figure shows, for scenario WD_70, 30 percent of commercial vehicle traffic is moved from the time the terminal gates are open (6am-6pm) and shifted to the morning and night shifts on weekdays. Similarly WD _80 shifts 20 percent of commercial vehicle traffic from the period of 6am-6pm to the morning and night shifts. WE_80 and WE_90 shifted 20 percent and 10 percent of commercial traffic to weekend hours, respectively. The figure shows the hourly volumes in the morning, midday, and afternoon peaks decreasing for each respective scenario.

Also shown in the figure is the increase in vehicle demand from the previous 2011 demand profile. As previously stated, it was assumed that commercial truck demand increased at a rate of 5 percent per year and automobile traffic increased at a rate of 2 percent per year.

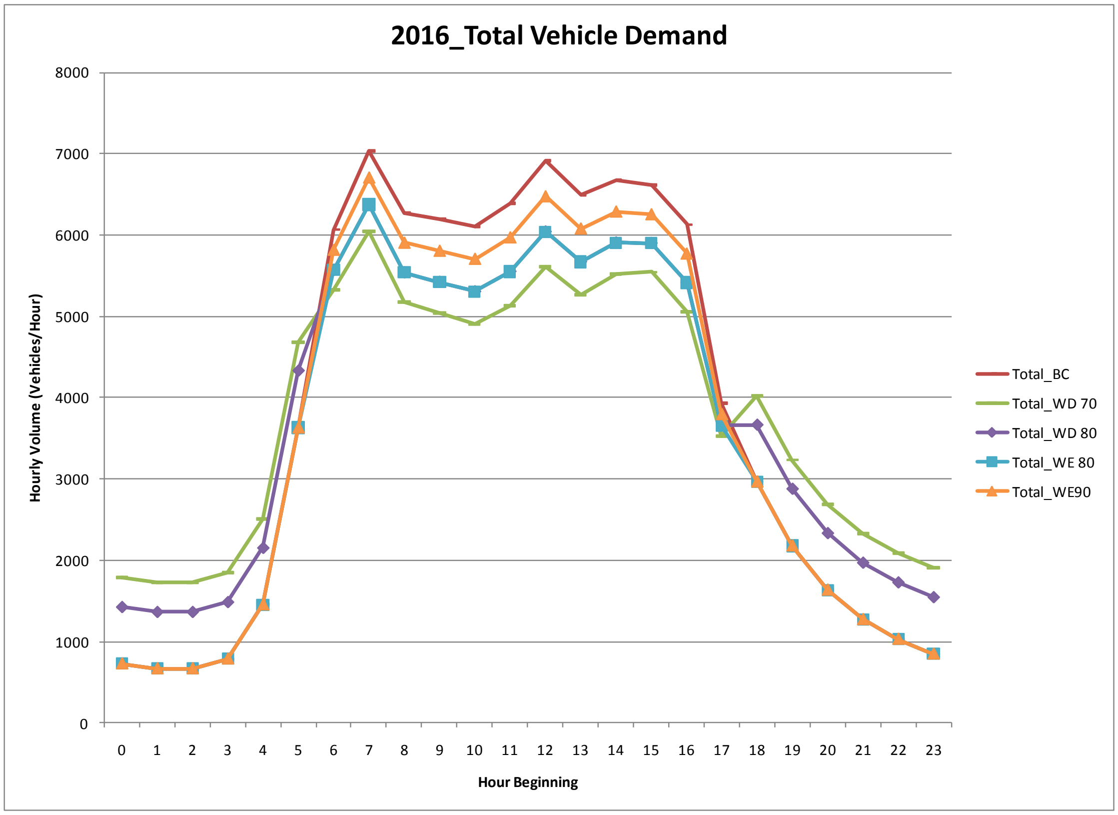


Figure 4-9: Total Vehicle Demand for all 2016 Scenarios

4.3.2 Commercial Vehicle Demand

Figure 4-10 shows the shifts in commercial vehicles for each 2016 scenario. Currently, terminal gates at the Port Newark/Elizabeth Marine Terminals are only open from 6am-6pm therefore the base case demand pattern shows truck volume beginning around 6am at around 2500 trucks/hours, eventually peaking during midday at approximately 4400 trucks/hour. Similarly, the commercial vehicle demand pattern for WE_80 and WE_90 only span between 6am-6pm since the demand is shifted to weekend hours for these scenarios. The figure shows that for WD_70 and WD_80 the demand was shifted uniformly to the morning and night shifts for each respective scenario. Since the number of commercial vehicles that were shifted to the morning and night work shifts was not significant enough to affect the level of service on the port road network, it was assumed that these demands could be distributed uniformly rather than randomly as shown in the figure below.

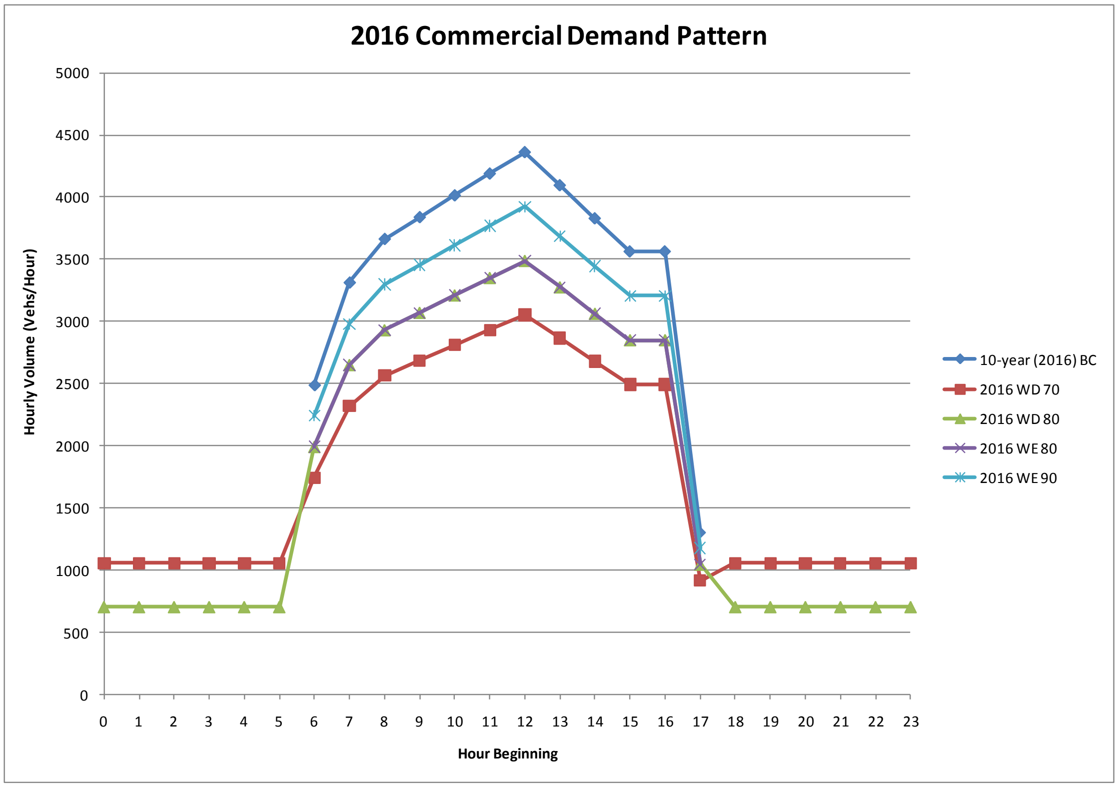


Figure 4-10: Commercial Demand Pattern 2016 (All Scenarios)

4.3.3 Average Truck Travel Times

Figure 4-11 shows the average truck travel times output by VISSIM for each hour of the simulation and for all scenarios for the 2016 simulation year. Average truck travel times on the Port roadside network peak between 7AM and 8AM reaching approximately 18 minutes, a significant 11 minute increase from the 2006 base year scenario. Truck travel times average 16 minutes during the midday peak hour and slightly over 16 minutes in the PM peak hour. Unlike the results from the 2006 and 2011 simulations, significant changes in average travel times are seen for the different demand shifting scenarios. For scenario WE_90, 10 percent of the commercial vehicle demand on the Port network between 6AM and 6PM is shifted to the weekend. The figure shows average truck travel times slightly decreasing during the peak travel periods. A decrease of 2 minutes is seen in the AM and midday periods, and nearly 1 minute in the PM period. However this is not significant enough to allow for a sufficient level of service on the roadside network.

Scenarios, WD_80 and WE_80, both shift 20 percent of the commercial demand during normal operating hours to either the weekend or off-peak hours. The figure shows these two scenarios have similar average travel times, slightly below those of the WE_90 scenario. For these two scenarios, travel times are acceptable during off-peak hours, however high travel times and delays are seen in during the three peak periods of the day.

Scenario WD_70 shifts 30 percent of commercial demand from the operating hours of 6AM-6PM to off-peak hours, including early morning and late night shifts. The figure shows very significant improvements in average truck travel times from the 2016 base case. Travel times for the three peak periods of the day are only slightly higher than those of the 2006 and 2011 base cases. This indicates that scenario WD_70 could potentially bring traffic conditions on the Port roadside network to a very acceptable level of service, comparable to the conditions in the 2011 base case. In order to achieve this level of service the Port would have to implement a combination of gate strategies discussed in the literature review that could force 30 percent of truck traffic away from the park operating hours. Extended gate hours and a gate appointment system would most likely be necessary for this to occur.

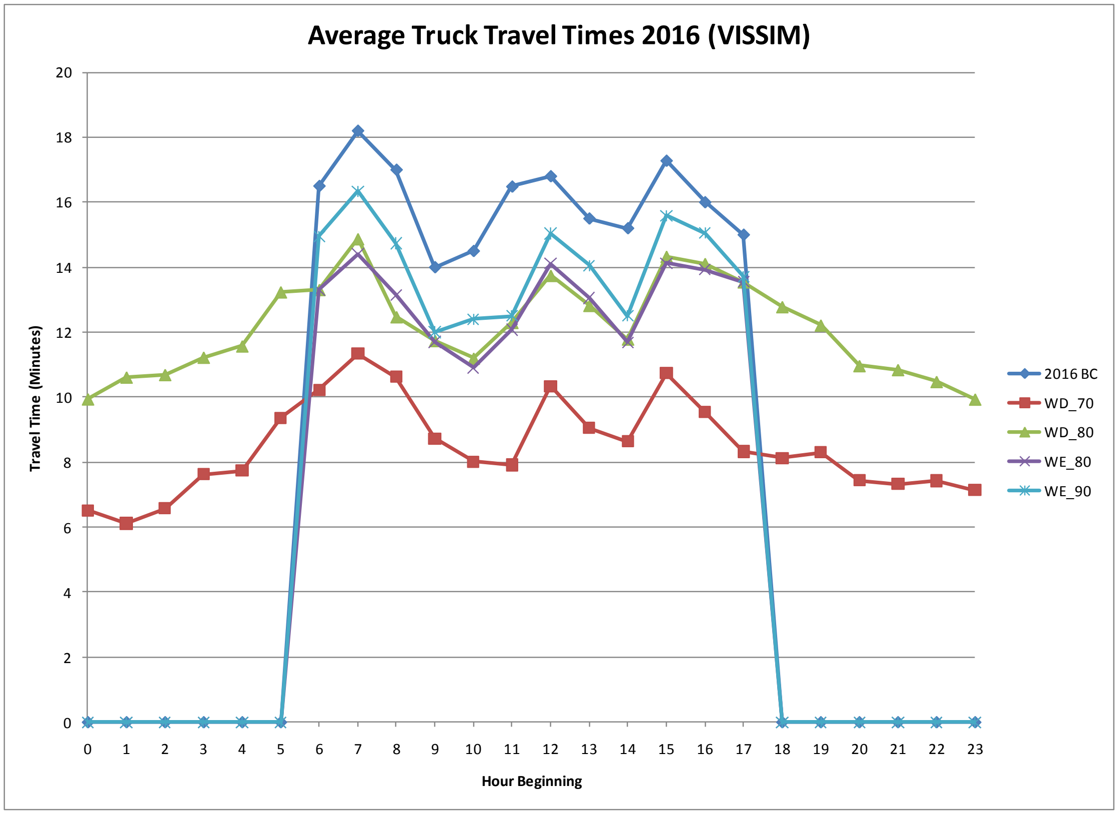


Figure 4-11: Average Truck Travel Times 2016 (All Scenarios)

4.3.4 Average Delay

Average delay is estimated by taking the difference of the average truck travel time and the free flow truck travel time for each hour of the simulation. This is travel delay and does not include delay at the terminal gates. Figure 4-12 shows the average delay per truck output by VISSIM for each hour of the simulation and for all scenarios for the 2016 simulation year. Similar to the average truck travel times for this scenario, a more significant decrease in delay per truck is seen for each of the demand shifting scenarios. Delays for the 2016 base case are much higher than the delay from the 2006 and 2011 base case simulation for the hours between 6AM and 6PM, reaching just above

12 minutes in the AM peak period and nearly 12 minutes during the midday and PM peak hours.

