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MICROSIMULATION MODELING
OF GATE APPOINTMENT STRATEGIES AT AN INTERMODAL RAIL TERMINAL

A Thesis

Presented for the

Masters of Science

Degree

The University of Memphis

Aleksandra Maguire

December 2009

Dedication

This thesis are dedicated to my dear mom, Mira Stamenkovic,
whose love, encouragement and wonderful sense of life
will inspire me forever
1952-2005

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Lastly want to thank my Mom and Dad for making sure I was always on the right path in my life and for instilling importance of education. And finally, I want to thank my wonderful husband Kevin, and my daughter Mila, for their unconditional love and support.

ABSTRACT

Maguire, Aleksandra. M.S. The University of Memphis. December 2009. Microsimulation modeling of gate appointment strategies at an intermodal rail terminal. Major Professor: Martin E. Lipinski, Ph.D.

The purpose of this thesis was to analyze the potential effect of gate strategies in reducing the impact of the newly expanded Burlington Northern Santa Fe (BNSF) intermodal facility on the transportation network adjacent to the yard. The goal of the research was to evaluate peak hour arrivals at the gate in a 24 hour period, and to determine if scheduled truck arrivals can relieve congestion at the gates and on the surrounding roadway network. To understand the effects the yard will have on the road network, the network was simulated using Paramics Microsimulation Software. Using the microsimulation software, three cases were evaluated: (1) Existing vehicle demand, (2) Tripled truck numbers from expected future demand and (3) Use of gate appointment systems on increased vehicle demand. Results indicate based on available data that gate appointment systems alone will not have a significant impact on reduction of network congestion.

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Section 1: Introduction

Freight movements in the U.S. are on the rise, and are expected to almost double by 2035, with international shipments growing faster than domestic shipments (Federal Highway Administration 2007). Even with the recent downturn in freight volumes due to recent economic conditions, forecasts are that freight volumes will increase and will result in substantial increases in congestion. Although the rise in goods movements is expected, little has been done to control freight congestion. The intermodal industry which involves more than one form of transportation in a single shipping sequence (Intermodal Association of North America 2009.), is experiencing significant congestion and efficiency issues. Container movements at major nodes, from ports to rail or truck, or from rail to truck are the places where most freight transfers. Delays at these nodes are increasing and they can cause delay in overall transportation to shippers, especially where there are products that require just-in-time operations.

A very distinct example of this issue and the impact of the growth in freight movements at an intermodal terminal is illustrated by the rail-truck terminal of Burlington Northern Santa Fe (BNSF) Railway Company in Memphis TN. In 2006 BNSF Railway began major expansion of its existing Intermodal facility, increasing the capacity from the existing level of 300,000 lifts per year to an ultimate capacity at full build-out of more than one million lifts per year (BNSF Railway 2009). Additional space and cranes will result in improved terminal operations, but the expansion will generate a significant increase in truck traffic entering and exiting the site and will add to the already congested road network around the terminal. The microsimulation modeling approach in this thesis used the BNSF Intermodal terminal expansion as a case study to determine the potential impact of a gate appointment system for relieving gate and network congestion.

Improving terminal capacity and reducing throughput time has been a focus area for operators of intermodal terminals. Some of the measures taken to improve functioning of intermodal terminals are: use of new or existing technologies, use of new larger cranes, stacking containers higher, and reducing idling time of trucks at the gates with the use of different gate strategies.

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 on the road network on nearby arterials, freeways and access ramps. Inefficient gate operations can spill over to the surrounding roadway network causing serious safety and congestion problems, 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 truck-related terminal 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, which are reservation systems for trucks that can be made via phone or internet for times available at the terminal, so that truck arrivals at the terminal can be spaced out.

- Extended hours of operation for terminal gates, which have proven to be very beneficial at ports because they improve throughput of the containers, but they also require changes in port operations, as well as operations of shippers, warehouses and trucking companies. The implementation of the extended gate hours is also linked to peak periods shipping charges to companies that choose to use those times.

- Advanced technologies at the gates and terminals, which involve the use of new terminal operating systems and the use of new modern equipment (i.e. cameras, radio frequency readers on containers, fingerprint recognition, GPS technology).

- Truck buffer areas, which are designed for the situations when truck queues in front of the gate reach the public road. The trucks from public roads are then moved to a truck buffer area, until the queues in front of the gate are cleared out.

The research presented in this thesis is concentrated on evaluating the potential impact of gate appointment systems on truck wait times at intermodal terminal gates. A gate appointment system is used to improve gate efficiency by the scheduling of truck arrivals throughout the day. In this way, truck arrivals are not concentrated at just peak hours, and terminals can use the truck arrival information to organize containers within the yard, by the order of the arrivals. Reduction of the time trucks spend at the gate is important since truck queues at the gates contribute greatly to congestion problems at the terminal area, and also congestion on the road network in urban areas. The environmental impact from idling trucks is also of great concern, because this may cause a significant decrease in air quality. Reducing the time required for throughput is important, since delayed trucks in the supply chain increases the total transportation cost, which eventually is mainly passed on to consumers.

A number of marine container terminals (from now on referred to as ports) are already using gate appointment systems, and there is lot of research published on the use of appointment systems in different ports around the world. Some terminals that are using appointment systems are: The Port of Miami, The Port of Vancouver, The West Basin Container Terminal at L.A., Evergreen L.A. terminal, The Port of New Orleans, The Port of Georgia, The Port of Rotterdam (Euromax 2), and The Port of Brisbane, Australia. The Port of New Orleans (EPA Smartway Transportation Partnership) and the Port of Vancouver have implemented mandatory appointment systems (Port of Vancouver, 2009). Railroad companies use truck appointment systems when they are a part of a port terminal system. Canadian National Railways uses a mandatory appointment system at the Brampton and Montreal terminals to deliver or pick up steamship traffic (Canadian National Railway 2009).

This research investigated the potential impact of gate appointment systems for improving congestion around intermodal rail terminals. Microsimulation modeling was applied to a case study of the BNSF intermodal facility to determine whether or not a gate appointment system would improve congestion levels on the surrounding roadway network.

Section 2: Gate Strategies and Truck Appointment System

The railway industry recognizes that intermodal shipping is increasing, and more terminals are being built or are expanding and improving their operations efficiency to serve this growing need. Goods that are shipped by different modes of transportation need to be delivered in a timely and efficient manner to meet door to door and just-in-time delivery requirements. This requires the use of on-road diesel trucks to move containerized cargo and goods in and out of terminals. Most trucks are operated by independent owner operators or are part of a short haul drayage fleet. At the terminal gates trucks form queues of idling vehicles at peak times of day. This creates significant environmental and operational problem.

To improve overall terminal yard side-to-landside operations, reduce congestion at terminal gates and its resulting economic, operational and environmental implications, alternative solutions have been proposed and implemented over the last few years. These can be distinguished into two planning/control levels: a) the strategic level (e.g. capacity expansion), and b) the tactical/operational level (e.g. extending gate hours, appointment systems etc). The latter strategy, which is the focus of this thesis, is implemented with the objective of reducing congestion at peak hour periods by evening out and controlling the demand at the gate side of the terminal which in theory can reduce or even minimize the stochasticity of the parameters that affect the yard side operations (i.e. time and sequence of pick-up or delivery of containers arriving or leaving the terminal by truck). In addition, overall roadway congestion could be lessened by some of the strategies, due to a trickle-down effect (Cambridge Systematics 2009). In order for these strategies to be implemented and be effective, further encouragement and support needs to be provided to the terminal operators through the development of policies, laws, and enforcement strategies. Examples of such policies are the California Assembly Bill AB 2650 (Giuliano and O'Brien 2007) and the Off-Peak Program created by PierPass (Cambridge Systematics 2009). As demand increases and operation efficiency decreases at the container terminals and the surrounding roadway network, it is expected that more states will follow this paradigm.

2.1 Gate Appointment Strategies

Gate appointment is a truck reservation system that provides a certain number (limited by capacity of the terminal) 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 (Giuliano and O'Brien 2007). 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 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 review of the current literature (Lord and Morais 2006). One way of processing trucks with appointments is to have dedicated lanes. 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 slot interchange area of the terminal (i.e. area for pick-up and delivery of the containers by trucks).

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 to 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 the this strategy: a) providing incentives to drayage operators that will 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 (time it takes to go through terminal) 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.

2.3 Automation Technologies

Growth of freight and containerized traffic around the world has influenced industries to use new and advanced automation technologies for management and operating 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 a Terminal Operation System (TOS), which manages every component of the terminal. Every individual terminal is different and they all decide which technologies they want to implement within the TOS. Technologies used at the terminal gate are:

- *Optical Character Recognition (OCR)* which is used to automatically identify containers, chassis information and truck plate at entry and exit gates, with the use of cameras and scanners (Ioannou).
- *Global Positioning System (GPS)* used to identify container position anywhere within a terminal
- *Radio Frequency Identification Devices (RFID)* are objects that wirelessly transmit locations 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 255).

- *Closed-Circuit Television Camera* is used to monitor traffic and terminal activities and gates.
- *Bar Code Readers and Mounted Data Collection Computer* is used to identify containers at gates and anywhere else at terminals.
- *Real-Time Location Systems (RTLS)* are 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 255).

2.3.1 Automatic Gate System (AGS)

An Automatic Gate System or AGS helps 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 TOS (COSMOS 2008). AGS uses camera portals and optical recognition to read the number on the container, search the billing file to see whose cargo it is, and to 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 (PGP)

Pacific Gateway Portal is a nonprofit company operated by the Port of Vancouver. PGP is a port user information system in a web based form. 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 terminals web page. Appointments are matched with transactions determined by the terminal on the basis of terminal capacities. 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 (Port Metro Vancouver 2009). 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 is a virtual container yard service provider used at the Port of Oakland, as an on-line service. It integrates ocean carriers with motor carriers through a virtual container yard (VCY) to perform mutually beneficial congestion management, to reduce costs and to 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 off-dock equipment needs to cover export bookings" (SynchroMet). SynchroMet reduces empty truck miles and waiting time at local marine terminals, which has a positive impact on the local environment.

2.3.4 SEA LINK

SEA LINK ®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. SEA LINK ® is a uniform truck driver identification system, which helps trucks move more efficiently through terminal gates. SEA LINK ® uses ACES (Automated Cargo Expediting System) to send out information from truck drivers to terminal operators (The Port Authority of NY &NJ).

2.3.5 eModal system

The eModal system applications focus on truck and marine terminal gate interfaces. This 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 mobile graphical interface for checking the cargo that comes to 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.

2.4 Terminal Operating Systems (TOS)

Terminal Operating Systems are operating systems that manage the flow of containers through terminals, ensuring the containers are properly shipped and handled. There are many companies which offer TOS services, but most of them use specific functions of terminal operations. The following section describes TOS available for use on the market.

2.4.1 NAVIS (Yard Management)

NAVIS is an automated system which 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 software 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.

2.4.2 COSMOS System

COSMOS System is a fully automated and integrated yard control and planning system for terminals. COSMOS system has 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). 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).

2.4.3 Embarcadero (ESC) System

ESC 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) which comes with 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 transaction. SmartGATE uses Optical Character Reader (OCR), RFID, and GPS and technologies. A unique feature 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).

2.4.4 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 capability to use one database server for different terminals. CATOS system is integrated with different parts of 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.

2.4.5 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.

