GATE STRATEGIES' IMPACTS ON MARINE CONTAINER TERMINAL ACCESS NETWORKS USING SIMULATION

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ABSTRACT

Intermodal Marine Container Terminals (IMCTs) are experiencing consistent growth in container volumes. Even with the downturn in global economic conditions, forecasts are estimating that freight volumes will continue to increase and result in substantial increases in congestion both at the seaside and the landside of terminals. Marine terminals are under pressure to increase their capacity to accommodate the increasing demand and vessels' size thus addressing any resulting economic and environmental implications. To this end, several strategies are being developed to improve operations at the berth, yard and gate side of marine container terminals. The focus of this paper is on the gate side operations, where dray trucks enter and exit the terminal to deliver and/or pick up a container. To improve these operations several strategies, including truck appointment systems and extended gate hours, have been proposed. Relevant scientific articles have been produced with a focus primarily on the improvement of gate operations and terminal efficiencies as a result of the implementation of such strategies. Relatively less attention has been given to issues related to the roadway network providing land-side access to the container terminal gates. With a focus on the terminal roadway access network, this paper presents a simulation-based approach, which may be used to evaluate impacts of gate strategies on drayage operations, and assess congestion impacts.

Keywords: marine container terminals, gate strategies, truck appointment system, extended gate hours, simulation

INTRODUCTION

Despite the recent economic downturn and the high level of uncertainty that characterizes today's business environment, the outlook for world trade and container shipping volumes is rather positive. Recent forecasts of container shipping volumes show attractive growth rates taking place in the next three to five years. In 2014, the market is expected to be served by a carrier fleet with an approximate capacity of 19.3 million TEUs. This trend is coupled by the continuing tendency to build mega vessels (e.g. Maersk Triple-E class with a capacity of 18.000 TEUs), which exert further pressure on the marine terminal facilities (Economist Intelligence Unit, 2012), especially in major import regions. To cope with the increasing number (and growing size) of container vessels, major ports have invested in infrastructure and equipment looking also for targeted actions in order to sustain or even improve their operations with the overall aim to expand their capacity fast enough to keep pace with trade requirements. The increased volume of containers required to be handled by marine container terminals in tight time windows, leading to higher levels of congestion along with significant economic and environmental implications, the latter of which are of great importance for terminals located close to urban areas (Giuliano and O'Brien, 2007), highlight the need for the development and adoption of countermeasures at a strategic, tactical and operational level to improve berth, yard and gate side operations.

While great emphasis has been placed, by the scientific community, on the improvement of gate operations and terminal efficiencies in order to increase capacity and enhance throughput performance, relatively less attention has been paid, methodologically, on the integration of the land-side access network and terminal operations. To this end, this paper presents a simulation based approach used to model the operations of the incoming and outgoing drayage trucks at a port. The model has been implemented within the Vissim software package and has been calibrated with real world data from the Newark / Elizabeth area of the Port of New York and New Jersey. Realistic estimates of truck traffic, travel time, delay and various other performance metrics for a base case scenario and several other implementation scenarios, focusing on the two (2) most common operational strategies i.e. gate appointment systems and extended hours of gate operation, have been produced. Using these metrics, emissions estimates are produced for each of the scenarios while sensitivity analysis has been performed to identify the impact on truck travel times and delays on the roadside network in the vicinity of the terminals for different simulation years and demand scenarios.

The rest of the paper is structured as follows; literature review is presented in the following section highlighting the increasing trends in international trade and the impact that growing container volumes have on intermodal terminals and their surrounding areas. The simulation model and the methodology used for its development and calibration are presented next. Subsequently the different scenarios that were built are presented and analysed while the last section concludes this paper by presenting results and findings as well as research and policy implications.

LITERATURE REVIEW

Since the 1980s when international container trade started increasing at a rate exceeding by far that of maritime trade as a whole, intermodal container terminals have experienced constant growth in container volumes which, according to recent forecasts and despite the recent economic downturn, are expected to further increase by 2020 (UNESCAP, 2007). Subsequently and with road transport being the predominant mode for moving containers in and out of marine terminals, truck terminal gates are experiencing tremendous congestion causing significant delays with major economic and environmental implications. As a result, efficient gate operations prove to be an issue of great importance for intermodal freight terminals with their impact not being isolated to the efficiency of operations within the terminal but also extending to the surrounding roadway network. Maksimavicius (2004) highlighted the need for operational strategies in comparison to physical capacity expansion as he found that increase in the number of gateways would not necessarily improve total freight processing time; as long as terminals' accommodating policy remained insufficient. To this end, several studies have been conducted on this research field and different operational strategies have been implemented with gate appointment systems and extended weekday and weekend hours of operation for terminal gates being the most widely adopted.