The average delay per truck for the WE_90 scenario is approximately 10 minutes during the three peak hours. For both the WE_80 and WD_80 scenarios the average delay per truck is close to 8.5 minutes, since both scenarios shift 20 percent of the commercial demand to either weekends or off-peak hours. The figure shows a very significant reduction in average delay per truck for all hours of the day for the 2016 WD_70 scenario, correlating to the average truck travel time for 2016. This is the only 2016 scenario that reduces average delay per truck to indicate an acceptable level of service on the Port’s roadside network.

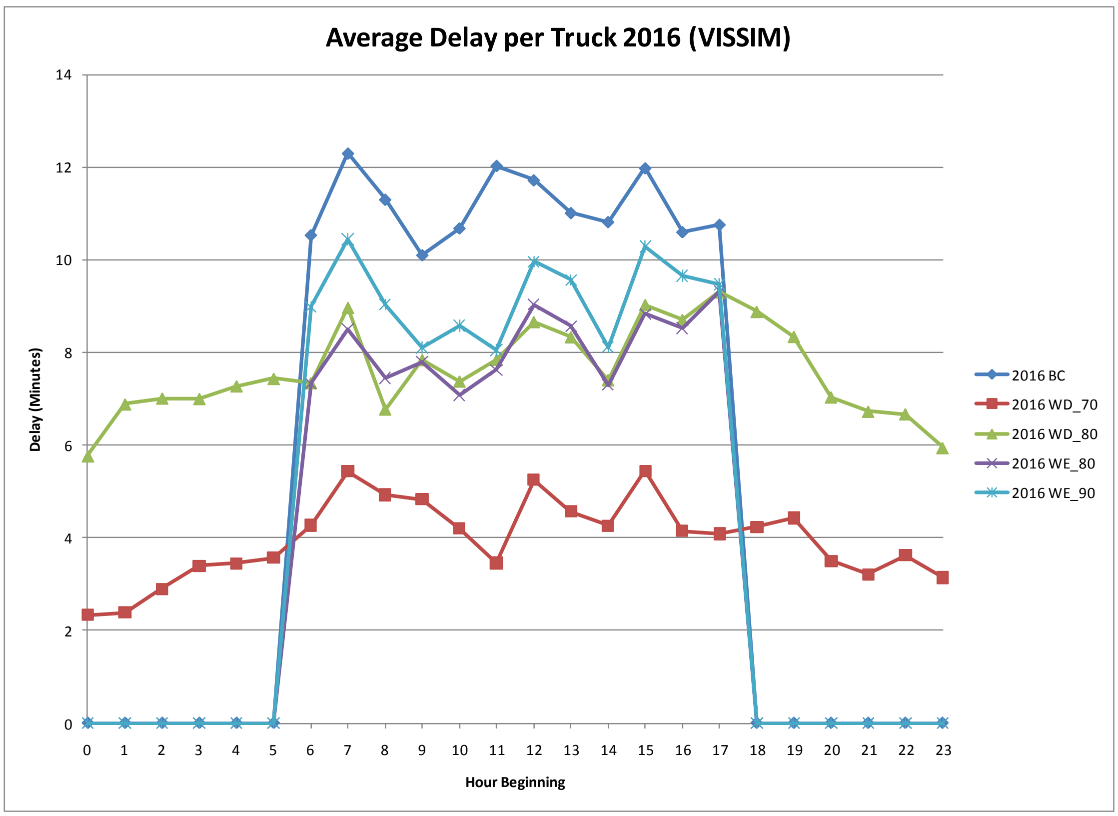


Figure 4-12: Average Delay per Truck 2016 (All Scenarios)

4.4 2021 Scenarios

This section presents the results from the 2021 simulations. Scenarios simulated for 2021 include the base case or "Do-Nothing", WD_70, WD_80, WE_80, and WE_90. The Vissim network used for the 2011 simulations was used for the 2016 and 2021 simulations, due to the complexity and uncertainty of projects planned to be completed by these dates. The large increase in vehicle demand due to increasing international trade will significantly impact conditions on the Port roadside network in 2021. This section shows the total vehicle demand, commercial vehicle demand, average truck travel times, and average delay per truck for all hours of the simulation.

4.4.1 Total Vehicle Demand

Figure 4-13 shows the total demand for the five different scenarios including "Do-Nothing", WD_70, WD_80, WE_80, and WE_90 for the 2021 base year. The demand in this figure includes both commercial vehicles and private automobiles. In the AM period and midday periods, total hourly volume peaks at 8,200 vehicles per hour. The PM peak period reaches a total hourly volume of nearly 7,900 vehicles per hour. As the figure shows, for scenario WD_70, 30 percent of commercial vehicle traffic is moved from the time the terminal gates are open (6am-6pm) and shifted to the morning and night shifts on weekdays. Similarly WD _80 shifts 20 percent of commercial vehicle traffic from the period of 6am-6pm to the morning and night shifts. WE_80 and WE_90 shifted 20 percent and 10 percent of commercial traffic to weekend hours, respectively. The figure shows the hourly volumes in the morning, midday, and afternoon peaks decreasing for each respective scenario. Also shown in the figure is the increase in vehicle demand from the previous 2016 demand profile. As previously stated, it was assumed that commercial truck demand increased at a rate of 5 percent per year and automobile traffic increased at a rate of 2 percent per year.

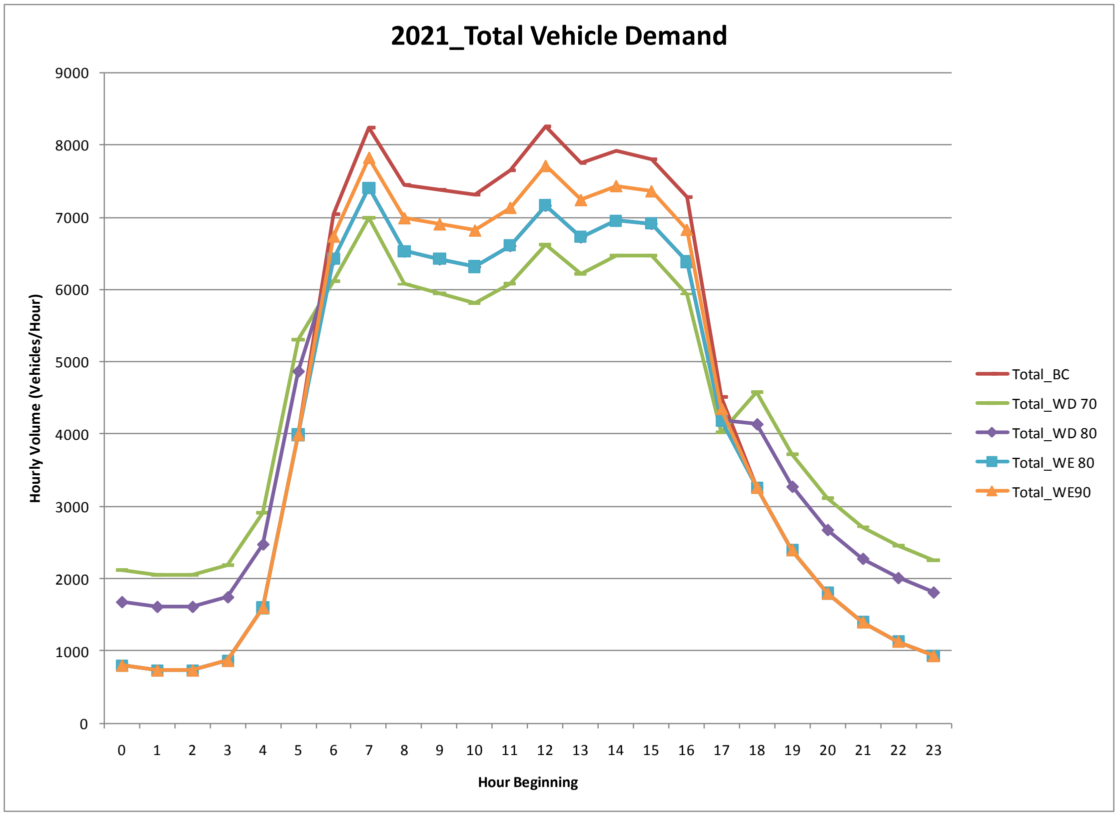


Figure 4-13: Total Vehicle Demand for all 2021 Scenarios

4.4.2 Commercial Vehicle Demand

Figure 4-14 shows the shifts in commercial vehicles for each 2021 scenario. Currently, terminal gates at the Port Newark/Elizabeth Marine Terminals are only open from 6am-6pm therefore the base case demand pattern shows truck volume beginning around 6am at around 3,000 trucks/hours, eventually peaking during midday at a rate of approximately 5,400 trucks per hour. Similarly, the commercial vehicle demand pattern for WE_80 and WE_90 only span between 6am-6pm since the demand is shifted to weekend hours for these scenarios. The figure shows that for WD_70 and WD_80 the demand was shifted uniformly to the morning and night shifts for each respective scenario. Since the number of commercial vehicles that were shifted to the morning and night work shifts was not significant enough to affect the level of service on the port road network, it was assumed that these demands could be distributed uniformly rather than randomly as shown in the figure below.

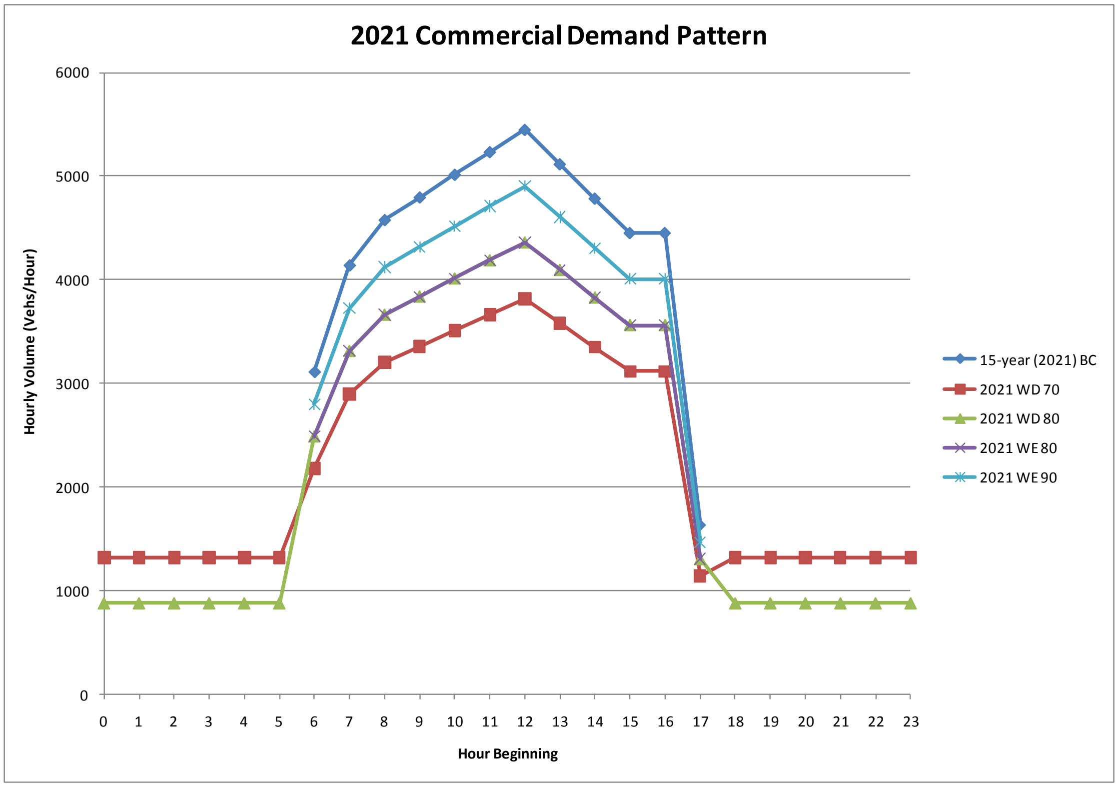


Figure 4-14: Commercial Demand Pattern 2021 (All Scenarios)