Section 3: Case Studies and Related Literature

The impact of tactical/operational level gate strategies on drayage operation efficiency is not very well understood, and is an area where researchers and practitioners are becoming increasingly involved. This section provides a detailed description of the studies that have been published to date.

3.1 Simulation Studies

One of the first studies to appear on modeling the truck arrivals at a marine container terminal was by Sgouridis and Angelides (2002) who performed simulation modeling of all the major processes and handling of containers arriving at a port, in order to improve operational efficiency of the second largest container terminal yard in Greece. This paper focused on the service of the arriving trucks at the terminal. A discrete event simulation model for the inbound arriving containers and their processes was developed based on the existing conditions at the port. The potential terminal improvements were also considered in the model. The objective was to minimize the truck turnaround time (TTT) and to better utilize available handling equipment. Benefits of a computer management system for yard operations were also analyzed. The findings from the modeling were that the arrival of trucks should be organized and evened out throughout the day in order for the TTT to be minimized. The TTT was reduced by 15% with trucks arriving evenly during the day. The use of a computer management system was implemented in the simulation, and the truck import area was improved with the use of two instead of one import pads for trucks waiting to be serviced. The organization proved to be very effective with 40% improvement of TTT, and 24 % improvement of TTT with heavier truck traffic.

Delay of trucks waiting at queues at port terminals is caused by different factors, some of which are large truck arriving volumes, short operation hours of ports and slow gate processes (Juang and Liu 2003). A queuing model was applied to study delay factors by Juang and Liu at the A.P. Moller, Port Elizabeth Terminal (APM). The purpose of the model was to analyze the needs for state legislation in extending gate hours. Parameters used in model are average arriving volume of trucks and service time at gate. Numerous interviews and observations and terminal functions were used to come up with these parameters. Trucks are arriving on random bases at terminal gates, and this arrival pattern is represented with Poisson's distribution. The model results showed that when port terminal has a low ratio of containers arriving over service time, there are no queues. Operations at port terminals should than be organized with fewer gates open and full utilization of terminal equipment. Results from the model also indicated that service time is very sensitive, and any changes to service time can cause huge delays (Juang and Liu 2003).

Impacts of appointment systems on drayage truck efficiency are not very well known. A paper from The Logistics Institute of Georgia on planning of container drayage operations given a port appointment access system looks at planning of drayage operations. Planning is based on an “Integer programming heuristic that explicitly models a port appointment access control system” (Errera and Namboothiri 185). Real world situations are represented by a set of hypothetical problems that represent most accurately behavior or the drayage companies. The model is based on the minimal transportation cost, to determine drayage company operations of pickup and delivery. Drayage firm operations are restricted by the port appointment access system that the port is using. The schedule for a driver of a drayage company is determined on the basis of appointments made to pick up certain numbers of containers during the day, and best routes for a drayage company with the use of appointments during the day. The research shows that optimization of drayage operations is complicated by adding port appointment access systems. Access capacity provided by port terminals is important, since vehicle productivity can be increased by 10 to 24 percent when access capacity is increased by 30 percent (Errera and Namboothiri 2008). Drayage firms need to schedule an appointment by the demands of customers, and also to improve customer satisfaction. The length of the appointment window is also important for drayage firms, and test results indicate that reducing appointment windows by half can have significant impact on drayage firm functioning by reducing their ability to maintain expected levels of customer service.

Modeling of marine container terminals is also important in order to optimize all the processes evolving at an intermodal terminal. A critical issue at marine terminals is gate capacity, since limited gate capacity leads to congestion. A model published in 2008 used "a multi-server queing model to analyze marine terminal gate congestion and analyze cost of trucks waiting at the gate" (Guan and Liu 4). The authors chose one of the marine container terminals in the Port of New York/New Jersey. An optimization model was developed to minimize ovearall gate system cost. Minimizing queing at a gate is good both for the trucking companies, since they don't have to wait long and the gate operators, since they can have a minimum number of gates open while providing good service to all trucks. The goal is to have both satisfied. Capacity of a gate system is determined by the number of gate lanes, by hours of operation, and the productivity that gates operate under. A model that was developed based on gate capacity is the Multi-Server queing model, and it depended on physical layaout and characteristics of the terminal and its operations. The model also depends on truck arrival rate which is dynamic. In order to optimize a gate system, two costs are analyzed – gate operating cost and truck waiting cost. These two costs have an opposite relationship. The goal is to keep both costs at a minimum so that total system cost is minimized. The model is validated using field observed data and statistical testing. For truck arrivals two peak periods in a day were analyzed, one in the morning and one in the early afternoon. The goal was to even out the truck arrival throughout the day.

In order order for a system to be optimized, there are two things that can be done: one is to increase number of gate booths, and the other is to control truck arrival rates, which can be done with truck appointment systems. The authors (Guan and Liu 2008) find the appointment system approach more feasable since it doesn't require greater expenditure of manpower and land expansion. But in order for an appointment sytem to work there has to be coordination between shipping lines, terminal operators, shippers and trucking companies (Guan and Liu 2008). This option needs to include major stakeholders to work on new operating procedures of all the major players included to implement a succesful appointment system.

Huynh (2005) observed operations at the port of Houston (Babours Cut Terminal), to identify potential solutions to reduce truck turn time. Two alternatives that can have a positive effect on truck turn time reduction time are the increase of the yard cranes and the introduction of truck appointment systems. This dissertation (Huynh 2005) looked at the effect of both alternatives, through a simulation model done with simulation package Arena, and also with a regression model for adding more cranes to the yard terminal. Findings were that if more road cranes are used to handle trucks in and out of the terminal, truck turn time will decrease. Huynh also looked at the implementation of truck appointment systems, and he proposed a methodology for determining the number of trucks terminals should allow, especially the trucks allowed in a specific area of yard per time window (referred to as cap) (Huynh 2005). Capping was important in order for an appointment system to be effective so that the number of trucks entering a yard with the appointment system schedule can be served by yard cranes in the shortest time. The issue of no-show and delay is also a part of the model. The model was developed with the maximum number of trucks a terminal can handle with the specified resources. The results of the model showed that truck appointment system was beneficial in reducing truck turn time. On the other hand if the cap was set too low for a certain time frame, it had a reverse effect on both the crane operation and truck turn time.

Freight Information Real-Time System for Transport (FIRST) is supported by the Federal Highway Administration's Office of Freight Management and Operations, the Congestion Mitigation and Air Quality Improvement Program, and the I-95 Coalition. It began in 2001 to provide real time information to the port of NY/NJ freight community members (Srour et al. 2003). FIRST uses Intelligent Transportation Systems (ITS) technology to manage intermodal freight systems. It is an internet-based, real-time network that incorporates different sources of freight information into a web portal that is accessed by port users to obtain port and cargo information. It was designed by the private sector of the intermodal freight industry and public sector partners. The web site used for the FIRST system, provides real-time information on cargo status to all involved customers and terminal operators. Trucking companies can find out the status of containers online and plan each trip to the port so unnecessary trips are not made. A simulation model using accepted transportation queuing theory concepts was developed to study benefits of the appointment system. Queuing activity at terminals was observed with or without the appointment system in use at various levels of acceptance (0-100%). Data used was from field observation of queuing activity over a five-day period in June of 2002. The results were that when appointment systems were used at 100%, the total time vehicles spent in terminal was reduced by 48%, compared to 0% use of the appointment systems. The success of the appointment system depended on the level of compliance, since with the low acceptance queuing increased at gate terminals. According to the FIRST evaluation report (Srour e t al. 2003), this system did not make a significant impact since it was not used as desired.

3.2 Impact of Legislation, Policy, and Regulations

In California in September 2002, AB 2650 (California Assembly Bill) was passed. The bill became active in 2003, and it presents regulations that require marine port terminals to either extend hours of operation for truck pick-ups and deliveries, or begin use of appointment systems for trucks, or find some other ways to reduce truck queues at terminal gate entries (Giuliano and O'Brien 2007). This was the first bill in any US state implemented to lower congestion and air pollution. It includes fines on marine terminal operators who allow heavy-duty trucks to idle for more than 30 minutes while waiting to enter the terminal. The California Port Community Grant Program was established by this law, funded from fines on marine terminals, to provide grants to truck drivers to replace and retrofit diesel engines.

The approach to use a gate appointment system at the port of Los Angeles and Long Beach was studied for the assessment of AB 2650. The appointment system was monitored over a 16 month period from January 2004 through June 2005 (Giuliano and O'Brien 2007). Data was gathered from different sources – interviews with managers of both ports, eight marine terminal operators, trucking industry representatives, longshore labor, public agency representatives and elected officials. During this period both terminals were observed. Surveying of trucking companies supplemented the observations. Data was also provided by terminals.

One constraint this study had is lack of data on terminal gate queues prior to the use of the gate appointment system. Terminal operators had flexibility in making appointments, and a wide range of policies was used across terminals. Trucking companies used 5-30 % of appointments on all three port gates during the observed period. The problem was that no terminal had special arrangements for trucks once they entered the gate and were inside the terminal.

The response from terminal operators on use of the gate appointment was mixed. Some operators did not see a purpose for using them, since appointment systems made their work more complicated with all the activity going on in a port all day. The terminal operators that liked appointments thought that they are essential for terminal operations since arrival of trucks is leveled out throughout the day and this made peak hour times more bearable.

Trucking company response showed that appointment systems were mainly used for import pick up, when trucks would not spend a lot of time in a terminal anyway. The main problem was that even the trucks that had appointments didn't have reduced turn time, because once inside the gate they didn't have priority. Also, there were a significant number of missed appointments.

The study showed that although appointments were used there was no evidence that truck wait time was lowered significantly. The problem with this study is that they did not use any previous queue data (before the use of appointment system), the number of appointments was small, and there was almost no priority for trucks with appointment once inside the terminal. Effectiveness of appointment systems in reducing truck turn times was analyzed with the use of comparison between the averages of terminals that used appointments for 35% or less, and for more than 35% of transactions. The average turn time was compared for both groups, and the wait time was larger for second group, since it was 3 hours, compared to 2.4 hours for the first group. Truck turn time for companies that have used appointments for most of the transactions were longer. The conclusions were that for appointment systems to be effective, a large number of trucks will have to use the appointment system, and there has to be some priority for trucks entering the terminal. For the appointment systems to work some incentives have to be used encouraging trucks and terminals to use them. Terminals do not see gate congestion as a problem, and trucks saw no advantage because it did not reduce their turn time. In order for this study to show good results, more appointments must be made to show the effects of evening out truck arrivals. Gate appointment is still a more favored alternative than extended gate hours, since the cost is lower (Giuliano and O'Brien 2007).

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. All the previous information before the appointment system was in use is assumed. The main concern is lowering queue time, but just outside the gate, since once inside the gate truck waiting is the responsibility of the terminal. The problem was that containers at the terminal were not ready for 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 marine terminal operators need to be required to use appointment systems in order for it to work. That way emissions and noise will be reduced, overall terminal operations improved, and truckers will benefit from better operations.

In February 2004, Assembly Bill (AB) 2041 was introduced in California requiring extended gate hours (Solomon and Bailey 2004). The OffPeak program was created to provide an incentive for cargo owners to move cargo at night and on weekends, in order to reduce truck traffic and pollution during peak daytime traffic hours and to alleviate port congestion, at the ports of Los Angeles (LA) and Long Beach (LB). In July of 2005, the program was implemented and through legislative influence (AB 2041), required the Ports of LA and LB to charge for goods moved at peak hours from 8:00 a.m.

and 5:00 p.m. All cargo owners of loaded containers entering and leaving the ports during the day shifts were charged Traffic Mitigation Fee (TMF).