Gate appointment system

To ease congestion at terminal gates, one of the proposed recommendations is the implementation of an appointment system at in-bound gates, which can be effective in controlling truck random arrivals, modifying peak hours of demand, minimizing truck idling, and improving the utilization of the terminals' capacity (Boile et al., 2012). Being introduced in the California Assembly Bill (AB) 2650 in 2002 as an alternative option to be adopted by marine terminals to lower congestion and air pollution, gate appointment systems received a positive response by the trucking industry, initially as a proposal, according to a relevant study at the Ports of Los Angeles and Long Beach, because of the prospect of reducing truck turn time and given the fact that drivers get paid by the load and not for the time they work. However, after its implementation, truckers did not give a satisfactory rate to the initiative as they believed that it simply shifted queues from the gate to inside the terminal (Giuliano and O'Brien, 2007). Similar reservations have been expressed by the trucking industry in Europe. This result revealed that the appointment system could be successful provided that it is integrated into the terminal operating system as in that case terminal operators can better manage truck flows and container movements inside the terminal.

To promote the establishment of gate appointment systems, Guan and Liu (2009) analysed congestion at marine terminal gates using multi-server queuing models. The results indicated truck waiting costs as an issue to be addressed and for this purpose they proposed a gate appointment system to reduce gate congestion and increase system efficiency. With the objective to reduce truck turn time, Huynh and Walton (2005) recommended implementing an appointment system at entrance gates evaluating the maximum number of trucks with appointment for each defined zone and time window such that the average truck turn time did not exceed a maximum. Their results indicated that the implementation of such a system is not always effective unless its parameters are efficiently determined.

Following a similar direction, Huynh (2009) performed an evaluation study on a critical component of the gate appointment systems i.e. scheduling rules, proposing two types of scheduling strategies: (i) individual appointment systems (IAS) and (ii) block appointment systems. He concluded that there is a real benefit for a terminal without an appointment system to employ the IAS as it kept yard cranes highly utilized while improving the yard turn time.

Further studies revealed other factors hindering the successful implementation of gate appointment systems such as containers not being ready for pick up by a truck with an appointment (Giuliano et al. 2008) and truckers ignoring the system (when it was not mandatory) as they experienced great difficulty in setting-up an appointment 24 hours in advance; mainly due to other transactions scheduled that day indicating the flexibility that must characterize such systems.

Extended gate hours

In addition to a gate appointment system, the strategy of extending the hours of operations of gates is another method that can reduce externalities of operations at marine container terminals. The concept behind extended gate operations is to manage truck arrival patterns and avoid high concentration during peak hour periods, thus, spreading demand for container processing to off peak hours (evening, night and even weekends) where unutilized capacity exists.

Sgouridis and Angelides (2002) analysed the effect of truck arrival patterns on terminal performance. They simulated inbound container movements and placed truck turn times thresholds of 30 minutes (or less) and a transfer equipment (straddle carrier) utilization factor of 60% and above. Truck turn times improved by 15% when truck arrivals were evenly distributed throughout the work day. They also determined that truck turn times and transfer equipment utilization could improve by as much as 40% and 7% respectively, by trucks shifting their operation from peak to off-peak hours.

A similar strategy to the one proposed by Sgouridis and Angelides (2002), entitled PierPASS OffPeak Program, has been in place at the San Pedro Bay Ports (Los Angeles and Long Beach) since 2005, providing incentives for cargo owners and carriers to move cargo at night-time periods and on weekends. However, no major shift of truck traffic volumes from daytime peak to night-time traffic was reported and no major impacts on reducing congestion on roadways were identified. Therefore, it was recommended that such a strategy should be combined with other strategies such as congestion pricing and appointment systems and that this combined approach should be used if a similar program is implemented at other ports.

As indicated from the reviewed literature, significant scientific work has been undertaken focusing on gate operational strategies considering their impact on terminal operations. However, less attention has been placed on the impact these strategies may have on the Level-of-Service (LOS) of the roadside network in the vicinity of a container terminal. To this end, this paper evaluates the impact of the two (2) aforementioned gate strategies on the LOS of the surrounding, to the terminal, roadway network adopting a traffic simulation approach.

METHODOLOGY AND DATA

Development of a traffic simulation model meant choosing a software platform and selecting a specific port to be used as a test bed for the simulation. The Port of Newark/Elizabeth (PNE) was selected as the test bed for two reasons: (i) physical accessibility to the site and demand data availability, and (ii) the port contained three IMCTs with diverse characteristics representative of different terminals at other ports. A travel demand model (VISUM[1]) and a traffic simulation package (VISSIM[1]), were used to build hourly trip tables and a Dynamic Traffic Assignment (DTA) model to perform all the simulation scenarios. An extensive sensitivity analysis on base and future-year demand scenarios was performed to compare the impacts of the different gate strategies to truck travel times and delays and to determine the most efficient parameters of each gate strategy for each future year.

The study area

The study area port is located within the cities of Elizabeth and Newark in New Jersey and is one of the busiest in the country and the world having handled, through its three container terminals (APM, Maher and PNCT), approximately 5.5 million TEUs in 2011[2], showing a significant increase in volumes (Figure 1). The surrounding roadside network is not a complex one with three major access roads, three major terminal entrances and one main road that runs through the network in the north-south direction.