4.4.3 Average Truck Travel Times

Figure 4-15 shows the average truck travel times output by VISSIM for each hour of the simulation and for all scenarios for the 2021 simulation year. Average truck travel times on the Port roadside network peak between 7AM and 8AM reaching approximately 20 minutes, a slight 2 minutes increase from the 2016 base case. However after the AM peak period, average truck travel times continue to increase reaching an average truck travel time of 27 minutes in the PM peak period in the 2021 base case. This is due to the fact that the Port roadside network reached maximum capacity in the AM peak period resulting in a continual increase in average truck travel time. The figure shows that there is no distinct "peaks" in average travel time, indicating that the network is just continually congested during from 6AM-6PM.

Scenario WE_90 shifts 10 percent of the commercial demand during normal operating hours to the weekend. The figure shows the average truck travel time reaching approximately 13 minutes in the AM peak period. Travel times then decrease before the midday peak period where the network reaches maximum capacity. As seen in the figure average travel times continue to increase after 12 PM reaching a maximum of 24 minutes around 4PM.

Scenarios, WD_80 and WE_80, both shift 20 percent of the commercial demand during normal operating hours to either the weekend or off-peak hours. The figure shows these two scenarios have similar average travel times, slightly below those of the WE_90 scenario from the beginning of the simulation until the AM peak period. Unlike scenario WE_90, these two scenarios only reach maximum capacity during the three peak periods, but not during off-peak times. Therefore "peaks" in the average travel time figures can be seen. The level of service on the roadside network during these two scenarios is very low and an acceptable level of productivity cannot be reached. The vehicle demand on the network is simply too high. A more significant shift in commercial vehicle demand is needed to allow an appropriate level of service on the roadside network.

Scenario WD_70 shifts 30 percent of commercial demand from the operating hours of 6AM-6PM to off-peak hours, including early morning and late night shifts. The figure shows very significant improvements in average truck travel times from the 2021 base case. Although there are significant improvements in average truck travel times from the 2021 base case, the average travel time is nearly 12 minutes over the entire simulation. This would still result in heavy delay and would not allow for an acceptable level of productivity for the terminal. A larger shift in commercial vehicle demand will be needed in 2021 for average truck travel times to be at a level that will allow terminals to be productive and competitive with other terminals on the east coast.

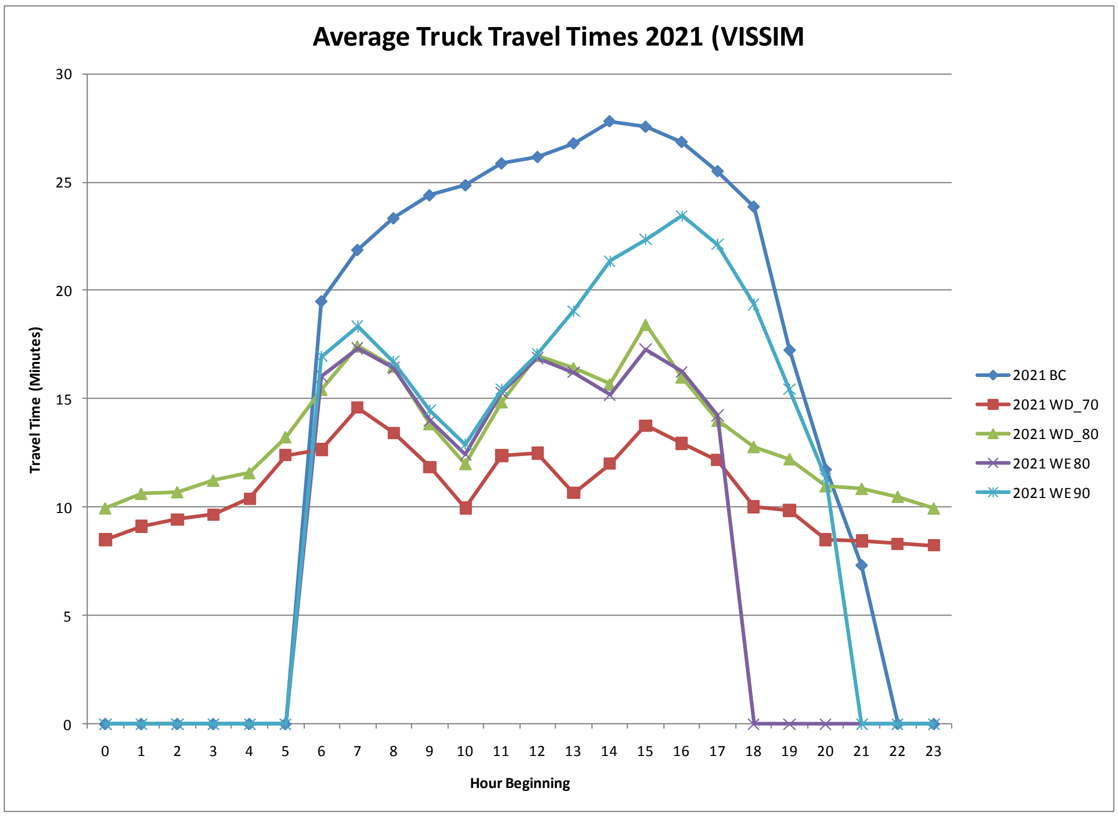


Figure 4-15: Average Truck Travel Times 2021 (All Scenarios)

4.4.4 Average Delay

Average delay is estimated by taking the difference of the average truck travel time and the free flow truck travel time for each hour of the simulation. This is travel delay and does not include delay at the terminal gates. Figure 4-16 shows the average delay per truck output by VISSIM for each hour of the simulation and for all scenarios for the 2021 simulation year. Similar to the average truck travel times for this scenario very high levels of delay are seen for all scenarios. Delays for the 2021 base case are much higher than the delay from all three previous base case simulations for the hours between 6AM and 6PM peaking around 23 minutes as shown in the figure below.

The average delay per truck for the WE_90 scenario is approximately 12 minutes during the AM peak period, however the delay jumps to approximately 17 minutes during the midday and PM peak hours. For both the WE_80 and WD_80 scenarios the average delay per truck is close to 11 minutes, since both scenarios shift 20 percent of the commercial demand to either weekends or off-peak hours. The figure shows a very significant reduction in average delay per truck for all hours of the day for the 2021 WD_70 scenario, correlating to the average truck travel time for 2021. This is the only 2016 scenario that reduces average delay per truck to indicate an acceptable level of service on the Port's roadside network. Although scenario WD_70 shows significant decreases in delay, a larger shift in commercial vehicle demand will be needed in 2021 for average truck travel times to be at a level that will allow terminals to be productive and competitive with other terminals on the east coast.

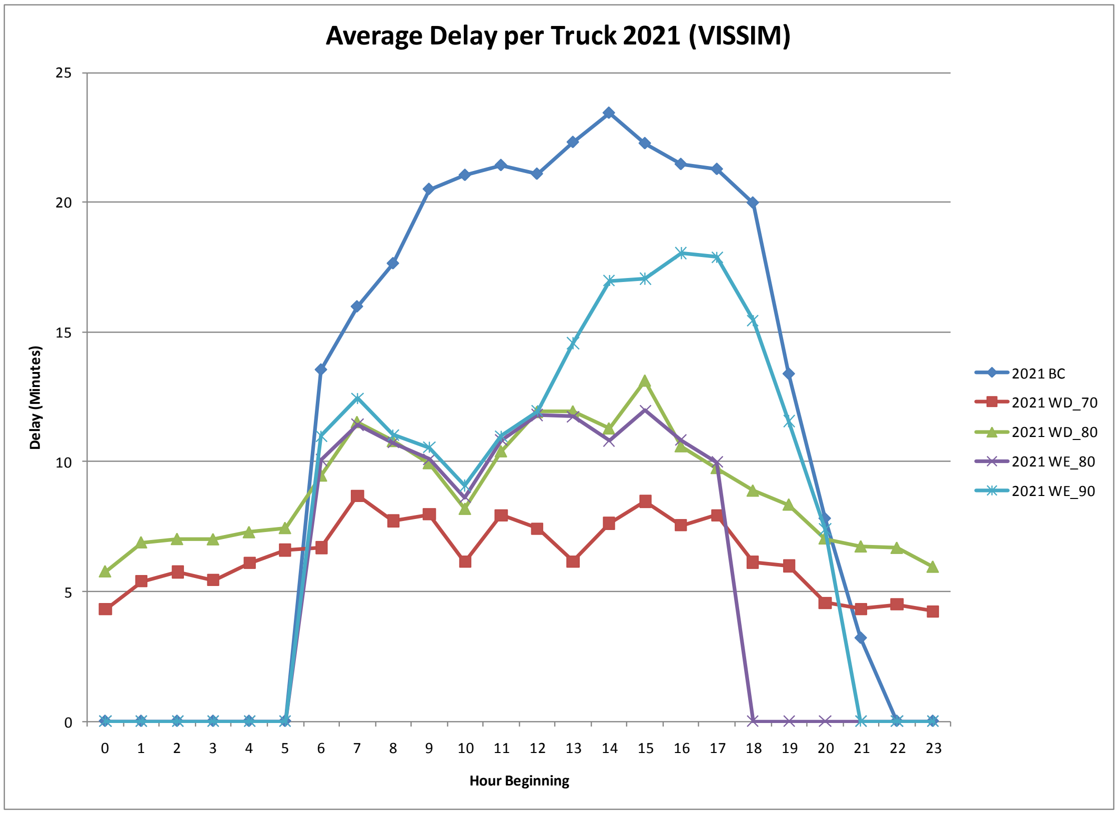


Figure 4-16: Average Delay per Truck 2021 (All Scenarios)

4.5 Peak Hour Travel Times

This section shows average truck travel times and total truck delays for all scenarios and all simulation years compared for each peak period (AM, midday, and PM). The AM peak period is from 7AM-8AM, the midday peak period is from 12PM-1PM and the PM peak period is from 3PM-4PM. A more comparative analysis can be seen here for the three selected hours of the simulation.

4.5.1 AM Peak Period (7:00 AM – 8:00 AM)

Figure 4-17 shows the average truck travel times for each scenario during every simulation year for the AM peak period (7AM-8AM). The figure shows the 2006 base year travel times average slightly over 5 minutes. Only minor variance is seen for each demand shifting scenario in 2006. The 2011 average truck travel times did not significantly increase from 2006 due to the infrastructure addition mentioned earlier. However, more variance in average truck travel time is seen for each demand shifting scenario due to the increase demand.

A large increase in travel time, nearly 11 minutes, is seen from the 2011 base case to the 2016 base case. This large increase is due to the significant increase in travel demand. However for the 2016 simulation year, a large variance in travel time for each scenario is seen. Reducing the commercial demand between the hours of 6AM-6PM shows significant decreases in average truck travel time during the AM peak travel period. Shifting 30 percent of commercial demand to the early morning and late night shifts has the potential to reduce the average truck travel time nearly 40 percent from the base case.