A recent study by Cambridge Systematics (Cambridge Systematics 2009) evaluated the OffPeak Program in order to analyze the effectiveness of the program in reducing congestion, and the possible factors that can lead to better results if implemented at other ports. Truck traffic analyses at different periods of day were performed and results showed that the program managed to increase the number of trucks at off peak hours, and relieve pressure at gates during peak hours. During the peak-hours truck traffic on the surrounding freeways has dropped by 24 %, after only ten months of implementation of the program (Cambridge Systematics 2009).Truck traffic congestion within the terminal was also reduced throughout the day. 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 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 OffPeak Program didn't have major impacts on reducing congestion on roads. The recommendation was that the congestion problems could be solved with the use of 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.

The Transportation Development Centre of Canada published a study in 2006 that reviewed current practices and startegies 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 via literature review and surveys of ports in North America, followed by on-site visit and interviews. Gathered information included port and terminal activities, technologies, information systems and environmental programs and legislation. The report concetrated on the twelve largest North American ports by highest annual transiting container volumes (TEUs per year), and by availabilty of automated technologies.

The report findings are important for recommendation to Canadian ports to improve port/terminal operations efficiency, reduce delays, reduce congestion and GHG(Green House Gasses) emissions. One of the ways to improve efficiency is use of gate appointment systems and the report studies previous experience of ports that used it. In order for improvements to take place at Canadian ports there has to be strategy in place. This startegy includes policies and regulations, air quality mitigation programs, infrastructure improvemnts, and new port information systems and technologies. Close coordination of all stakeholders is necessary for the succesfull operations.

The use of appointment systems at observed ports was mostly successful (Lord and Morais 2006), and it depended on factors that are producing congestion. The major problem at the ports with no mandatory appointment system was that the truck drivers didn't use it. One reasons for not using the appointment system was the 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 unknown of road congestion on a given day, and the number of trips planned for one day. Some drivers just fail to show up for appointment times. The findings of the report indicate that appointment system must be flexible to be successful. This means that it can: "

- Handle cancellations
- Re-assign reserved time that has been canceled
- Allow appointments to be made during the day of arrival, not just 24 hours ahead of time
- Decline or discourage double/triple appointments for the same container
- Assess 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 found one of the best ways to improve efficiency is by the use of gate appointment systems and documented components to establish a good 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 the succesful operations.

3.3 Appointment System Examples for Marine Terminals

Hong Kong International Terminals (HIT) is one of the world's busiest ports. It operates with limited space, with no possibility to expand to meet the growing demand.

In 2003 Hong Kong operators handled 20 million TEUs, making Hong Kong the busiest port in the world (Murty et al. 2005). With the increase in exports from this region Hong Kong terminal had to optimize their operations.

In 1995 one of the authors professor Katta G. Murty and several IEEM faculty members, started working on a decision support system for the Hong Kong port. One of the critical decision problems at the port is allocation of appointment times to external trucks to minimize their turnaround time, to smooth out truck arrivals, and reduce the number of trucks in the yard during busiest times. Hong Kong International Terminals started using an appointment system in 1997. Trucks coming to terminal to pick up had to make an appointment, and the trucks bringing export containers didn't have to make the appointment. The reason for this is because most trucks that bring export containers arrive from mainland China and they have to wait at the border crossing.

In every 30 - minute time slot, each block at the terminal has a certain number of appointments available. Numbers of appointments at each block are determined using a simulation model. In order to develop the simulation model some values had to be estimated. The number of external trucks that didn't show up for appointments is estimated from past data. The time it takes a yard crane to serve a truck is also estimated. The target is to keep the number of trucks waiting for service at six or less. Since there are not a lot of slots available the earlier the trucker makes an appointment the more slots it will be able to choose from. If the truck tries to come in with no appointment, it has to go to a booking center to make an appointment, unless it is an external truck with an export container that also has to pick up a container. The results from implementing the gate appointments at the Hong Kong International Port Terminal were that turnaround time for external trucks was reduced by 30 percent from 60 minutes to 40 minutes.

The Port of New Orleans uses an appointment system, which is mandatory, to improve the terminal operations and the use of the system. The appointments are made online with the use of a Gate Entry Management (GEM) system. The operation of the web-based system is organized with the use of digital cameras, optical character readers, transponders and AM radio broadcasting within gate system (EPA Smartway Transportation Partnership 2009). This system allows trucks companies to make appointments within available time periods, and it also allows terminal operators to organize terminal operations in the order of arriving trucks. Truck drivers have a 30 minute window within their scheduled appointment. The amount of time a truck spends at the gate is also reduced, because all the paperwork is eliminated with the use of the web application. Terminal operators also have more time to eliminate possible errors. The use of the appointment system was very beneficial for the Port of New Orleans, since truck idling at gate was reduced, terminal operations and throughput was improved, and truck companies and terminal operators are cooperating better with fewer delays.

The Georgia Port Authority including Port of Savannah also implements a web-based appointment system for containers entering and leaving the port. The system is a real-time online system and it provides 24-hour access to customers to update data on container shipments. Since its implementation, the system has been very beneficial to The Georgia Port Authority because it has managed to lower truck queues and waiting times at gates and overall truck processing time at terminals by 30 percent (EPA Smartway Transportation Partnership 2009).

3.4 Potential Impact of Gate Strategies at Intermodal Container Terminals

Gate strategies at intermodal container terminals are a very important part of the terminal operation process. These strategies can solve problems of truck queues at the gate and help with congestion problems associated with queues, as well as the vehicle emission problems. Random arrival of trucks can also be controlled with the use of different gate strategies, and peak hour truck traffic can be handled better. Terminal operations can be better utilized and organized, when truck arrival is more even, and the congestion is lower.

In order for the gate strategies to work all the involved users need to agree to use gate strategies as required. A large percentage of trucks will have to use the appointment system, and there has to be some priority for trucks with appointments. Incentives are necessary to get trucking companies to buy-in to appointment systems and make their appointments. 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 this type of 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 good option to increase throughput at terminals. It will require that additional workers be added, hours and pay contracts adjusted and buy-in from associated businesses, but there is potential for greater amounts of container movement without the need to expand terminals.

Terminal operators at the container terminals usually do not like to use appointment systems, because it adds extra effort to an already busy terminal operation process. The trucks have to make the appointment within the available slots, and terminal operators have to organize not only appointments, but also containers in order for efficient pick up. Trucks arriving at gates have to be registered and identified. This process can take some time depending on the level of automation each terminal uses. Additionally, extra effort has to be made to speed up the processing of trucks with appointments inside the terminal.

The length of the appointment window or time provided for a trucking company to drop off or pick up the container is also an important measure. It is important that trucks are given enough time, considering the fact that they can be delayed on roads. The possibility of rescheduling appointments is another option that intermodal terminals need to offer. As there are no fines or other penalties associated with missing an appointment window, not all trucks will show up for scheduled appointments. That is why regulations and incentives need to be in place for both terminals and truck companies.

The most favored option in regulation of truck traffic at the terminal gate is the use of technology. Automation Technologies mentioned in the previous section are very advanced and promise solutions to a lot of problems in terminal operations. Gate technologies like AGS are already used in a lot of terminals, and they are good because they don't need as many terminal operators on the gate side. The BNSF Intermodal terminal in Memphis is already using AGS combined with Optical Character Readers and cameras, which is helping significantly in speeding up gate operations. AGS is favored for both terminal operators and truck drivers because no extra work is involved in making or arranging gate operations and access.

Intermodal rail terminals use a lot of similar equipment and technologies, as well as the strategies as the marine container terminals. Port terminals are usually open Monday-Friday from 8am to 6pm; while most of the rail intermodal yards are open longer (e.g. The Burlington Northern Santa Fe - BNSF yard in Memphis is open 24 hours, 7 days a week). Rail terminals have an advantage over port gate terminals, since they do not have operating time constraints. The increase in containerized traffic and bulk traffic is a problem for both, since more trucks move at the same time, making queues of idling trucks at the gate.

Gate strategies in intermodal rail terminals are mostly in use when they are part of marine container terminals, and the intermodal rail terminals mainly use the AGS. AGS provides efficiency and security at the rail terminal gates, ensuring that trucks get inside rail terminals much faster, which eliminates or lowers the wait time at the gate. Use of gate appointments system with AGS at the intermodal terminals can be a good option when trucks arrive at the terminals at the peak times of the day.

Storage of containers can be either on chassis or storage on the ground. Storage on chassis requires more space, but it is beneficial because it can lower truck turnaround time. Chassis storage of containers does not require yard cranes or stacking equipment, as these containers are parked at the assigned places. Trucks that come to drop off or pick up containers usually use chassis storage. These trucks typically use appointment systems less, as they only come to pick up or drop off a container, and the containers on chassis do not have to be reorganized as in grounded operations. Storage on the ground is similar to storage of containers at the ports where containers are usually stacked at a storage area, which saves space, but can slow down operational time. The rail intermodal terminal organization is thus different because of the use of on-chassis storage.

Gate strategies are becoming a very important part of the organization of the Intermodal terminals. Currently they are in use more at the marine container terminals than in rail intermodal terminals. As the amount of containers handled by rail increases some new strategies may have to be implemented to insure efficient rail terminal operations. Thus, gate strategies, and in particular appointment systems, may prove to be useful in improving operations at rail intermodal terminals.

In order to evaluate effectiveness of gate strategies on the BNSF Rail Intermodal Terminal, especially potential use of appointment systems, a road network model is developed for this research. The model represents actual road conditions on the transportation network around the yard, and is used to simulate the effect of gate strategies on the truck arrivals and potential queues at the gate assuming truck volumes increase with the expanded facility capacity.

Section 4: Model and Methodology Development

This research was conducted in order to further evaluate the importance of gate strategies and appointment systems using the specific case study of the BNSF intermodal terminal in Memphis. Outlining the advantages and disadvantages of gate systems is also a part of the research objectives.

The road network in the area around the BNSF Intermodal terminal was modeled with the Paramics micro-simulation software. The simulation was performed to analyze the effect of road network delays and congestion in a 24-hour period on the gate operations. The simulation was performed for current demand, and expected worst case scenario numbers after the expansion of the BNSF intermodal terminal. Using a gate appointment system and smoothing out the arrival of trucks was also simulated to evaluate the potential impacts. The results were used for the representation and comparison of different scenarios designed to approximate the current system, potential truck volume increases due to the facility expansion, and the effect of an appointment system. The model methodology and the results from the simulation can be used in future research when more current and representative volume data is available.

4.1 BNSF Facility Description

The BNSF intermodal rail-rail and rail-truck terminal in Memphis is an example of a large intermodal terminal that may experience some of the problems that the freight industry is facing, and thus was selected as the case study for this research. Memphis is strategically located on the Mississippi River and in the central United States. It is served by five class one railroads, seven interstates, fourth largest inland port in the U.S., the world largest hub airport by freight volume handled and it is a preferred location for numerous distribution centers and logistics companies because of its location (The Memphis Regional Chamber Departments of Economic and Community Develpoment 2007).