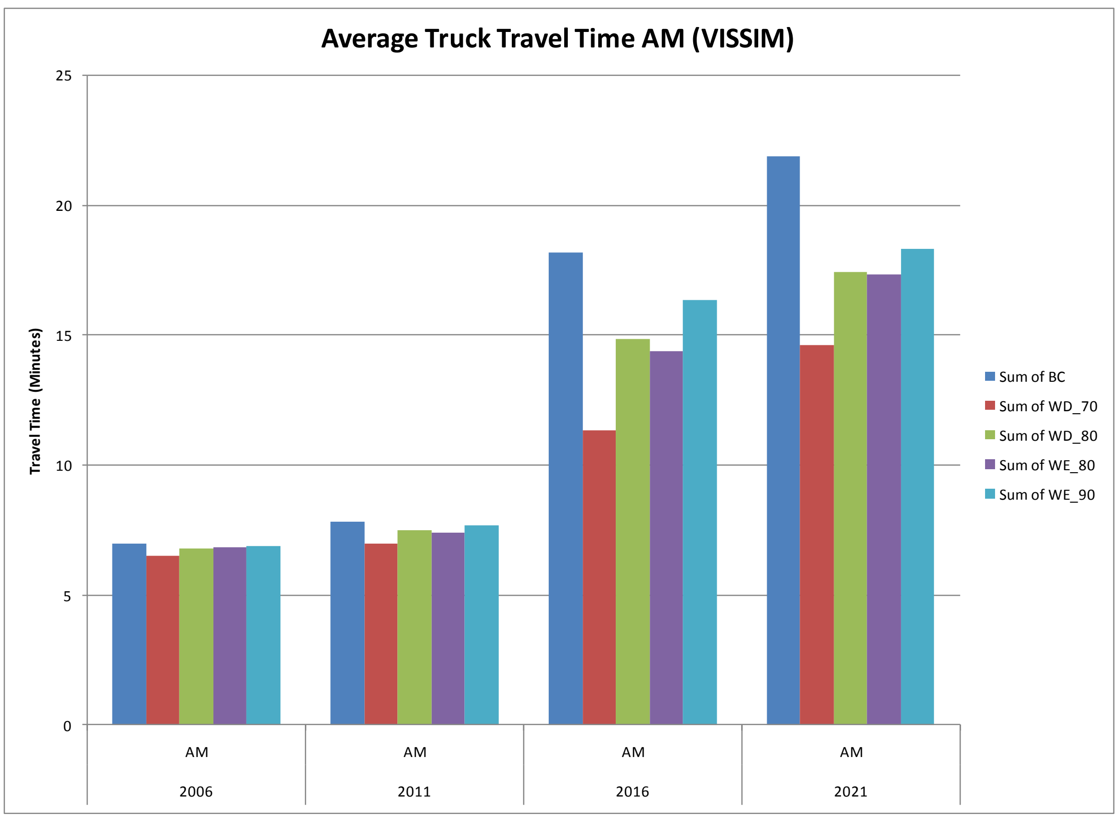


Figure 4-17: Average Truck Travel Time AM (All Scenarios and Years)

4.5.2 MD Peak Period (12:00 PM – 1:00 PM)

Figure 4-18 shows the average truck travel times for each scenario during every simulation year for the MD peak period (12PM-1PM). The figure shows the 2006 base year travel times average slightly over 5 minutes. Only minor variance is seen for each demand shifting scenario in 2006. The 2011 average truck travel times did not significantly increase from 2006 due to the infrastructure addition mentioned earlier. However, more variance in average truck travel time is seen for each demand shifting scenario due to the increase demand.

A large increase in travel time, nearly 12 minutes, is seen from the 2011 base case to the 2016 base case. This large increase is due to the significant increase in travel demand. However for the 2016 simulation year, a large variance in travel time for each scenario is seen. Reducing the commercial demand between the hours of 6AM-6PM shows significant decreases in average truck travel time during the MD peak travel period. Shifting 30 percent of commercial demand to the early morning and late night shifts has the potential to reduce the average truck travel time nearly 40 percent from the base case.

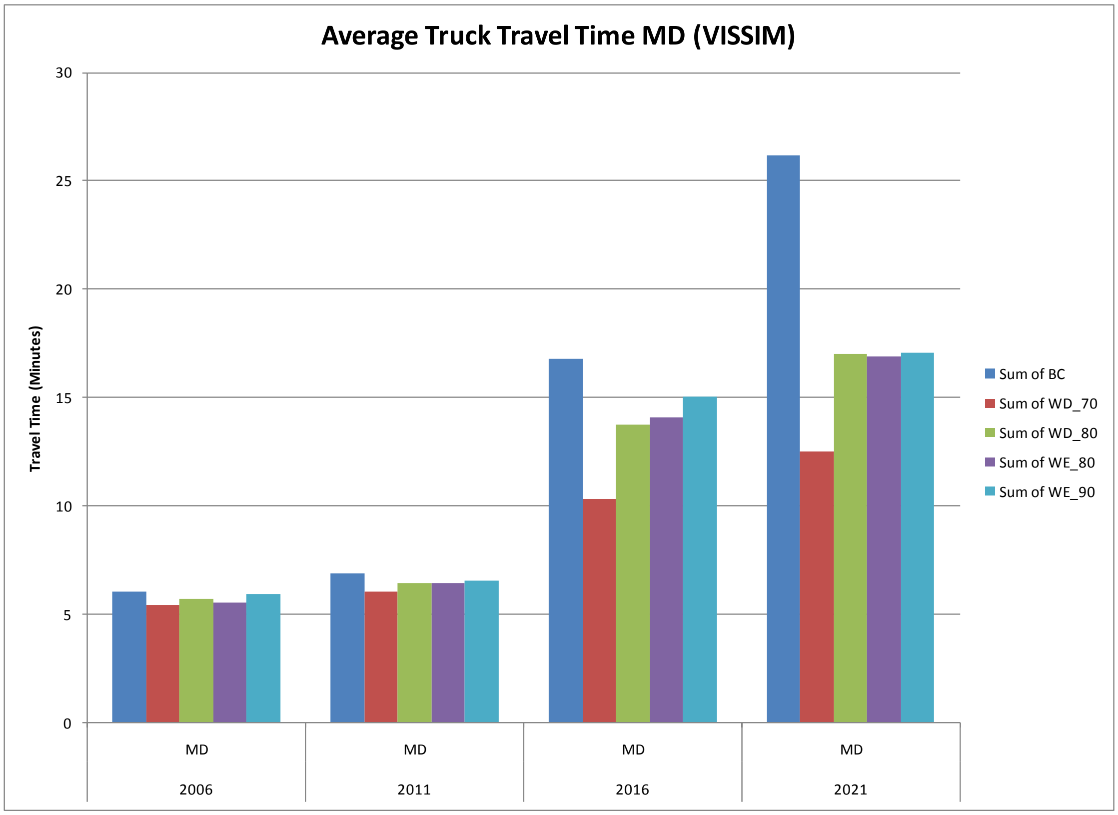


Figure 4-18: Average Truck Travel Time MD (All Scenarios and Years)

4.5.3 PM Peak Period (3:00 PM – 4:00 PM)

Figure 4-19 shows the average truck travel times for each scenario during every simulation year for the PM peak period (3PM-4PM). The figure shows the 2006 base year travel times average slightly over 5 minutes. Only minor variance is seen for each demand shifting scenario in 2006. The 2011 average truck travel times did not significantly increase from 2006 due to the infrastructure addition mentioned earlier. However, more variance in average truck travel time is seen for each demand shifting scenario due to the increase demand.

A large increase in travel time, nearly 11 minutes, is seen from the 2011 base case to the 2016 base case. This large increase is due to the significant increase in travel demand. However for the 2016 simulation year, a large variance in travel time for each scenario is seen. Reducing the commercial demand between the hours of 6AM-6PM shows significant decreases in average truck travel time during the PM peak travel period. Shifting 30 percent of commercial demand to the early morning and late night shifts has the potential to reduce the average truck travel time nearly 40 percent from the base case.

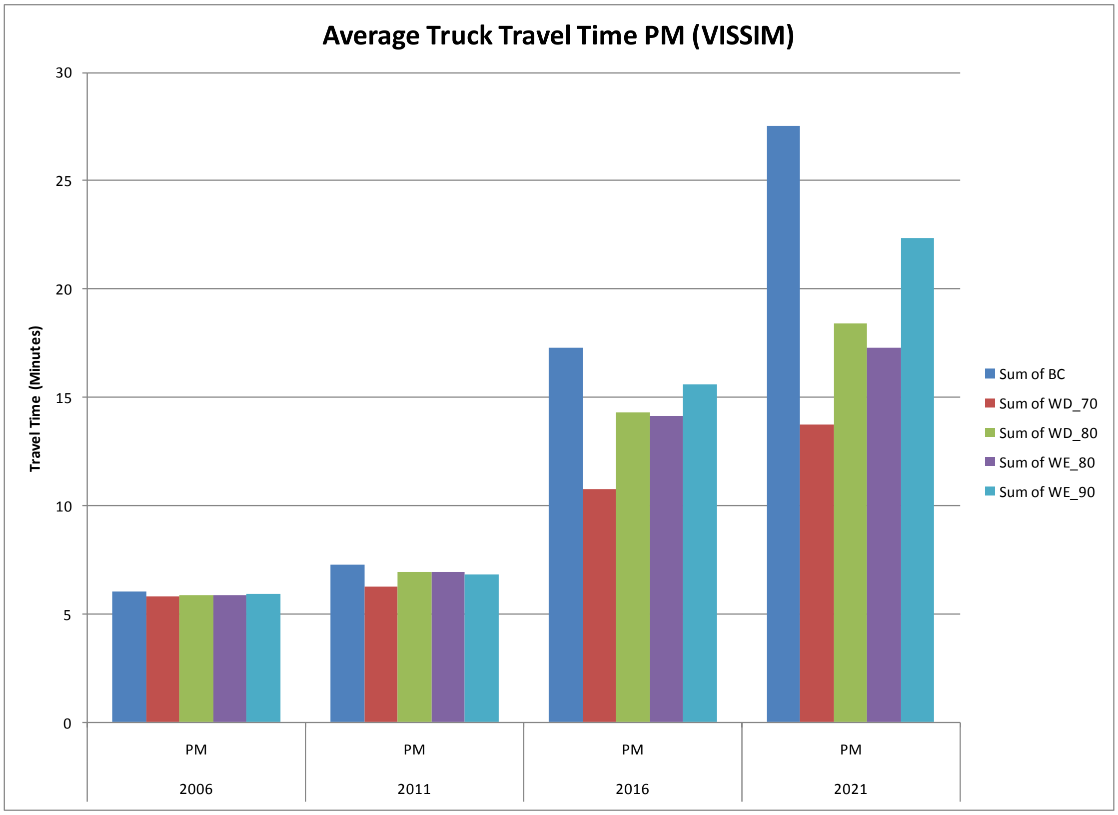


Figure 4-19: Average Truck Travel Time PM (All Scenarios and Years)

4.6 Peak Hour Delay

4.6.1 AM Peak Period (7:00 AM – 8:00 AM)

Figure 4-20 shows the total truck delay for each scenario during every simulation year for the AM peak period (7AM-8AM). The total truck delay was calculated by taking the difference of the average truck travel time and the free flow truck travel time, and then multiplying the difference by the truck volume for that time period. Minimal delay is seen in the 2006 AM peak period. The figure shows the base case exponentially increasing in the AM peak for each 5 year simulation. The WD_70 scenario shows the smallest increase in total truck delay between each simulation year, reaching a maximum of 400 total truck hours of delay in the 2021 AM peak period.

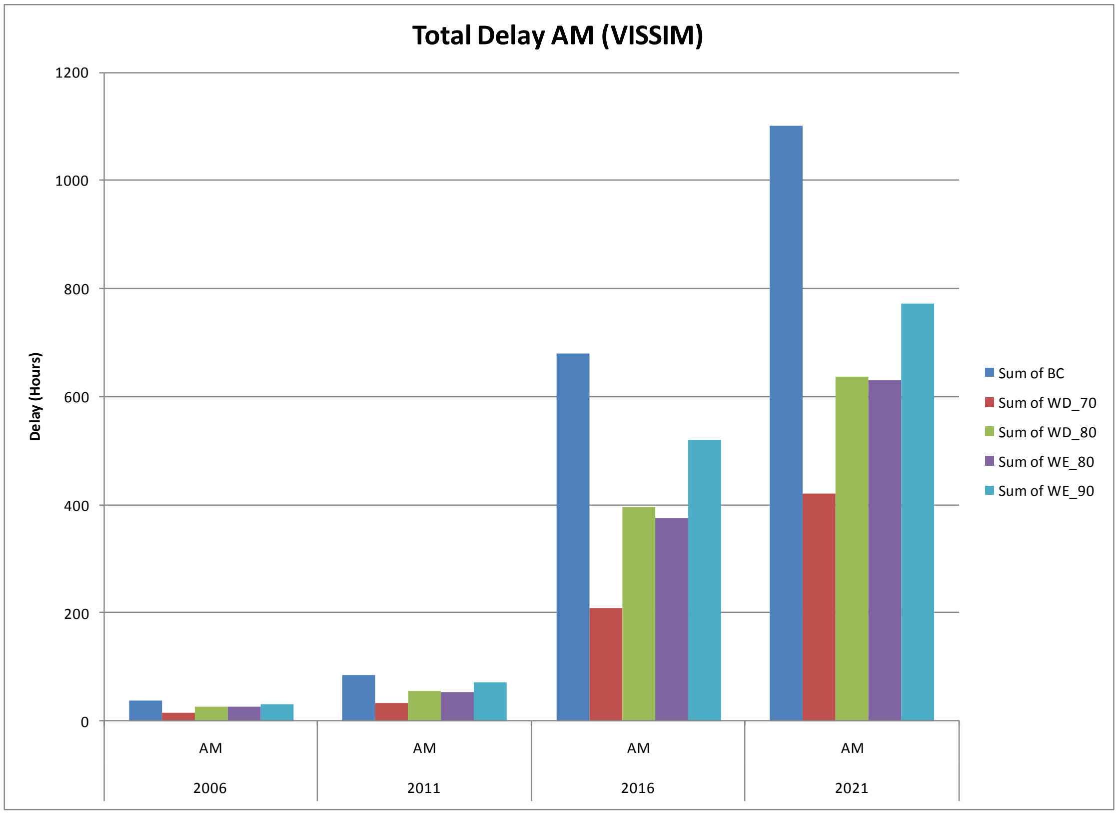


Figure 4-20: Total Truck Delay AM (All Scenarios and Years)

4.6.2 MD Peak Period (12:00 PM – 1:00 PM)

Figure 4-21 shows the total truck delay for each scenario during every simulation year for the MD peak period (12PM-1PM). The total truck delay was calculated by taking the difference of the average truck travel time and the free flow truck travel time, and then multiplying the difference by the truck volume for that time period. Slightly higher delay is seen in the 2006 MD peak period than the AM peak period. Similar to the AM peak period, the figure shows the base case exponentially increasing in the MD peak for each 5 year simulation. Again, WD_70 scenario shows the smallest increase in total truck delay between each simulation year, reaching a maximum of 500 total truck hours of delay in the 2021 AM peak period.

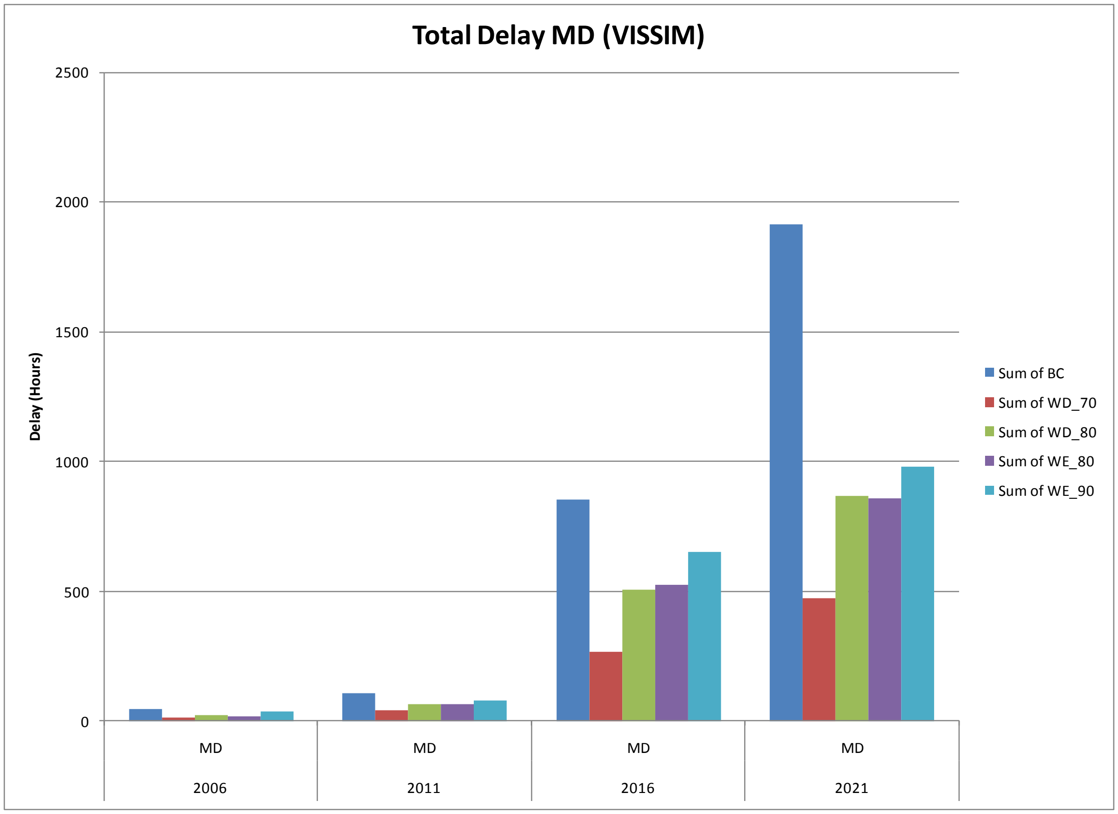


Figure 4-21: Total Truck Delay MD (All Scenarios and Years)

4.6.3 PM Peak Period (3:00 PM – 4:00 PM)

Figure 4-22 shows the total truck delay for each scenario during every simulation year for the PM peak period (3PM-4PM). The total truck delay was calculated by taking the difference of the average truck travel time and the free flow truck travel time, and then multiplying the difference by the truck volume for that time period. This figure shows results very similar to those in the AM peak period, with scenario WD_70 having the most impact on the reduction in total truck delay.

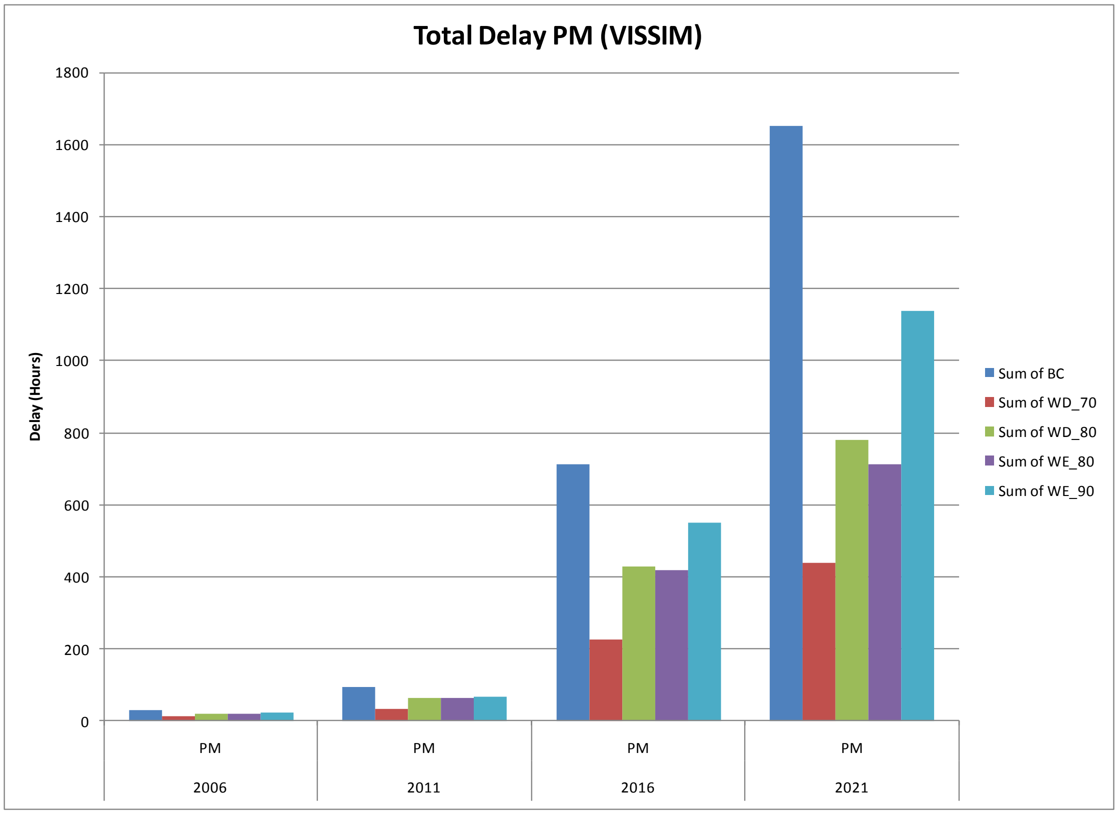


Figure 4-22: Total Truck Delay PM (All Scenarios and Years)

CHAPTER 5 CONCLUSION

5.1 Key Findings

As mentioned in Chapter 1 the goal of this thesis is to evaluate the impacts that common gate strategies have on the roadside network of container terminals using a DTA microsimulation tool (PTV America's Vissim). The Port of Newark/Elizabeth Marine Terminals in Elizabeth and Newark, NJ were chosen for the case study presented in this thesis due to the convenient location and available data from the Port Authority of New York and New Jersey. After an extensive literature review that was presented in Chapter 2, it was decided that extended gate hours and gate appointment systems were the operational strategies most likely to be implemented at the Port Newark/Elizabeth Marine Terminals.

Using Vissim's Dynamic Assignment Module these two operational strategies were tested at the Port Newark/Elizabeth Marine Terminals in order to evaluate the impacts and benefits on the Port's roadside network both presently and for future cases. The Vissim model was calibrated using 2006 traffic count data on the Port roadside network from the Port Authority of New York and New Jersey's 2006 Comprehensive Traffic Study. In order to incorporate these strategies into the Vissim simulations, generalizations were made regarding the way gate appointment systems and extended gate hours would control the truck demand at the Port Newark/Elizabeth. It is assumed that the most likely scenarios resulting from implementing a gate appointment system, extended gate hours, or both at the Port are as follows:

1. Do-Nothing

2. WD_70: 30 percent of commercial demand is shifted to the morning and night shifts (12am-6am and 6pm-12am)
3. WD_80: 20 percent of commercial demand is shifted to the morning and night shifts (12am-6am and 6pm-12am)
4. WE_80: 20 percent of commercial demand is shifted to weekends
5. WE_90: 10 percent of commercial demand is shifted to weekends

These four scenarios were created in Vissim by and compared against "Do-Nothing" scenarios for simulation years 2006, 2011, 2016, and 2021. For each simulation year and all scenarios total vehicle demand, commercial vehicle demand, average truck travel time, average delay per truck, and total truck delay were analyzed. The following are the key findings and suggestions that resulted from the case study presented in this thesis:

- Results from the 2006 base case scenario indicate no major delays (difference of average and free flow travel times) on the Port roadside network, although link volumes from the traffic assignment indicate that a number of links were approaching capacity during the peak days on a typical weekday (The Port Authority of New York and New Jersey, 2007).
- Since there were only minor delays during the 2006 base case simulation, results for the 2006 demand shifting scenarios including WD_70, WD_80, WE_80, and WE_90, showed only minor improvements.
- Capital improvements made on the Port roadside network between 2006 and 2010 were able to absorb the increase in demand entering and exiting the Port during the same time span. Therefore only minimal increases in average truck travel

times, average delay per truck, and total truck delay were seen in the results of the 2011 simulations.