The BNSF Railways intermodal terminal expansion was completed in 2009. The new intermodal facility encompasses 185 acres, and it has a total of 48,000 feet of railway tracks. The new facility can load and unload trains up to 7,500 feet long, and the yard is equipped with 8 total electric, rail-mounted gantry cranes. These cranes are environmentally friendly, because they do not produce any emissions, and the number of container lifts per year can be tripled from the existing number of containers handled by previous intermodal facility. The parking area is designed for up to 6000 trucks, with 4000 spaces for stacked parking and 2000 spaces for wheel parking. The gate layout at the BNSF Intermodal terminal consist of 8 In-Gate lanes and 7 Out-Gate lanes. The gate operations are utilized with the use of AGS and optical character cameras. The yard management can also use data from this gate system to better organize overall terminal operations (American Shipper 2009). The BNSF Intermodal terminal is located in a major industrial corridor of southeast Memphis, with a high concentration of trucking companies, warehouses and distribution centers, See*, Figure 4.1. Warehouses, Trucking and Logistics Companies in the study area, and Figure 4.2 Zoning and land use in the study area*. Most of the BNSF customers are located within 15-mile radius of the terminal. The current expansion, if fully utilized, will exacerbate the congestion problems on the transportation network in the area, which is already used heavily by trucks. One of major congested freight corridors in area is a Lamar Avenue. It is considered a major connector in the area since it connects various distribution centers, warehouses, trucking companies, the BNSF Intermodal terminal, the Memphis International Airport and the FedEx hub. To reduce the impact of road congestion problems, there are some strategies that can be applied within the intermodal terminal.

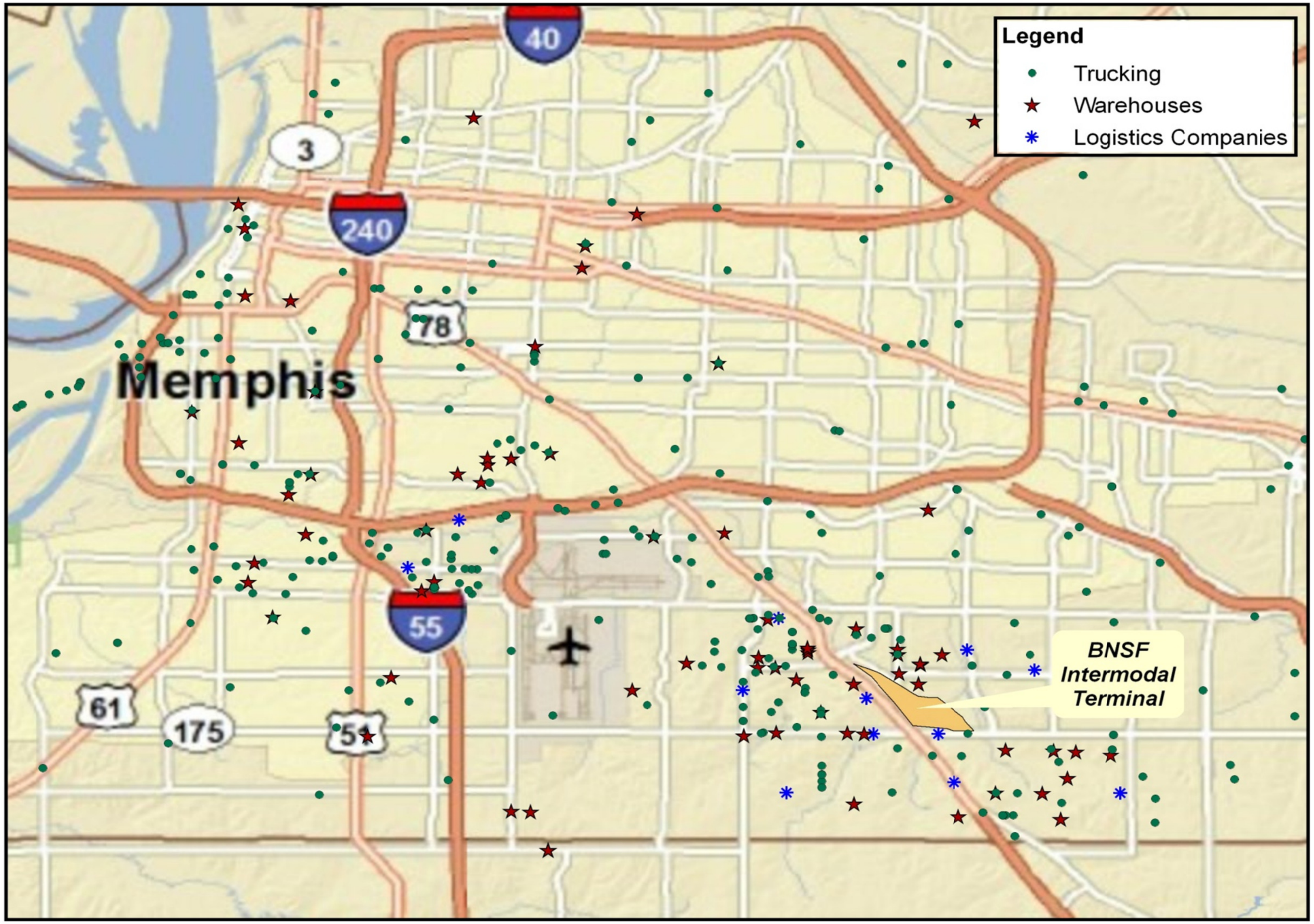

Figure 4. 1 Warehouse, Trucking and Logistics Companies in the study area

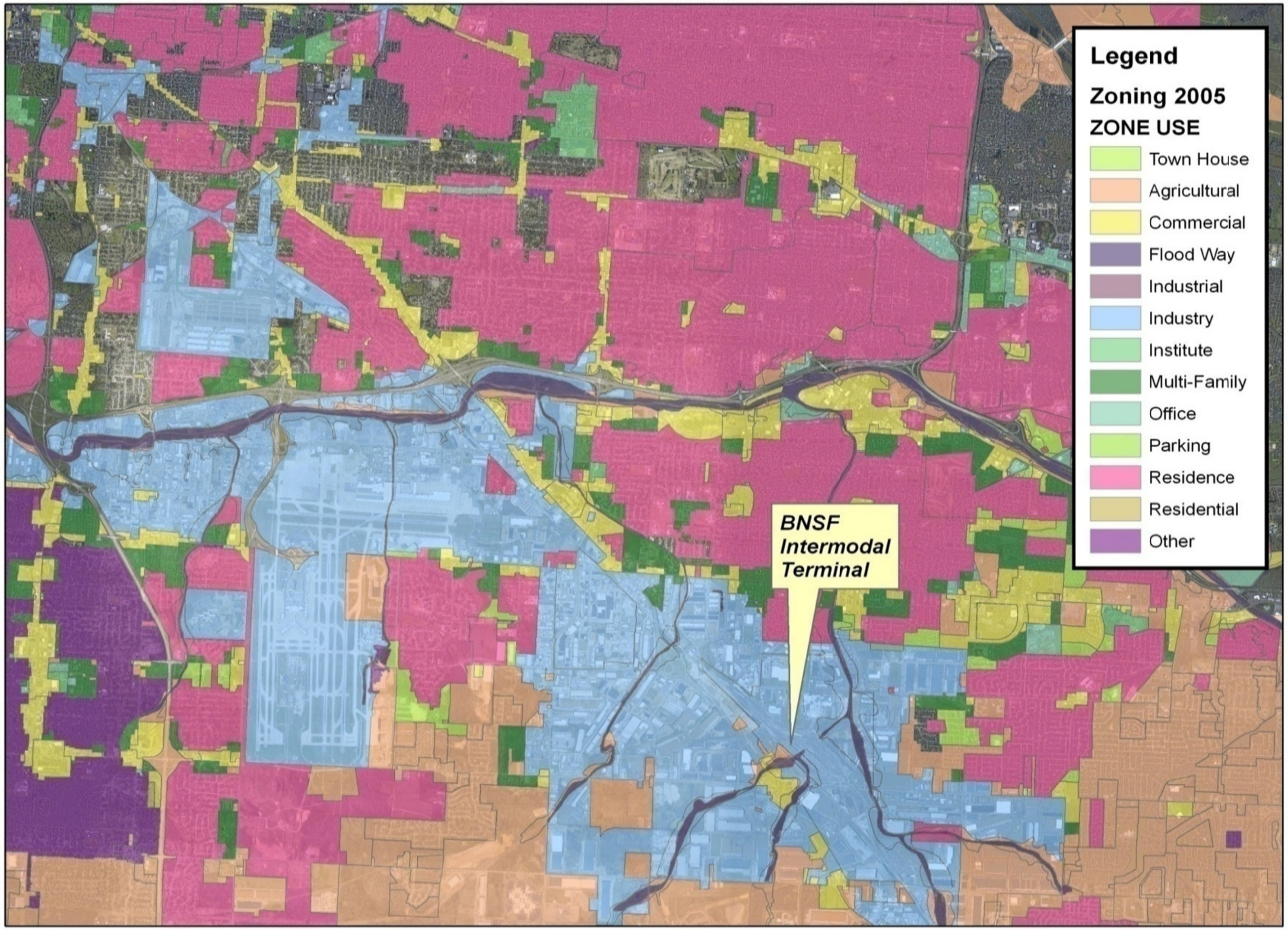

Figure 4. 2 Zoning and land use in the study area

The entrance and exit for the BNSF yard is located at the Lamar Avenue and Pleasant Hill road intersection. Truck traffic is heavy on the Lamar Avenue, as well as the surrounding roads, leading all the way to the Interstate 240 and the Interstate 55. The average level of service on Lamar Avenue at each intersection at different time periods is obtained from the University of Memphis Intermodal Freight Transportation Institute study from 2009, which is yet to be published (Cambridge Systematics and the University of Memphis) shown in *Table 4.1*.

Table 4.1. Average Level of Service in Lamar Avenue at Various Times

Intersection	**A.M. Peak Hour 7:30-8:30**	**Lunch Peak Hour 11:30-12:30**	**Midday Peak Hour 2:30-3:30**	**P.M. Peak Hour 4:30-5:30**	**Average**
Lamar at American Way	C	C	D	F	D
Lamar at Pearson	B	D	B	B	C
Lamar at Democrat	C	E	B	B	C
Lamar at Knight Arnold	B	C	B	C	C
Lamar at Winchester	F	F	F	F	F
Lamar at Concorde	E	B	A	B	C
Lamar at Shelby	F	F	F	F	F
Lamar at Tuggle	E	F	A	B	D
Lamar at Holmes	F	E	E	F	F
Average	D	D	C	D	D

Source: The University of Memphis Intermodal Freight Transportation Institute

Major highways and roads are used by trucks and that is why the simulation model only concentrates on those roads and the roads that lead to main transportation facilities.

4.2 Paramics Microsimulation

Simulation modeling is useful and effective for different transportation problems, and microscopic simulation is a good alternative that can help users evaluate potential solutions to many transportation problems. Microsimulation is a process of modeling individual vehicles and it is useful in modeling the area at and around intermodal terminal gate operations to predict congestion. Paramics is microscopic simulation software and it is very useful because it can model behavior and movement of individual vehicles on road networks (Quadstone Paramics 2009). Capabilities of Paramics are virtual modeling of transportation infrastructure and simulation of road traffic and other forms of transportation in microscopic detail. Paramics can model different types of vehicles, which can have different behaviors and characteristics associated with them. This is very valuable for areas with a high percentage of truck traffic. To accurately represent this complex and dynamic system, however, extensive data are needed to capture the overall movement of traffic in and around the rail intermodal terminal, as well as the spatial and temporal variations of these movements.