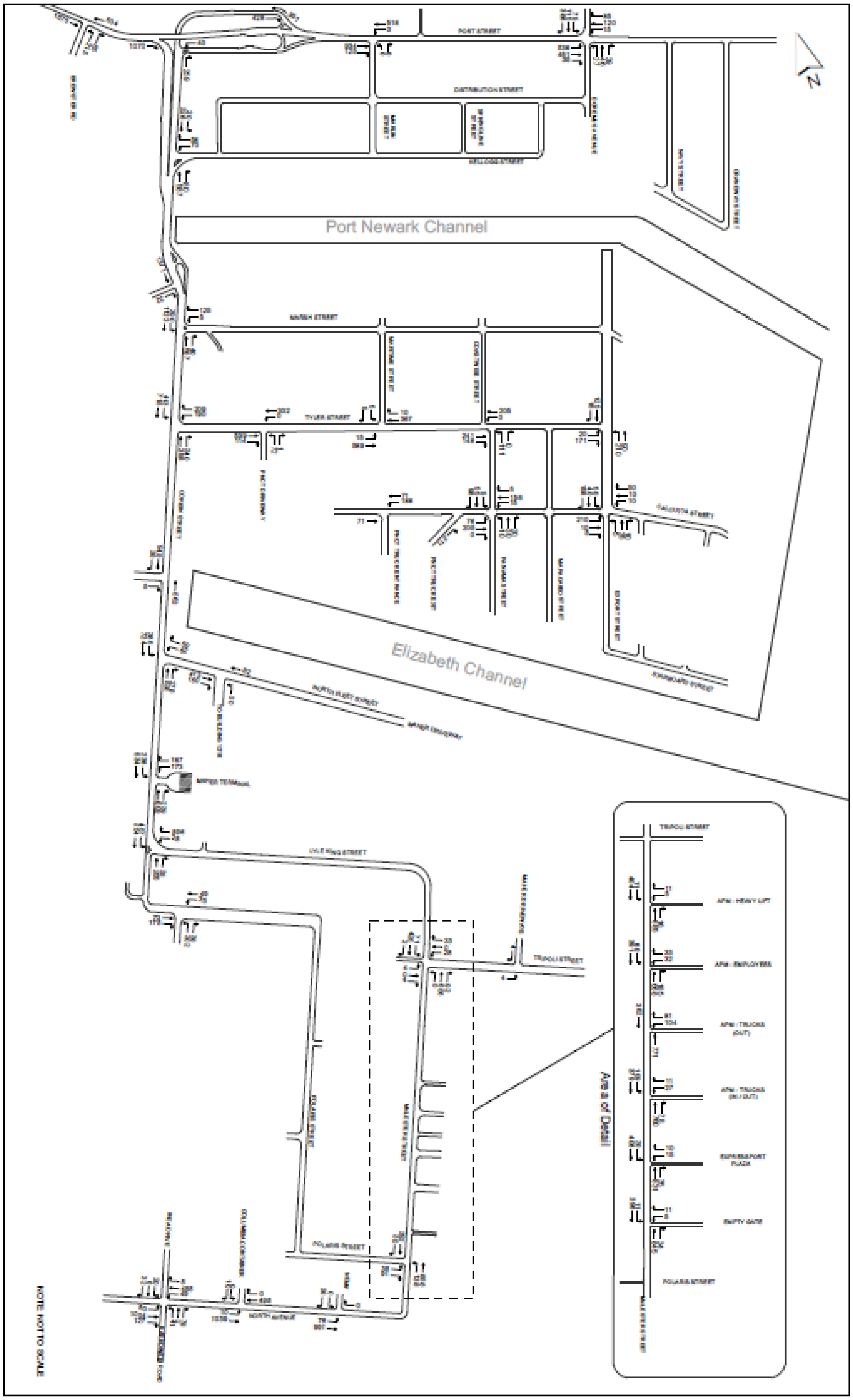
- Significant increases in average travel times and delays are seen in the 2016 base case.
- Scenario WD_70, where 30 percent of commercial demand is shifted from between the hours 6AM-6PM to the early morning and late night shifts, 12AM-6AM and 6PM-12AM, respectively, is the most effective demand shifting scenario during the 2016 simulations.
- Although scenarios WD_80 and WE_80 significantly decrease average truck travel times and delays for simulation year 2016, it is suggested that a 30 percent decrease in commercial demand be achieved (WD_70) in order for the level of service (LOS) of the roadside network reach acceptable levels.
- Implementing demand reducing scenarios at the Port by 2016 will drastically reduce the impacts of peak truck congestion that cause long truck queues that will spill over onto major corridors of the NY Metro Area. This in turn will significantly reduce the amount of emissions in the area.
- No demand reducing scenarios for the 2021 simulation year allow for an efficient LOS at the Port. It is suggested that demand between the hours of 6AM-6PM are reduced by more than 30 percent. This is due to the significant increases in vehicle demand projected in the future at the Port.
- Implementing a demand reducing scenario at the Port before 2021 will considerably reduce average travel times and delay from the base case. If additional gate strategies to improve truck turn-around time or speed up overall

port operations can be implemented to compliment one of the test scenarios, conditions on the roadside network may allow for an acceptable level of service at the Port.

5.2 Future research

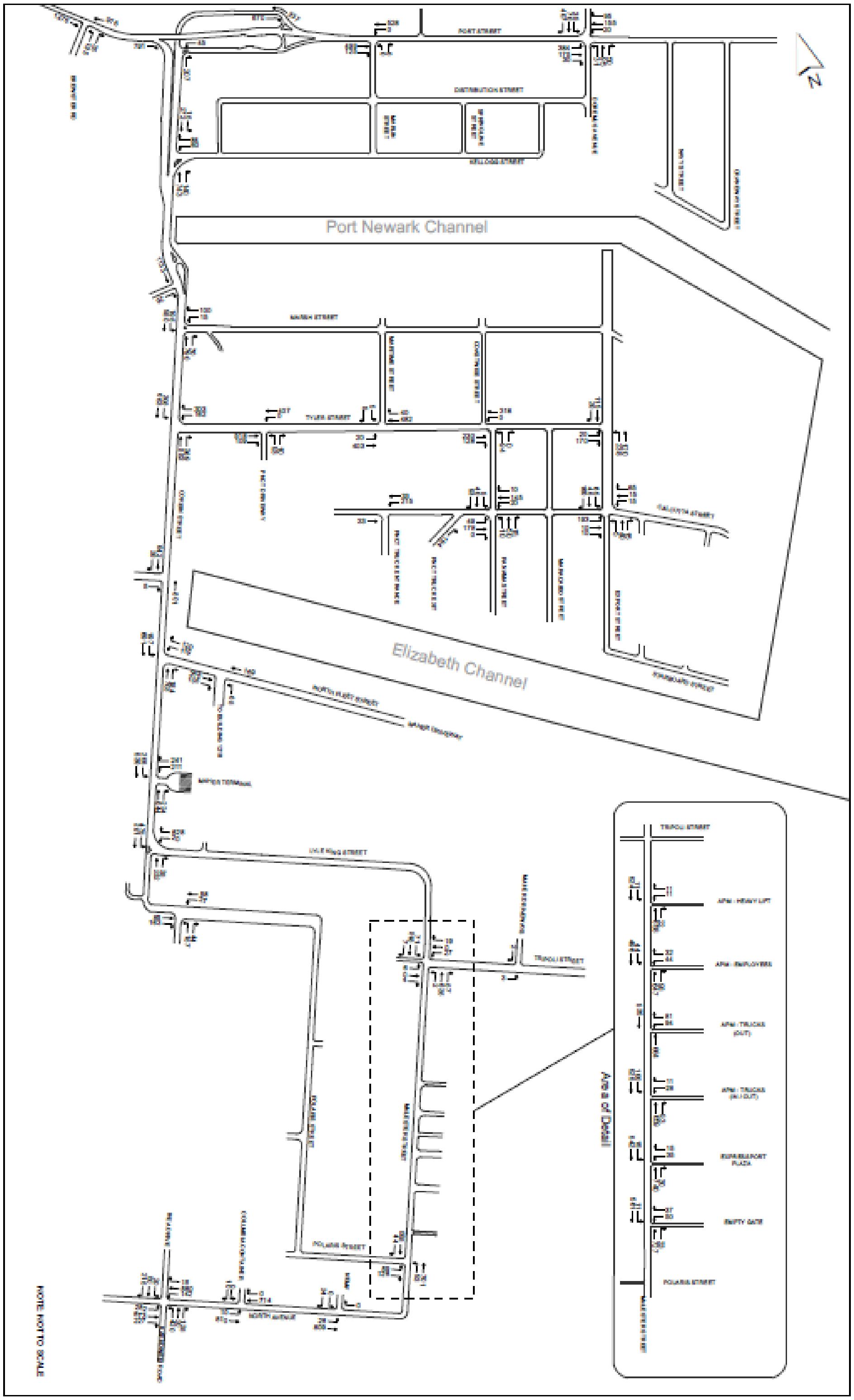
Correlating the different demand patterns at the gates with the productivity of the terminal operations (i.e truck turn times) in order to estimate a dynamic demand function for the departure of trucks from the terminals is a very difficult task. To address these fluctuations in the levels of service (LOS) within the terminal as the demand of arriving trucks at the gates varies a scenario analysis can be utilized. For each demand pattern of truck traffic arriving at the terminals, different LOS within the terminals can be assumed, and a number of demand patterns of truck traffic originating from the terminals will be produced. This approach can be considered as a worst-best case scenario analysis and is a substitute for developing dynamic traffic generation functions at the gates. Another interesting area of research would be the evaluation of the efficiency of the proposed gate strategies in reducing the amount of drayage related emissions. Using input results from the simulation model (i.e. travel times and vehicle speed) and the U.S. EPA’s vehicle emission modeling software MOVE2010, estimates of the total amount of emissions can be produced as well as an hourly profile following the different demand pattern scenarios.

APPENDIX



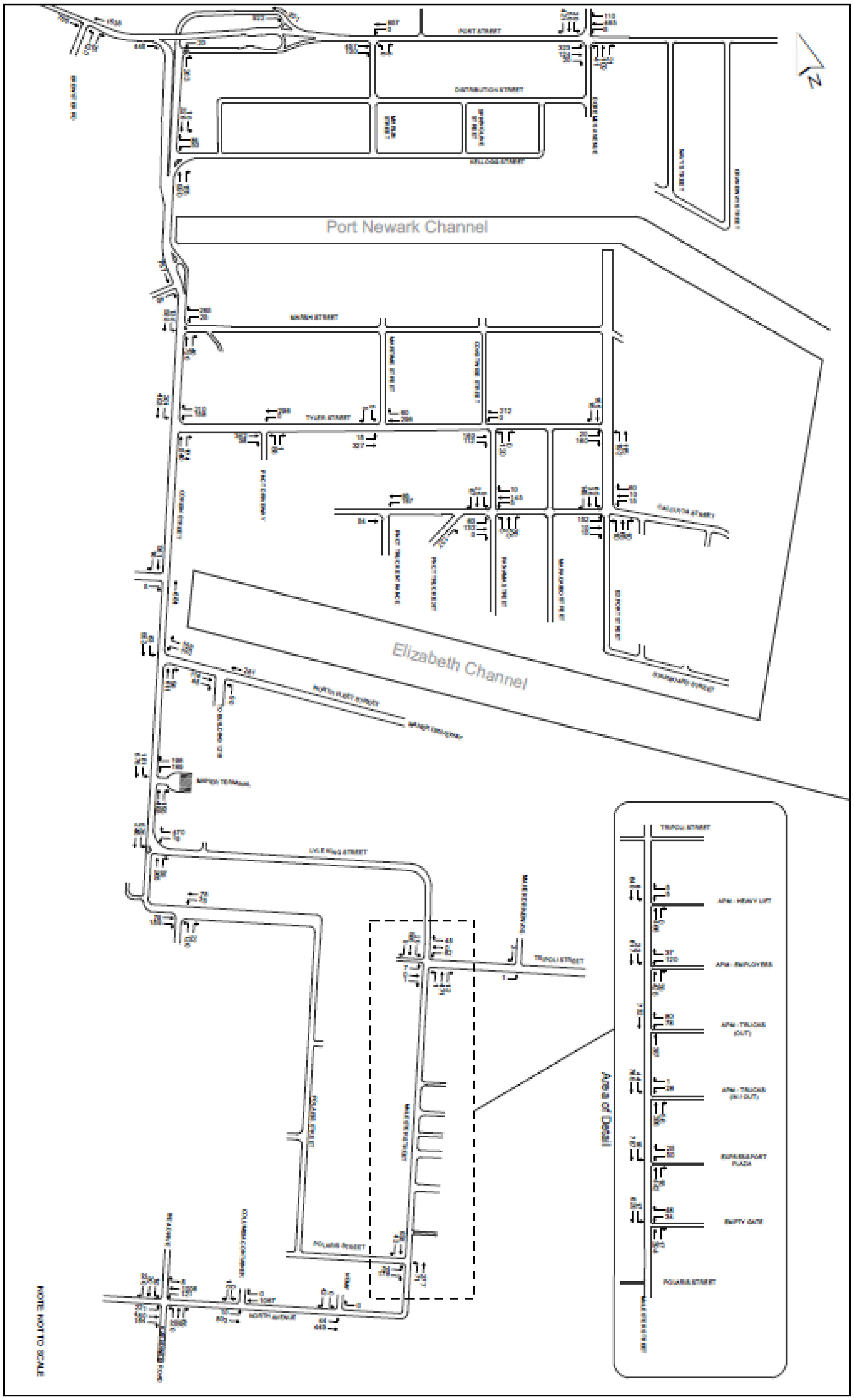
Source: (The Port Authority of New York and New Jersey, 2007)

Figure A- 1: 2006 Turn Counts (7-8AM)



Source: (The Port Authority of New York and New Jersey, 2007)

Figure A- 2: 2006 Turn Counts (12-1PM)



Source: (The Port Authority of New York and New Jersey, 2007)

Figure A- 3: 2006 Turn Counts (3-4PM)

Table A- 1: Visum Calibrated OD (7-8AM)

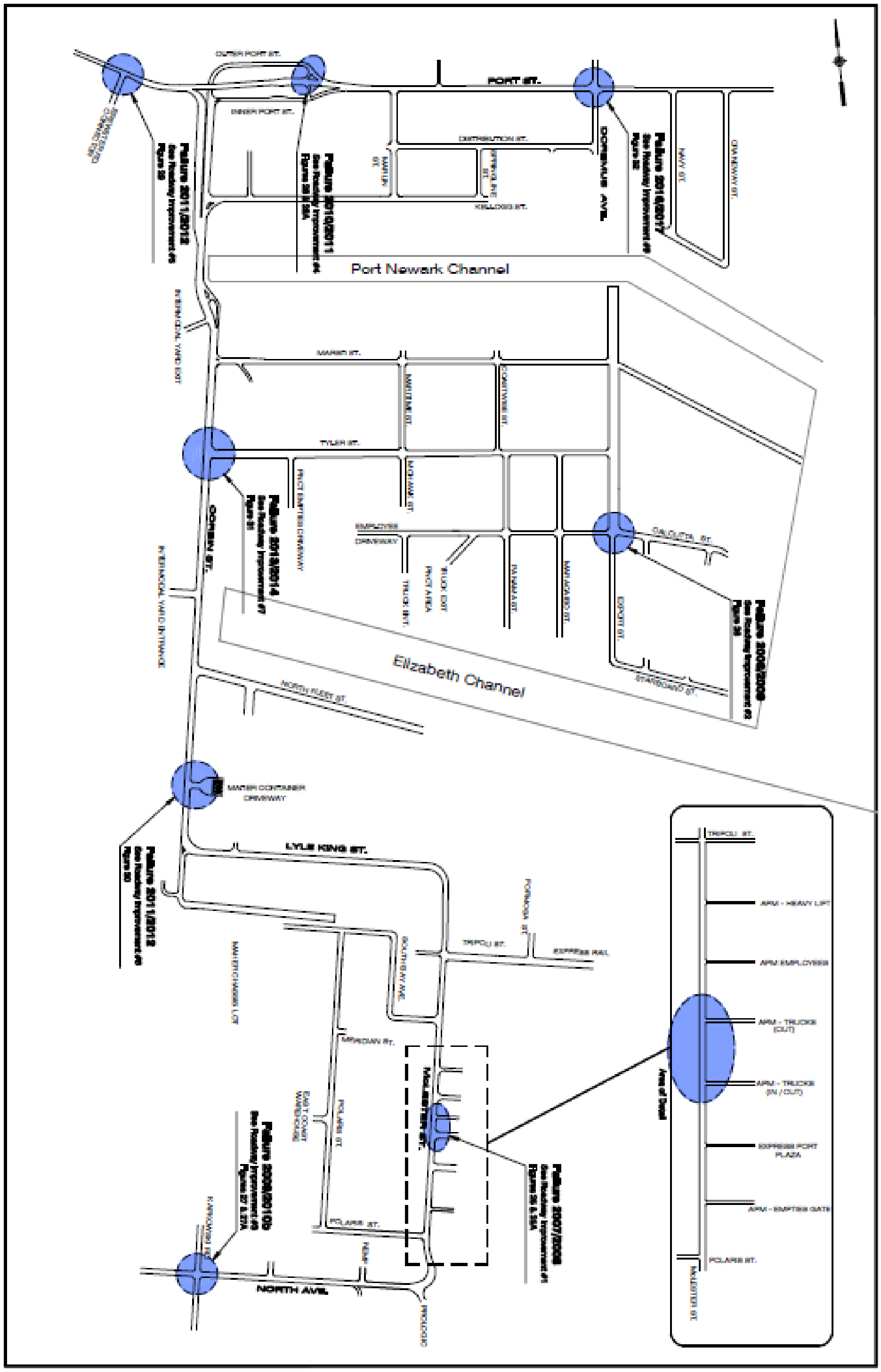
VISUM OD	1	2	3	4	5	6	7	8	9	10	11	12
	567	946	1055	692	208	1014	485	33	222	39	55	0
1	0	800	666	206	0	130	0	0	125	0	0	0
2	110	0	0	47	0	370	0	0	0	0	0	0
3	152	64	0	0	0	0	158	26	52	39	24	0
4	157	3	0	0	0	0	216	0	0	0	0	0
5	0	0	0	0	0	205	38	0	0	0	0	0
6	91	59	0	0	175	0	46	7	45	0	32	0
7	0	0	249	440	33	270	0	0	0	0	0	0
8	0	0	28	0	0	23	0	0	0	0	0	0
9	58	19	0	0	0	0	26	0	0	0	0	0
10	0	0	64	0	0	0	0	0	0	0	0	0
11	0	0	44	0	0	12	0	0	0	0	0	0
12	0	0	4	0	0	4	0	0	0	0	0	0

Table A- 2: Visum Calibrated OD (12-1PM)

VISUM OD	1	2	3	4	5	6	7	8	9	10	11	12
1	0	375	402	190	0	180	0	0	125	5	0	0
2	228	0	0	21	0	245	0	0	0	5	0	0
3	242	71	0	0	0	0	174	4	36	30	8	0
4	154	2	0	0	0	0	289	0	0	0	0	0
5	0	0	0	0	0	166	44	0	0	0	0	0
6	200	91	0	0	149	0	159	3	43	0	34	0
7	0	0	250	333	27	201	0	0	3	2	0	0
8	0	0	40	0	0	25	0	0	0	0	0	0
9	115	0	0	0	0	0	17	0	0	0	0	0
10	0	0	60	0	0	0	0	0	0	0	0	0
11	0	0	52	0	0	11	0	0	0	0	0	0
12	0	0	7	0	0	5	0	0	0	0	0	0

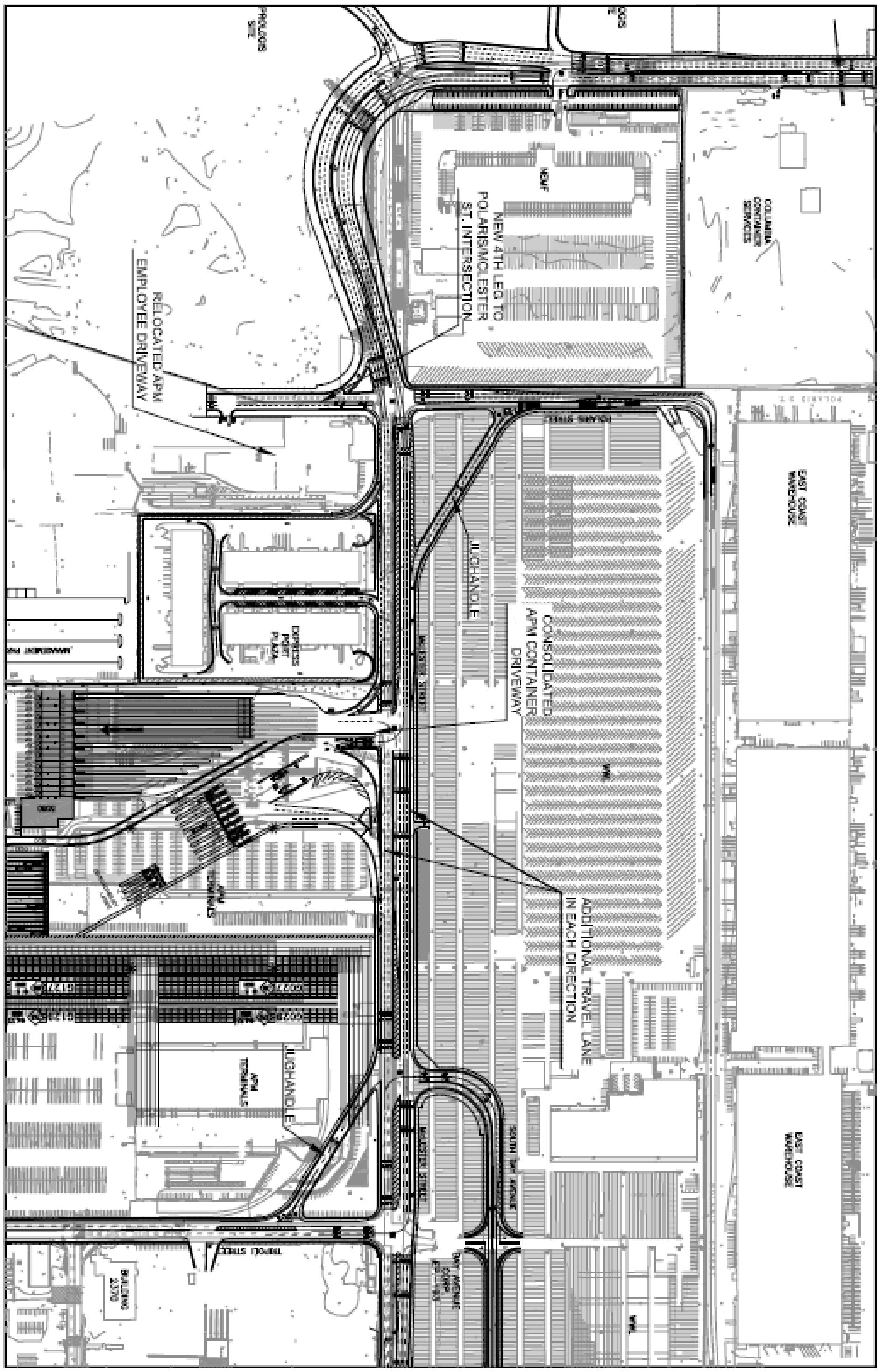
Table A- 3: Visum Calibrated OD (3-4PM)