4.3 Data Description

The simulation model development for the BNSF intermodal terminal was feasible only if availability of data is sufficient. For the model development a number of data sources were required:

- Roadway network data which including the number of lanes, length of roadways, speed limit of the roadways, number of nodes and design of intersections.

- Number of passenger vehicles that travels between the zones in boundary area in the form of Origin/Destination Matrix
- Number of trucks that travel between zones in the boundary area in the form of Origin/Destination Matrix.
- Signal timing at the intersections.

The network in Paramics was built based on the road geometry obtained from the City of Memphis geographic information files. Network data had to be checked for errors and corrected to represent the actual road network. More specifically, the number of lanes and posted speed limits were adjusted based on Shelby County aerial photography and data provided from the geographic information files. Some nodes in the network were disconnected or were not properly aligned, and this had to be corrected as well. Some of the intersections in the network had multiple fragments, and this made signalization of intersections impossible. These data were edited in the Paramics editor to reflect the most accurate conditions on the roadways as possible.

Borders of the modeled area were selected based on the connectivity from the point of the BNSF Intermodal yard and the exits to major roads and highways. The area was divided into zones based on US Census Bureau data on Traffic Analysis Zones (TAZ) from the year 2000 (US Census Bureau Traffic Analyis Zone). A traffic analysis zone (TAZ) is an area defined for traffic related data, especially trip to work and work to home statistics. Boundaries of these zones usually follow physical and natural geographic features, like roads, rivers, borders. Data on the transportation facilities in the area is important for development of Traffic Analysis Zones (TAZ), as theses data help define the TAZ boundary area better.

The data on transportation facilities were gathered from the Memphis Chamber of Commerce, which is compiled from the InfoUSA data (InfoUSA). Zones with large numbers of transportation and warehouse facilities generate and produce more truck related traffic than other zones, and they were divided in two separate zones. The Memphis International Airport, FedEx Hub and the BNSF Intermodal terminal were considered as the special generators. Highway ramps and exits were also considered major connectivity zones. The final simulation model developed for this research consisted of 53 zones, of which 45 were internal, or zones within the boundary area, and 8 were external zones, or zones outside the boundary area. *Figure 4.3* shows a snapshot of the roadway network and the traffic analysis zones. The external zones were located on the major roads or highway exits in the area, and they were numbered from 10 to 80. The internal zones were numbered based on the US Census Bureau original TAZ zones derived for the model.

Figure 4. 3 Road network and traffic analysis zones

One of the most important pieces of information needed for simulating the traffic condition in the study area was the number of vehicles during the 24-hour period so that the effects this has on the gate at the BNSF intermodal yard could be evaluated. Passenger vehicle demand data was obtained from the Memphis long range travel demand model (Memphis Long Range Transportation Plan 2007). The origin and destination (OD) data from the Memphis model was aggregated for the modeled area around the BNSF intermodal terminal. External zone trip data was also obtained from the Memphis long range travel demand model and the number of zones was aggregated to represent major road exits and entrances.

All of the OD data was complied into one 53 x 53 OD matrix, for a 24 hour period, from four different matrices in the Memphis model, for four different time periods. This matrix contains trips made between internal to internal zones, internal to external zones, and external to external zones.

Truck count data as well the OD data for all the TAZs in the modeled area were harder to collect. The Quick Freight Response Manual (QRFM) has guidelines available for incorporating freight into modeling processes (QRFM II 2007). Truck trip generation rates (*Table 4.2*) were obtained from the Phoenix Metropolitan Urban Truck Model (U.S. Department of Transportation 2008), and were applied to the socioeconomic data at the zone level, resulting in the total number of trucks, and also number of Four-Tire trucks, Single Unit Trucks and Combination trucks.

Table 4.2. QRFM Trip Generation rates

Generation Variable (Employment or Households)	Four-Tire Trucks	Single Unit Trucks (6+ Tires)	Combination Trucks
Agriculture, Mining, and Construction	1.110	0.289	0.174
Manufacturing, Transportation/Communications/Utilities, and Wholesale	0.938	0.242	0.104
Retail Trade	0.888	0.253	0.065
Office and Services	0.437	0.068	0.009
Households	0.251	0.099	0.038

Source : Quick Freight Response Manual II, 2007

Effort was made to collect information on the industries located in the area, including type of industry and number of employees. The data on types of industries acquired from the Memphis Chamber of Commerce were only available for Manufacturing and Transportation Industries, but not for the remaining clusters of industries that the QRFM provides truck trip rates for.

To address this issue, data for the generation variables per TAZ was obtained through the U.S. Census Bureau which has data availability at the Zip code level, (i.e. number of employees per different type of industry). Estimation by the portion of the square footage area of TAZ, within the square footage area of the zip code was made. Truck trip numbers were then generated, but the QRFM guidelines assume that these truck numbers are for both production and attraction at the zones. The next step was to obtain an OD matrix for the truck movements between all the zones. These data could not be developed, due to the lack of information on the factors for truck distribution between zones. Truck OD's in the modeled area were then assumed in order to run the model. The percentage of trucks in the whole modeled area was assumed to be 10 percent of all the vehicles.

Signal timing at the intersections for the modeled area was applied at 13 intersections (*Figure 4.4* shows these signalized intersections). Signal phase data was provided by the City of Memphis. The remaining intersections were left unsignalized.

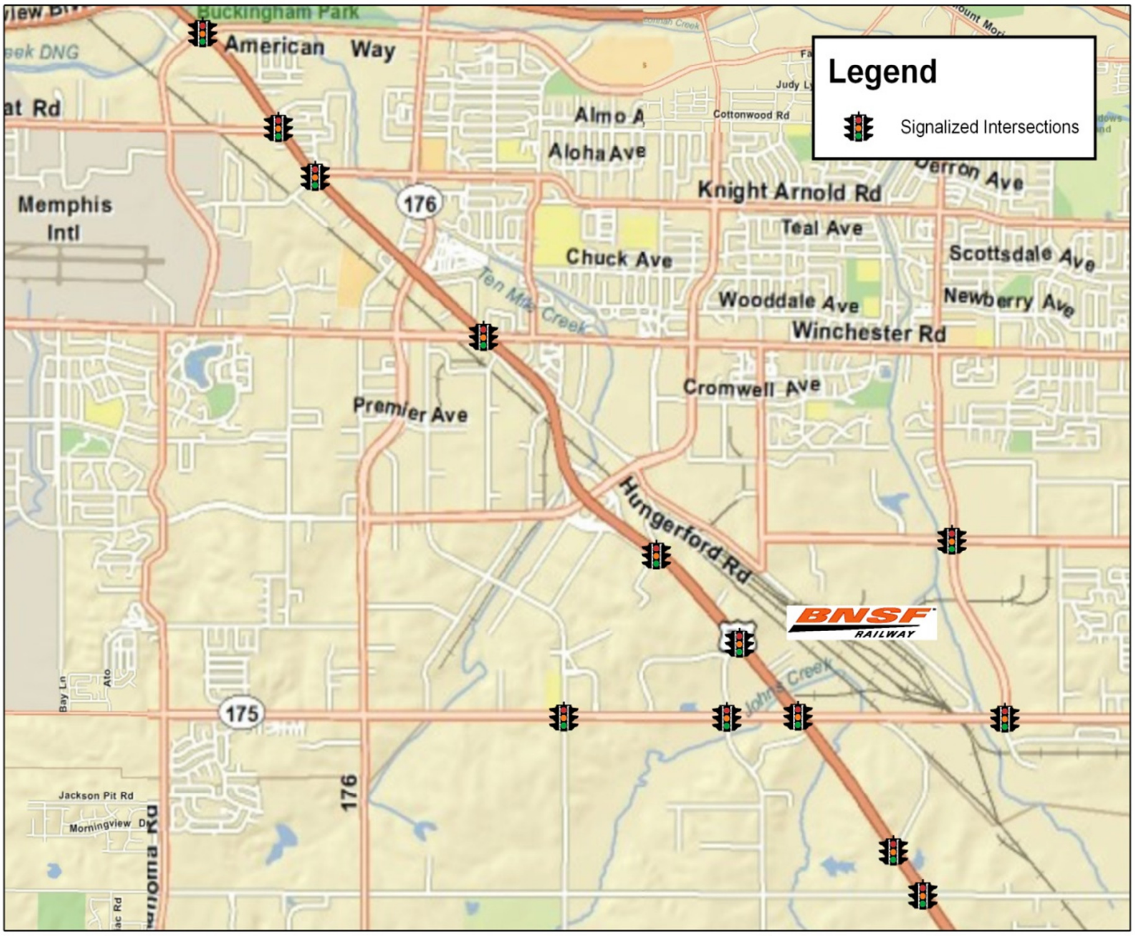

Figure 4. 4 Signalized Intersections in the Modeled Area

4.4 Model simulation cases

Three different cases were simulated

Case 1. Evaluation of the existing road network conditions and current demand

Case 2. Estimation of the impact of the new BNSF intermodal rail terminal expansion. For this case, truck demand was tripled from the existing estimated truck demand.

Case 3. Evaluation of adding a gate appointment system at the BNSF intermodal rail terminal. Truck demand generated and attracted at the BNSF terminal from Case 2 was released on the road network evenly over the 24 hour period.

Time of day distribution of the demand for the first two cases was obtained from the Memphis long range travel demand model (Memphis Long Range Transportation Plan 2007), and is shown in *Table 4.3*. All purpose trips were used for modeling purposes. Peak hour periods for the trucks in the simulation model were assumed to follow closely peak hour periods for the other vehicles. The Memphis model provides peak hour period truck demand from the vehicle classification count data, as shown in *Table 4.3*. When compared, values for peak periods for trucks and other vehicles by all purposes are very close. The simulation of the road network is performed using hourly demand distribution of all purpose trips for all vehicles. Release of the vehicles in the network was based on the hourly factors shown in tables 4.3 and 4.4.

Table 4.3. Trip by purpose by time period

Time Period	Percent of trips by purpose				
	Journey-to-work	**HBSchool/ HBUniversity**	**Other Home-Based Purposes**	**Non-Home-Based**	**All Purposes**
0:00-1:00	0.8	0	0.4	0.1	0.4
1:00-2:00	0.2	0	0.1	0.1	0.15
2:00-3:00	0.3	0	0.2	0.1	0.15
3:00-4:00	0.4	0	0.1	0	0.17
4:00-5:00	0.7	0	0.2	0	0.3
5:00-6:00	2.9	0.2	0.5	0.2	1.16
6:00-7:00	9.3	7.8	2.5	0.8	5.46
7:00-8:00	16.7	23.6	7	3.8	12.52
8:00-9:00	7.8	11.7	5.8	3.4	6.79
9:00-10:00	3.1	3.1	5.1	3.8	3.9
10:00-11:00	1.3	2.6	4.4	5.4	3.27
11:00-12:00	1.8	3.3	4.7	13.2	4.42
12:00-13:00	2.2	3.7	4.8	19.1	5.17
13:00-14:00	2.4	2.1	4.7	12.2	4.41
14:00-15:00	4	13.8	7	11.4	8.54
15:00-16:00	7.1	12.3	8.4	9	9.4
16:00-17:00	10.1	3.6	7.3	5.2	7.39
17:00-18:00	12.3	4.4	8.6	3.7	8.56
18:00-19:00	6.4	1.9	8.9	3.1	6.22
19:00-20:00	3.1	1.6	7.4	2.3	4.2
20:00-21:00	2	2.3	5.1	1.4	2.95
21:00-22:00	1.9	0.9	3.7	1	2.24
22:00-23:00	1.7	1	2.1	0.4	1.32
23:00-24:00	1.4	0.2	1.2	0.2	0.9
Total	100%	100%	100%	100%	100%

Source: Memphis Long Range Transportation Plan 2007.

Table 4.4 Time of day release factors by truck type

	AM Peak	Midday Peak	PM Peak	Off Peak	Total
Four Tire Trucks	17.8	29.6	26.2	26.4	100
Single Unit trucks	17.4	34.5	25.2	22.9	100
Combination trucks	16	33	23.8	27.2	100

Source: Memphis Long Range Transportation Plan 2007.

4.5 Model Results

The simulation was performed for a 24 hour period, and the measures of performance were generated for every hour. These measures included: vehicle flow, delay, occupancy of lanes, average travel time for vehicles between specific OD pairs, queue lengths, intersection delay and LOS (Level of Service).

We should note that although the model was successfully implemented, the results are derived from assumed truck data. Truck data collection is a detailed process and every Metropolitan Planning Organization (MPO) should be involved in gathering it in order to perform successful modeling of the urban areas with a high percentage of truck trips. When more data is available on truck activity, more accurate results can be generated.

The results from the simulation can be applied for network analysis, and possible truck delays and congestion at different points of the network. These results can be used to analyze the queues at the terminal gates at the certain times of day in a 24-hour period of time.

Model results were described for the three different cases defined in the previous section. The first case is the analysis of the existing network with the current numbers of vehicles provided from the OD matrix. The results are shown in *Figure 4.5* which show the LOS for the different links in the network for the AM peak time from 8 am till 9 am, and in *Figure 4.6* from 5 pm till 6 pm. These times showed the worst overall LOS on all the intersections in the area. The area chosen for analysis is the area around BNSF terminal, since the impact from the truck traffic on the surrounding intersections is the greatest.

The results from AM Peak show that there is significant congestion and delay at the Lamar Avenue and east Shelby Drive intersection, as the LOS is mainly F in both directions on Lamar Avenue. The other critical area is at the Lamar Avenue and Holmes Road intersection, where there is significant delay at westbound direction of Holmes Road, and northbound direction of Lamar Avenue.

The results for the PM Peak show significant delay on the same intersections of Lamar Avenue and east Shelby drive, with more delay at east bound direction of east Shelby Road. Holmes Road is also congested at the PM peak time, with longer delays at eastbound direction.

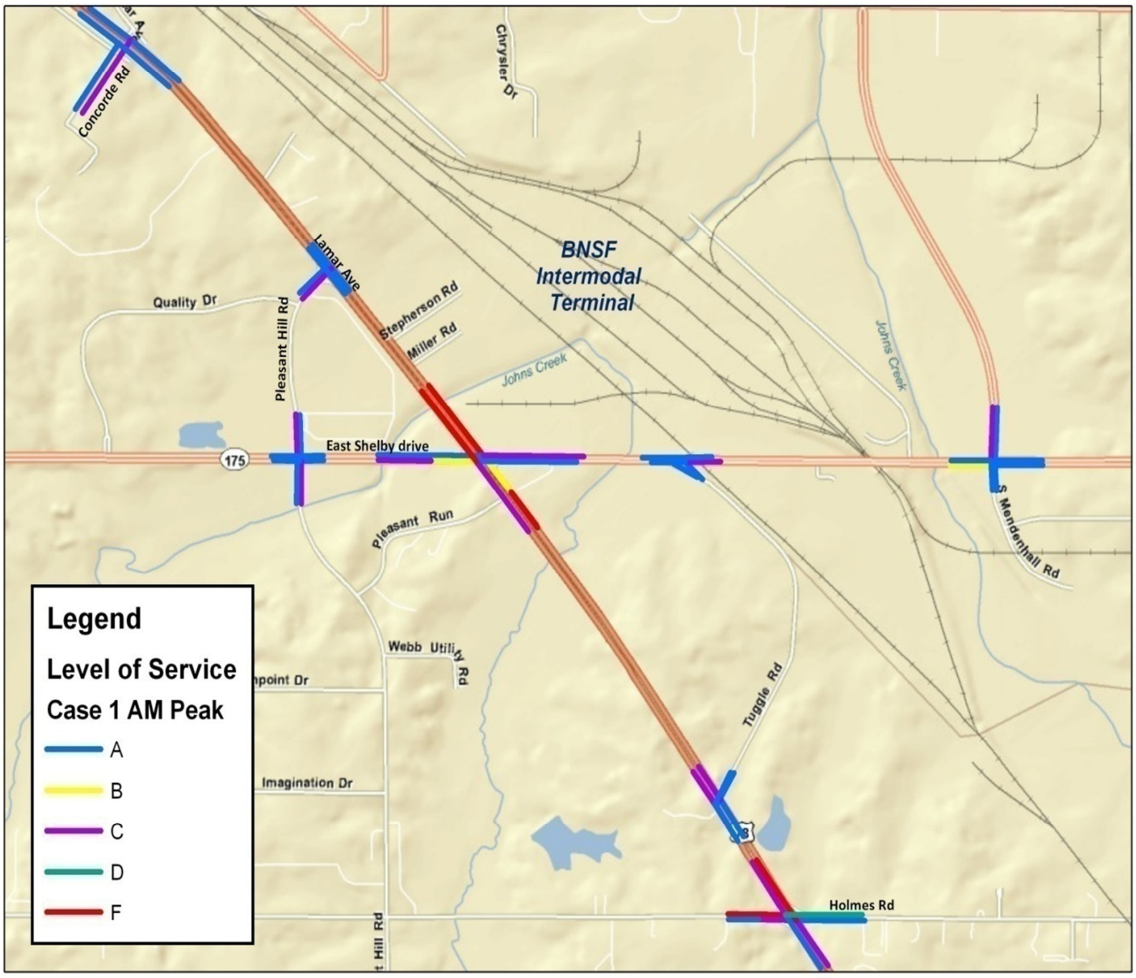

Figure 4. 5 Model Simulation Case 1 AM Peak

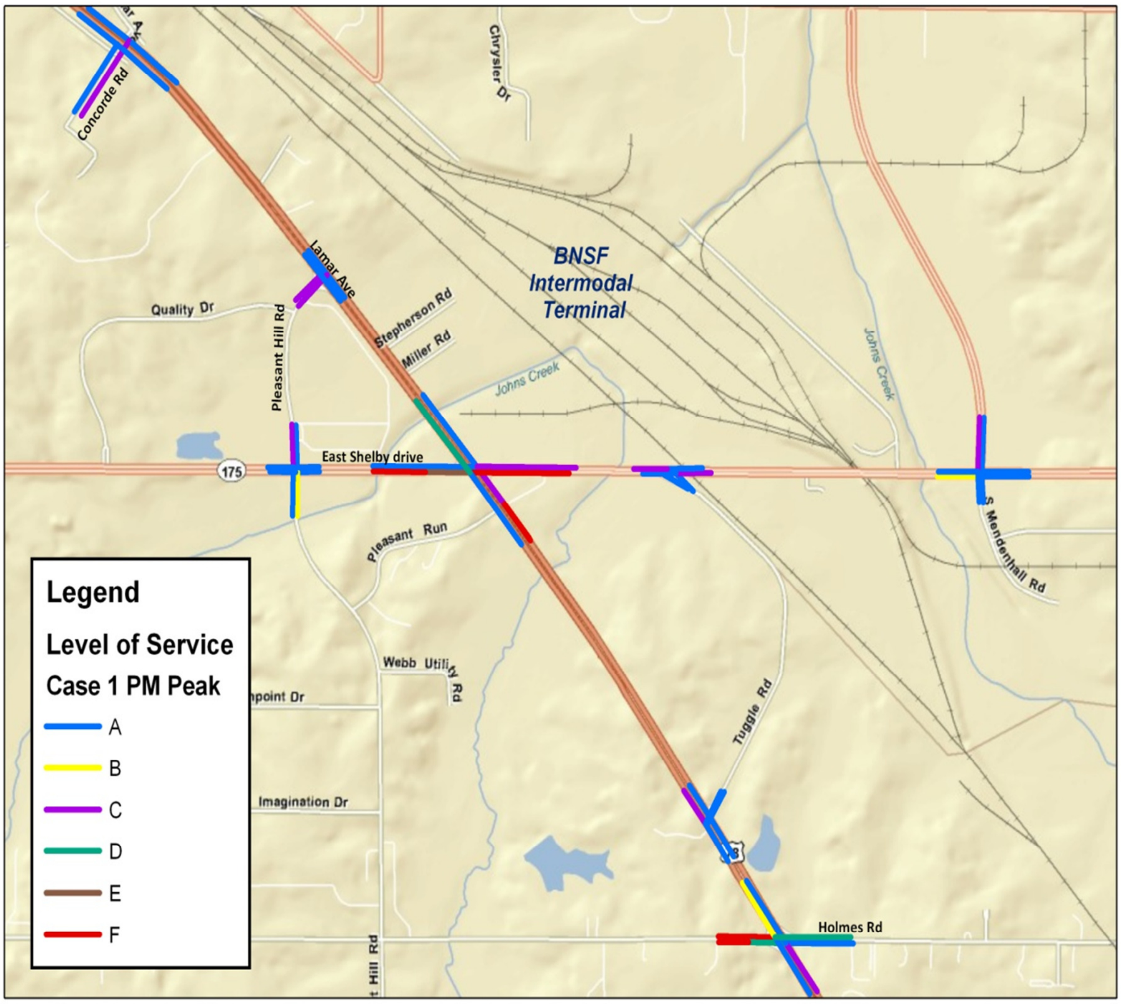

Figure 4. 6 Model Simulation Case 1 PM Peak

Model results from Case 2, when truck numbers that originate and are destined to the zone in which BNSF Intermodal terminal is located are tripled, are shown in *Figure 4.7*, for the AM Peak period and *Figure 4.8*, for the PM Peak period. The results from the AM peak show congestion and delay on the same intersections of Lamar Avenue with east Shelby Drive and Holmes Road. In Case 2, congestion is slightly higher on Lamar Avenue and East Shelby Drive, as the eastbound direction of East Shelby Drive and the northbound direction of Lamar Avenue have LOS C, compared to LOS B in Case 1.

Holmes Road is experiencing even greater congestion in Case 2, since LOS is now E at westbound direction of Holmes road, compared to LOS D in Case 1. The eastbound direction on Holmes road is now LOS D compared to LOS C in Case 1. The intersection of Lamar Avenue at Concorde Road is now more congested as indicated by LOS C at eastbound direction of Concorde road, compared to LOS A in Case 1.