VISUM OD	1	2	3	4	5	6	7	8	9	10	11	12
1	0	360	232	58	0	31	0	0	100	0	0	0
2	600	0	0	28	0	186	0	0	0	0	0	0
3	326	30	0	0	0	0	259	0	64	2	4	0
4	218	1	0	0	0	0	377	0	0	0	0	0
5	0	0	0	0	0	133	22	0	0	0	0	0
6	234	33	0	0	122	0	278	0	67	0	18	0
7	0	0	149	141	33	137	0	0	1	0	0	0
8	0	0	13	0	0	9	0	0	0	0	0	0
9	84	1	0	0	0	0	46	0	0	0	0	0
10	0	0	75	0	0	0	0	0	0	0	0	0
11	0	0	50	0	0	12	0	0	0	0	0	0
12	0	0	6	0	0	5	0	0	0	0	0	0



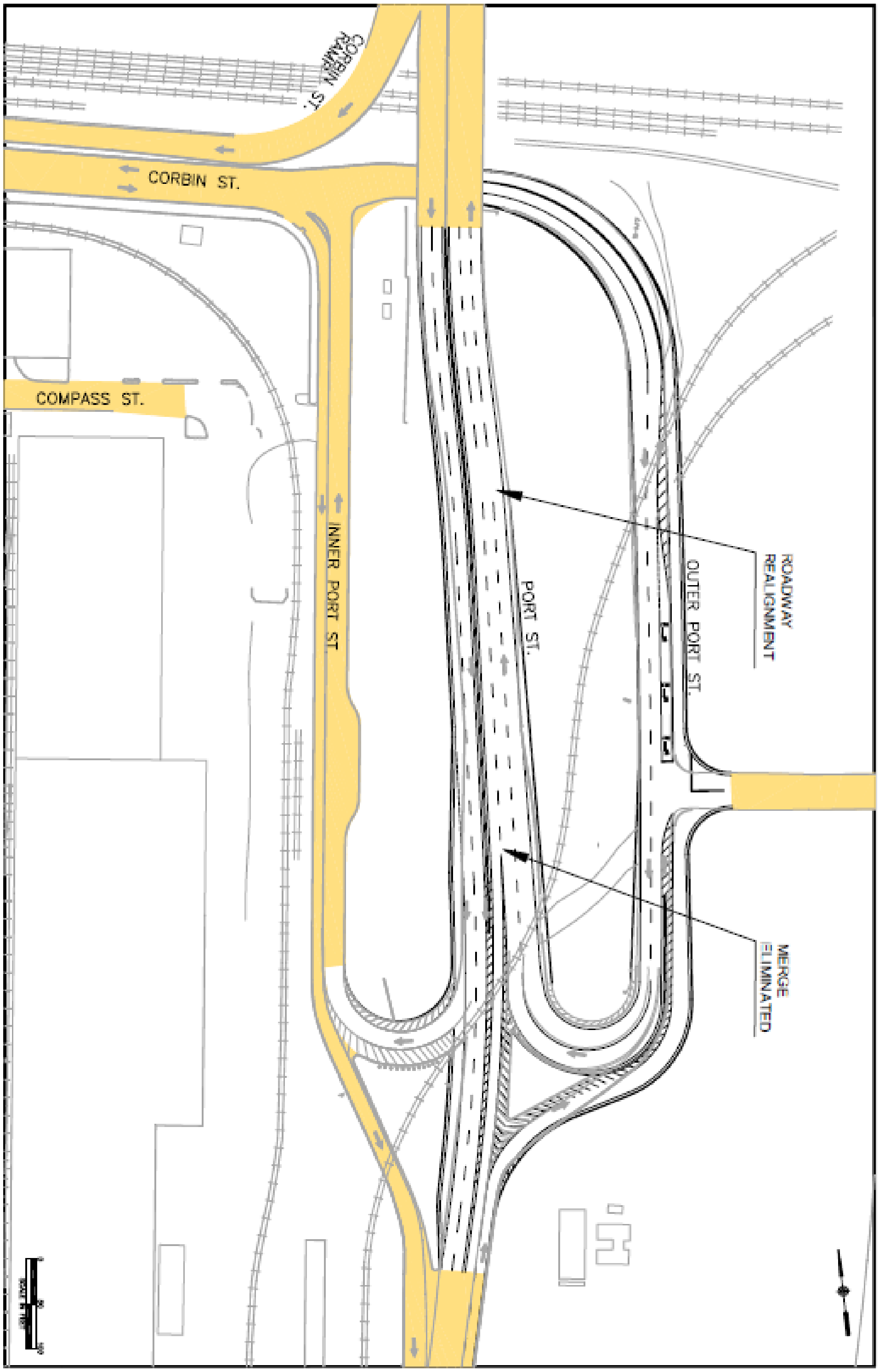
Source: (The Port Authority of New York and New Jersey, 2007)

Figure A- 4: Projected Network Failures



Source: (The Port Authority of New York and New Jersey, 2007)

Figure A- 5: APM and North Street Infrastructure Improvements



Source: (The Port Authority of New York and New Jersey, 2007)

Figure A- 6: Port Street Infrastructure Improvements

BIBLIOGRAPHY

APM Terminals. (2010). *Port Elizabeth Terminal*. Retrieved June 6, 2010, from APM Terminals: http://www.apmterminals.com/americas/portelizabeth/terminalinfo

Bowe, J. (2006). "The High Cost of Congestion". *TRB Freight Roundtable.* Washington, DC.

Bureau of Transportation Statistics. (2009). *America's Container Ports: Freight Hubs That Connect Our Nation to a Global Market.* US Department of Transportation.

Bureau of Transportation Statistics. (2006). *Freight in America, A New National Picture.* US Department of Transportation.

Bureau of Transportation Statistics. (2004). *Freight Shipments in America.* US Department of Transportation.

Bureau of Transportation Statistics. (2009). *National Transportation Statistics 2009.* US Department of Transportation.

Bureau of Transportation Statistics. (2008). *State Transportation Statistics 2008.* US Department of Transportation.

Cambridge Systematics. (2005). *An Initial Assessment of Freight Bottlenecks on Highways.* Federal Highway Administration, US Department of Transportation (USDOT).

Cambridge Systematics, Inc. (2009). *Port Peak Pricing Program Evaluation.* Federal Highway Administration, U.S. Department of Transportation.

COSMOS. (2008). *Automatic Gate System*. Retrieved July 31, 2009, from http://www.cosmosworldwide.com/automatic_gate_system.aspx

Cox, J., Mahoney, D., & Smart, M. (2009). Port Botany's Landside: Market Pricing to Address Congestion. *Economic Papers , 28* (1), 49-55.

D. Pachakis, T. Fidell, J. McNally, and L. Nye. (2008). Achieving Emission Reductions in Container Terminals Through Process Change. Moffatt & Nichol.

eModal. (2009). Retrieved July 31, 2009, from http://www.emodal.com/default.aspx

Federal Highway Administration. (2008). *Freight Story 2008.* US Department of Transportation.

Federal Highway Administration. (2009). *Port Peak Pricing Program Evaluation.* Washington, DC: United States Department of Transportation (USDOT).

Garcia, R. C. (2002). *Implementing A Dynamic O-D Estimation Algorithm within the Microscopic Traffic Simulator Paramics.* UC Berkeley: California Partners for Advanced Transit and Highways (PATH).

Giuliano, G., & O'Brien, T. (2008). Repsonding to Increasing Port-related Freight Volumes: Lessons from Los Angeles / Long Beach and Other US Ports and Hinterlands. *International Transport Forum - Discussion Paper No. 2008-12.* OECD/ITF.

ICF Consulting. (2005). *Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level.* Federal Highway Administration, US Department of Transportation.

Ioannou, P. A. (2008). *Intelligent Freight Transportation.* Retrieved April 2009, from Google books: http://books.google.com/books?id=-HI1YZarRAkC&pg=PA3&lpg=PA3&dq=Intelligent+Freight+Transportation&source=bl&ots=SfBnR44pZI&sig=jGpqU9jSEuv2KDDov_tHABJgxck&hl=en&ei=QBr7SqCuNYa1tgegi4GmCw&sa=X&oi=book_result&ct=result&resnum=2&ved=0CAwQ6AEwAQ#v=onepage&q=

Ioannou, P., Chassiakos, A., Chang, H., & Valencia, G. (2007). *Simulation Test-bed and Evaluation of Truck Movement Concepts on Terminal Efficiency and Traffic Flow.* Metrans TRansportation Center.

Juang, J., & Liu, R. (2003). Evaluating Marine Terminal Gate-In Delays and Rationale Of state Bills. CD-ROM. . *Transportation Research Board of National Academies, Washington, D.C* , 3-7.

Maher Terminals LLC. (2010). *Maher Terminals - Port New York and New Jersey*. Retrieved June 14, 2010, from http://www.maherterminals.com/index.cfm

NAVIS. (2009). *NAVIS yard management solutions*. Retrieved September 2009, from http://navis.com/products/navis/yard-management-solutions/index.jsp

Office of Freight Managment and Operations. (2009). *Freight Facts and Figures 2009.* Federal Highway Administration, US Department of Transportation.

Pachakis, D., Fidell, T., McNally, J., & Nye, L. (2008). Achieving Emission Reductions in Container Terminals Through Process Change. *HAQCC.* Rotterdamn: Moffatt & Nichol.

Pacific Gateway Portal. (2008). Retrieved May 2009, from http://www.pacificgatewayportal.com/pgpsite/

Parsons Brinckerhoff Quade and Douglas, Inc. (2007). *The New Jersey Comprehensive Statewide Freight Plan.* New Jersey Department of Transportation.

PierPass. (2005). *OffPeak Tackles Port Congestion.* Long Beach.

Port Metro Vancouver. (2009). *Trucking*. Retrieved July 2009, from http://www.portmetrovancouver.com/users/landoperations/trucking.aspx

Port Newark Container Terminal. (2010). *PNCT*. Retrieved June 14, 2010, from http://www.pnct.net/Facilities.aspx

PTV America. (2010). *About Vissim*. Retrieved June 16, 2010, from http://www.ptvamerica.com/index.php?id=2312

PTV America. (2010). *About Visum*. Retrieved June 16, 2010, from http://www.ptvamerica.com/index.php?id=1481

PTV America. (2009). Vissim 5.10 User Manual. PTV America.

PTV America. (2009). *Visum 10.0 User Manual.* PTV America.

Starcrest Consulting Group, LLC. (2008). *Drayage Truck Characterization Survey at the Port Authority and the Global Marine Terminlas.* The Port Authority of New York and New Jersey, Port Commerce Department.

Stracrest Consulting Group, LLC. (2007). *The Port of New York and New Jersey Heavy-Duty Diesel Vehicle Emissons Inventory.* The Port of New York and New Jersey.

Sydney Ports. (2008). *Port Botany Landside Improvement Program Final Report - Trial 1 (v1.03).* Sydney: Accenture.

The Port Authority of New York and New Jersey. (2007). *Port Newark / Elizabeth Marine Terminal Comprehensive Traffic Study Update 2006.* New York City: PANYNJ.

The Port Authority of NY &NJ. (2009). *Sea Link*. Retrieved September 2009, from http://www.panynj.gov/port/sea-link.html

The Tioga Group. (2009). Project 14 - Truck Drayage Practices. *Task 3 - Literature Review* . National Cooperative Freight Research Program.

The Tioga Group, I., & Dowling Associates, I. (2008). *SmartWay DrayFLEET Truck Drayage Environment and Energy Model, Version 1.0F User's Guide.* U.S. Environmental Protection Agency.

Theofanis S.,Boile M., Golias M. (2008, March 16-19). Evaluating roadside impact of different gate operation startegies at the container terminal using microsimulation. Annual Transportation Research Forum.