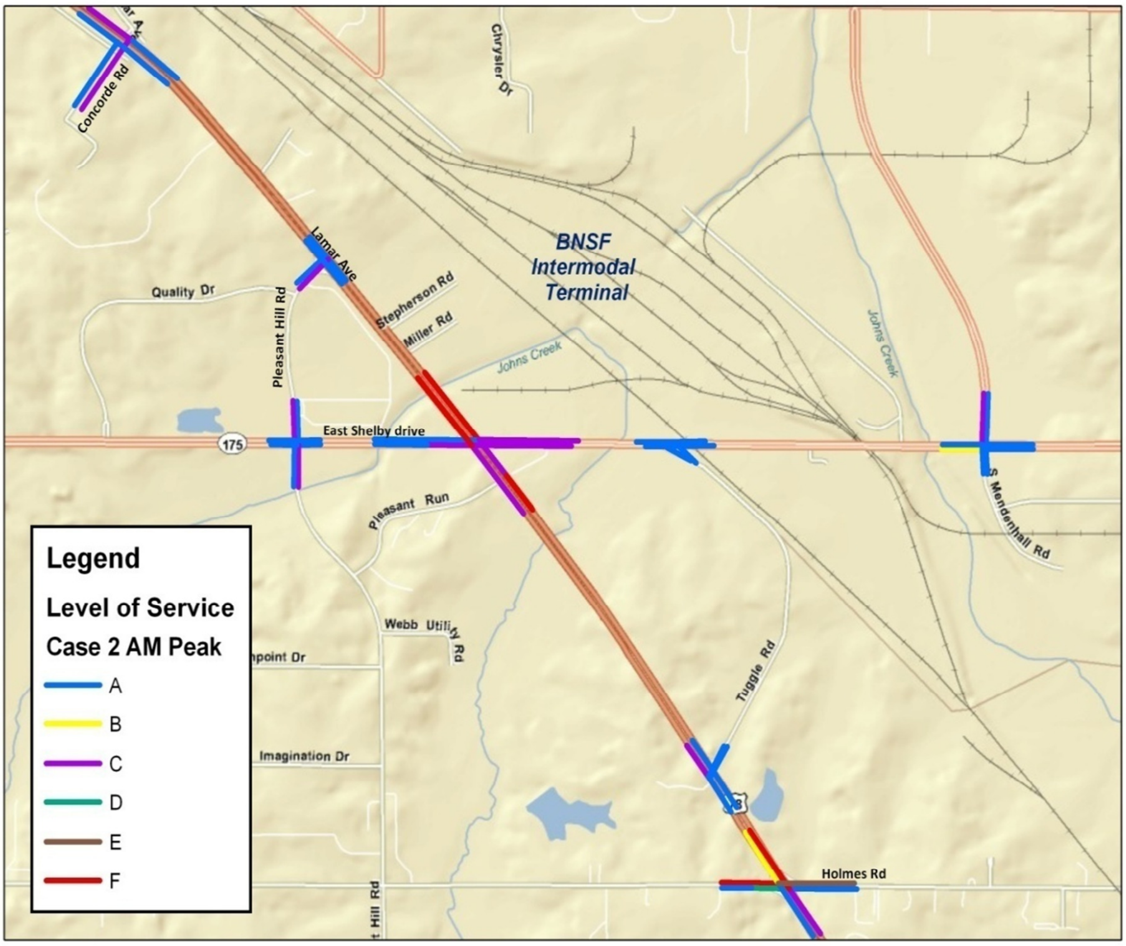

Figure 4. 7 Model Simulation Case 2 AM Peak

In Case 2 for the PM peak, more links on Lamar Avenue and Shelby Road have LOS F, making the overall LOS at this intersection F. The other links in the area do not show any significant differences from Case 1.

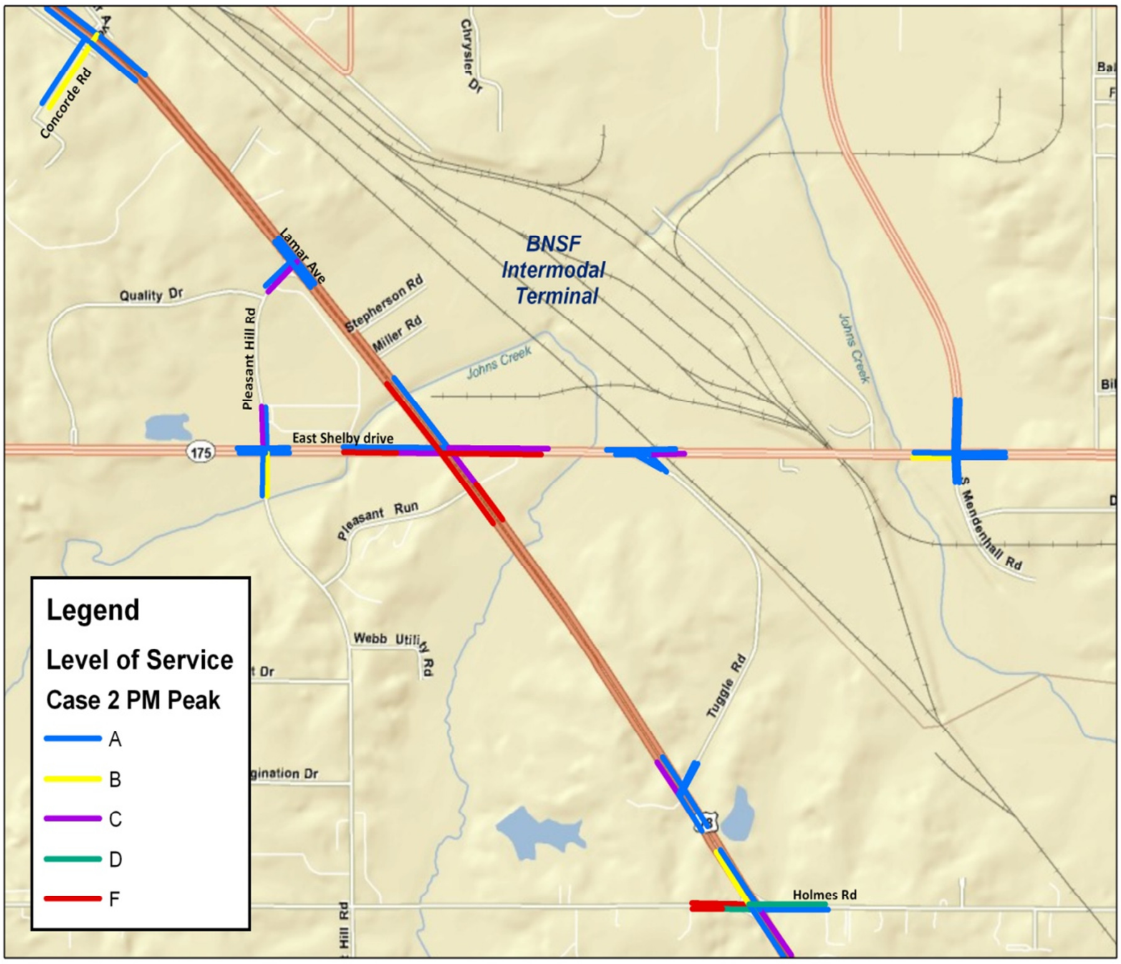

Figure 4. 8 Model Simulation Case 2 PM Peak

The results from Case 3, with the applied gate appointment system at the BNSF Intermodal terminal, when the truck arrivals are evened out during 24 hours, are shown in *Figure 4.9*, for the AM Peak period, and *Figure 4.10*, for the PM Peak period. Results for the AM peak show just a slight improvement of the Lamar Avenue and East Shelby

Drive intersection, as the eastbound direction of east Shelby Drive has improved from LOS C to LOS B. The intersection of Holmes Road and Lamar Avenue has the same LOS as in Case 2 on all links at the intersection. The LOS at the southbound direction of south Mendenhall Road has improved from LOS C to LOS B. The LOS on the other links in the area did not change significantly.

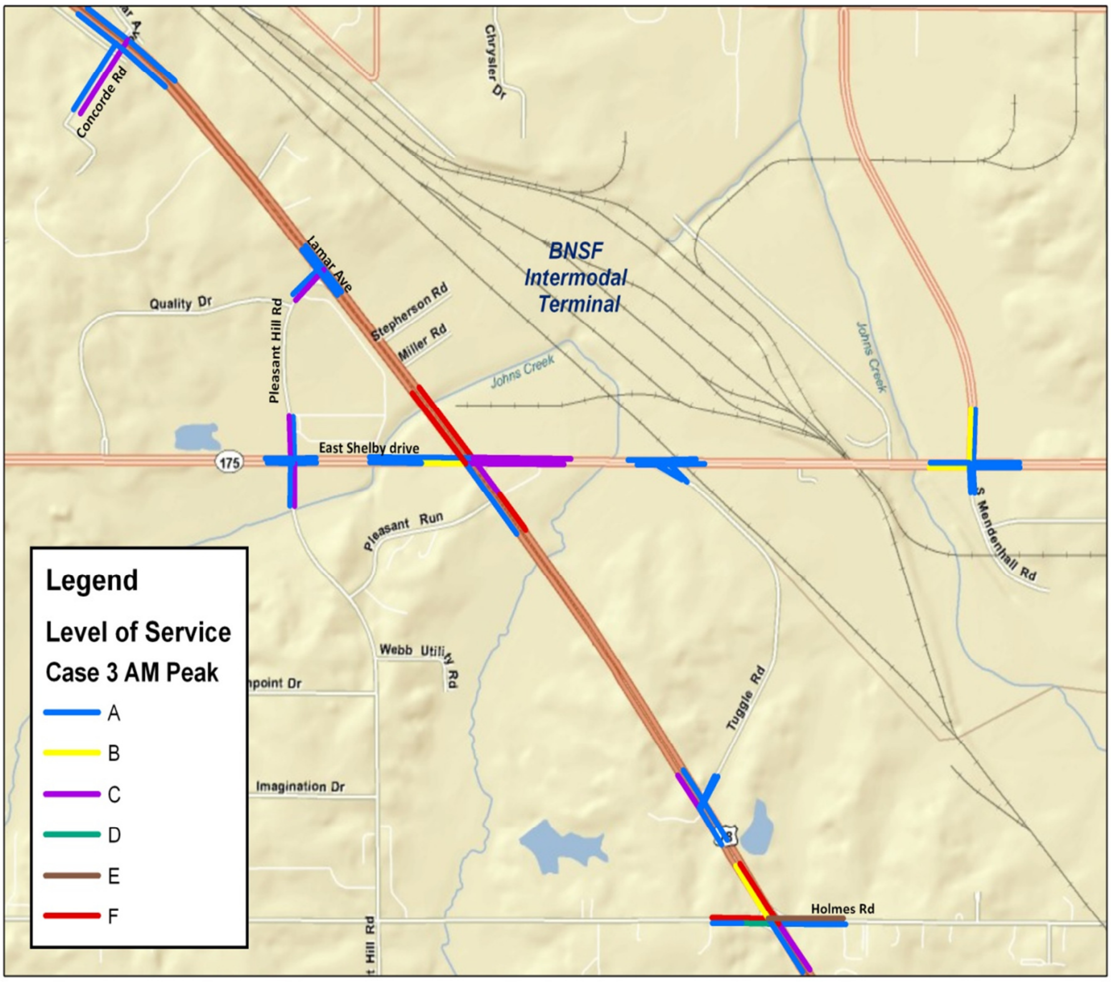

Figure 4. 9 Model Simulation Case 3 AM Peak

Results for the PM peak time period for Case 3 show additional improvement of LOS on the Lamar road and East Shelby Drive intersection from Case 2. LOS is reduced from LOS F to LOS C at the southbound direction of Lamar Avenue, and at the northbound direction from LOS C to LOS B. East Shelby Drive has a slight decline in LOS at the eastbound direction from LOS C to LOS D. The LOS on the intersection of east Shelby Drive and south Mendenhall Road has declined in LOS in Case 3 at the southbound direction of South Mendenhall Road from LOS B to LOS D and at the east bound direction of East Shelby Drive from LOS B to LOS C.

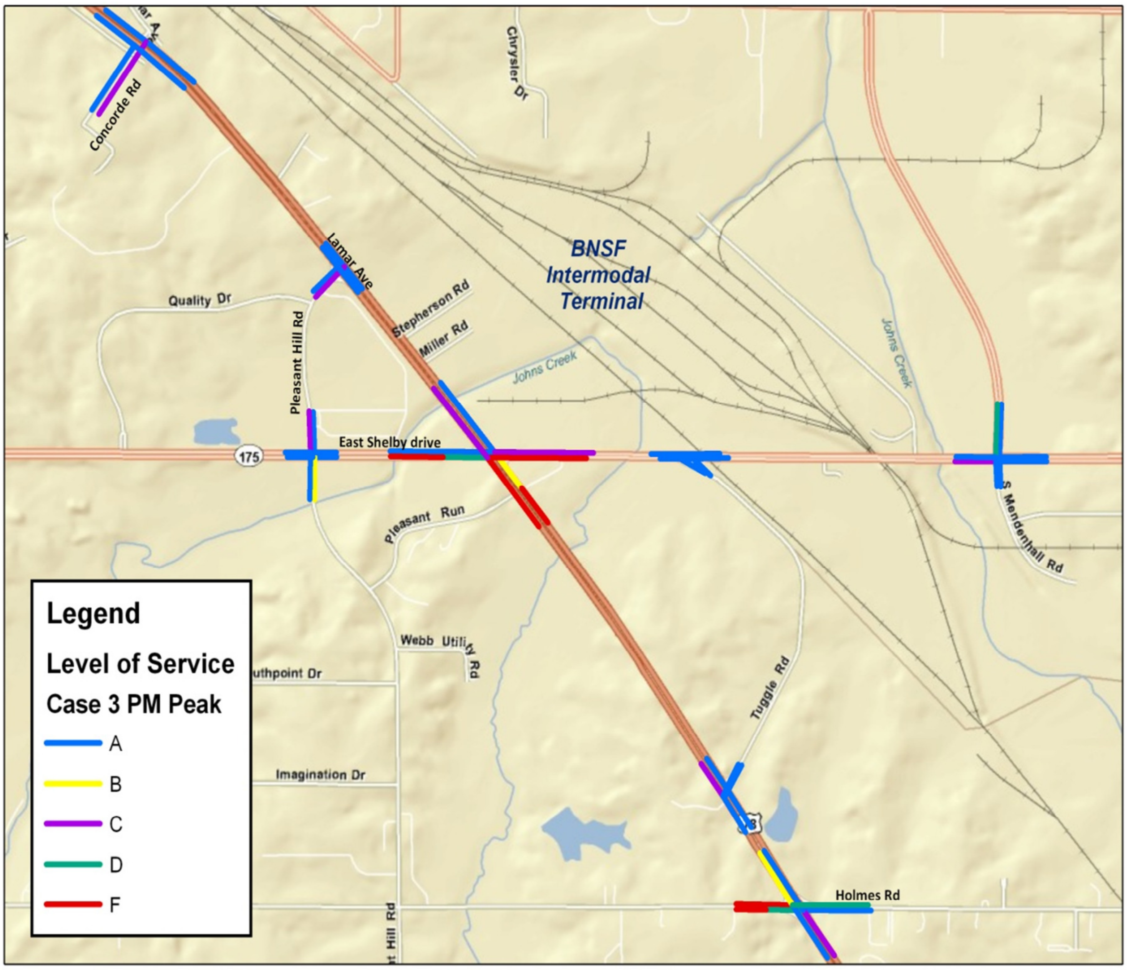

Figure 4. 10 Model Simulation Case 3 PM Peak

Section 5: Discussion and Analysis

5.1 Model Assumptions

The micro-simulation modeling of the roadway network around BNSF Intermodal terminal was performed successfully for all the cases. The results for all three cases are derived from the assumed truck data. The number of trucks on the network was assumed, due to lack of information on the number of trucks that travel between the zones in the network. The assumption was that 10 percent of trucks are released between all the zones, and this should be a reasonable assumption, since the network consists of both residential and industrial areas. The time of day factors, or the percent of release of vehicles in the 24 hour period, were also assumed, but they represent factors derived from a survey of passengers in 1998 (Memphis Long Range Transportation Plan 2007), and the results from this kind of traffic release were reasonable for all three cases.

The modeled area is very large, and there are around 60 signalized intersections, but for the purpose of analysis of the congestion and delay at and around BNSF Intermodal terminal, only 13 intersections were signalized. Other intersections in the model act like free flow intersections, and this assumption is not expected to create any significant problems given that the other intersections were far away from the study site and should not significantly impact flow around the BNSF facility.

Another assumption in Case 2 was that the truck numbers from the new BNSF facility will triple, and this is the worst case scenario for the numbers of loads handled in a year stated by BNSF. The results from this simulation are a better representation of the impact this increase of truck traffic will have on the road network.

In Case 3 simulation results are derived from the assumptions that all the trucks use gate strategies in Zone 370 where BNSF Intermodal yard terminal is located. The truck release times in the Paramics microsimulation are evened out in 24 hours for Zone 370 and this is a reasonable assumption for evaluating potential impact of the appointment system strategy since in order for a gate appointment system to be effective, a large number of trucks must use it.

5.2 Key Findings of the Research

The results of all three Cases of the micro-simulation modeling show significant congestion and delay at the main intersections in the area, at Lamar Avenue and east Shelby Drive and at Lamar Avenue and Holmes Road. The results from tripled truck numbers in Case 2 for both AM and PM time periods demonstrate that the overall LOS has declined at almost all of approaches at these intersections. This suggests that if the BNSF facility operates at full capacity the congestion on the surrounding road network will be high. The terminal gates at the BNSF intermodal terminal can be affected by this congestion, which will result in more trucks idling at the terminal gates, which is a significant environmental concern.

In Case 3 when the gate strategies were applied at the BNSF Intermodal terminal on an already tripled truck demand OD, congestion on the roadways for the AM and the PM peak time period was slightly reduced. This improvement was mainly observed at the intersection of Lamar Avenue and east Shelby Drive, although some links remained at LOS F. In the PM peak time period the intersections of the east Shelby Drive and south Mendenhall Road show declines in LOS. This may mean that Paramics micro-simulation is rerouting traffic from the busy intersections to the intersections with a lesser amount of delay.

The results from Case 3 are just slightly improved, and some links on the key intersections in the area still have LOS F. The simulation preliminarily indicates that the proposed gate appointment system will only lower the congestion slightly. Based on simulation results, this reduction in congestion and delay would only happen if the gate appointment system is mandatory at the terminal, and if the truck drivers are given incentives to use it. Since the congestion and the LOS are only slightly improving, this suggests that the gate appointment system strategy alone may not be effective in achieving significant reductions in congestion. The gate appointment strategy implemented with other complementary approaches might lead to more significant reductions in network and facility congestion. It should also be noted that while reasonable assumptions were made in the development of this model, the lack of available data, in particular with regard to truck volumes, may not accurately reflect the potential impact of a gate appointment system. If additional data becomes available allowing a more representative model to be developed, these scenarios should be revisited to further evaluate the potential impact of a gate appointment system on the BNSF facility and network congestion.

Section 6: Conclusions and Recommendations

The BNSF intermodal terminal expansion completion in 2009 is posing a major concern for the already congested road network in the heavy industrial area of Memphis. Truck traffic in the area is already great, and with the expected rise of truck demand at the BNSF terminal, it could potentially reach a point where all the intersections in the area are highly congested. That is why it is important to evaluate strategies that could be applied at the BNSF terminal to reduce congestion, before surrounding roads reach capacity.

Although not indicated in the results of the BNSF intermodal facility study, gate appointment systems have the potential to significantly improve operations inside the terminal as well as at the gate, based on results from previous studies. 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.

Coordination between trucking companies and the 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.

Results from the simulated road network at the BNSF Intermodal rail terminal are beneficial for the analysis of the congestion and delay on the major roadways and the intersections. Paramics micro-simulation results give a detailed representation of the behavior of travelers at the individual level. These results are also beneficial because the feedback from micro-simulation modeling can be provided for small time intervals, so that the congestion and delay on the network can be identified for particular times of the day. The only problem is the amount of data that is needed for Paramics microsimulation, especially for larger scale networks. Traffic counts and patterns between the zones and selection of zones is a major part of this problem, since the most recent data that is best for the modeling is not always available.

The results from modeling the most recent data available for this research demonstrate that the impact from the BNSF Intermodal rail terminal expansion, if capacity is reached, is going to have an impact on increasing delay and congestion on two of the intersections closest to the entrance on Lamar Avenue. A gate strategy simulation was applied on the increased capacity, with the assumption that large percentages of trucks are using appointments, and that the trucking companies as well as the rail terminal are given incentives. The results from these of assumptions and gate strategies application did not show significant decrease of the congestion on the major roadways and the intersections around the intermodal yard. One of the problems with these assumptions was that not enough truck data was available for just the BNSF Intermodal yard terminal truck traffic, and there is no real information on actual truck queues at the new AGS gates.

The solution to a problem of the congestion on the roadways around the BNSF terminal may have to be combination of gate strategies, gate technologies, and also road improvements. Analyzed results can be utilized for cost categorization in possible road improvements, such as adding more lanes, redesign of traffic signal timing, intersection improvements and upgrading existing roads to higher functionality roads.

6.1 Recommendations for Future Research

Increased efficiency at intermodal rail terminals due to any or all of the strategies discussed in this research can affect the overall transportation community by allowing more containers to be shipped, and moved more quickly away from the terminals, onto the other forms of transportation, and to their final destinations. The gate appointment strategies did not prove to be very effective for the analyzed time periods and assumed data in the modeled cases for the BNSF rail intermodal facility. However there was a lack of recent passenger vehicle data, and also the truck data was assumed for the whole area. There was also no data on actual truck queues at the new BNSF terminal.

In order to get more precise results new models runs with more recent and accurate data needs to be performed. The data from the most recent traffic counts was not matched with the observed count data due to lack of software extension for the Paramics software. This extension is the Paramics Estimator, and its major function is to estimate OD matrix data. The most recent OD data, especially truck data is also very important in getting most accurate results from the microsimulation. The Paramics microsimulation results can also be compared with the other microsimulation software, like Vissim (Visual Solutions Incorporated), TransCad (Caliper Corporation), and/or VISTA (Vista Transport Group Inc.). A comparative analysis of these kinds of results can give a better understanding of the potential problem that BNSF Intermodal terminal activities can have at their gate and terminal operations, as well as the surrounding roadways and intersections. New model runs can also be performed when there is a better understanding of the actual number of trucks that BNSF plans to handle with the new facility capacity, and also the actual truck traffic release times for a 24 hour period.

The results from this research can be very beneficial to future modeling purposes, or planning purposes. The structure of the network can be changed or evaluated to see what road improvements might best lower congestion. The problems at the nodes or intersections can also be analyzed with changes in traffic signal timings, or changing a design and intersection approach. This kind of model and results can be beneficial to all involved stakeholders, including the Memphis MPO and City of Memphis in planning future road improvements and the BNSF rail intermodal facility in identifying an effective combination of gate strategies to reduce congestion.

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