[1] (PTV America, 2009)
[2] http://www.panynj.gov/port/trade-stats.html

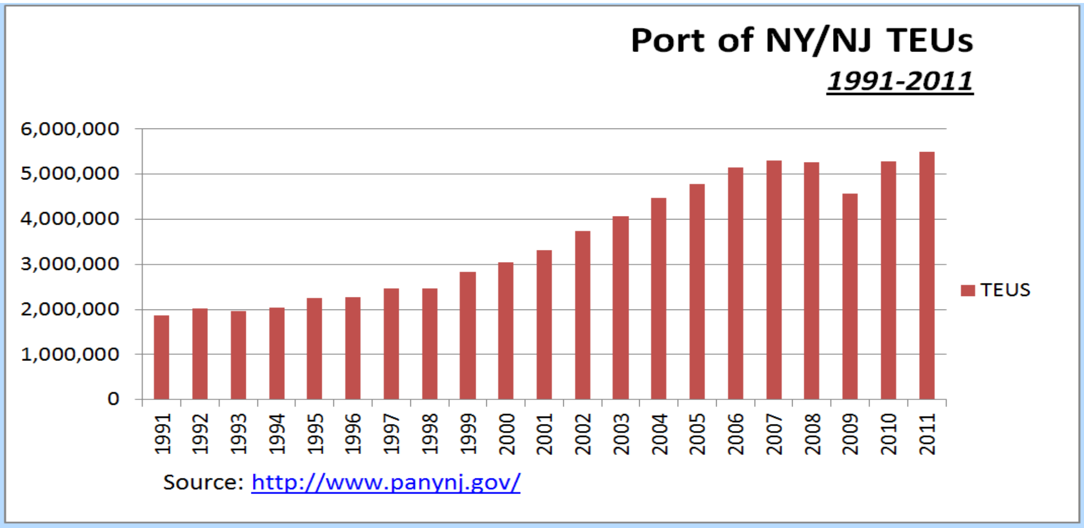

Figure 1 - Port of NY/NJ TEUs (1991-2011)

PNE consists of three container terminals. The first terminal operated by A.P. Moller-Maersk Group (APM), has an internal chassis depot, thirteen entrance lanes used by drayage trucks with a container or trucks with a bare chassis and two entrance lanes used by bobtail trucks. The second terminal operated by Maher Terminals LCC has an external chassis depot, fourteen entrance lanes used by container trucks and six entrance lanes used by chassis and bobtail trucks. The third terminal (Port Newark Container Terminals-PNCT) owned and operated by Ports America has an external chassis depot, two entrance lanes for chassis and bobtail trucks, eight entrance lanes that can be accessed by all trucks.

Roadway network and demand data

Development of a traffic simulation model requires a roadway network (geometric data, nodes, and links) and its physical and operating characteristics (e.g. capacity, number of lanes, speed limits), traffic demand (passenger and truck traffic), and traffic control data (e.g. signal timing). The former data was available through Google Maps, visual observation and from a micro-simulation model (Synchro) already available. Physical and operating characteristics, traffic demand and traffic control data was available through a comprehensive traffic study, performed by the Port Authority of New York and New Jersey (PANYNJ). The report provided the following data for the base year (2006):

1. Turn count information at all intersections within the port roadside network for each peak period (7:00-8:00AM, 12:00-1:00PM and 3:00-4:00PM)

2. Hourly traffic volumes entering and exiting the port

3. Peak period truck traffic

4. Peak period automobile (passenger) traffic

5. Daily traffic distribution for passenger and truck traffic breakdown by port access roadways for each peak period

6. Traffic signal timing for each peak period

These data was used as input in a successive averaging/iterative balancing technique, available from VISSUM, to derive base case hourly origin-destination (OD) matrices that were used as input from the DTA model in VISSIM. Hourly OD matrices were calibrated using count data available from the PANYNJ traffic report.

SCENARIOS ANALYSIS AND RESULTS

As indicated in a previous section of the paper, the case study's sensitivity analysis focuses on two (2) operational strategies i.e. gate appointment systems and extended gate hours. In order to incorporate these strategies into the DTA model, generalizations were made regarding the way these strategies would control truck demand at the Port Newark / Elizabeth Marine Terminals. It is assumed that the most likely scenarios resulting from the implementation of each or both of the strategies at the port are the following:

1. WD_70: 30% of commercial demand is shifted to the morning and night shifts (12am-6am and 6pm-12am)

2. WD_80: 20% of commercial demand is shifted to the morning and night shifts (12am-6am and 6pm-12am)

3. WE_80: 20% of commercial demand is shifted to weekend hours

4. WE_90: 10% of commercial demand is shifted to weekend hours

These strategies are compared to a "do-nothing" strategy for the simulation years 2006, 2011, 2016 and 2021 and are indicative of a number of scenarios that could be analyzed. Assumptions about the increase in truck and vehicle traffic were made based on the PANY/NJ 2006 Traffic Study where it is assumed that passenger and truck traffic increase approximately by 2% and 5% per year respectively. Next, we present and discuss results on truck[3] travel times and delays for each one of the simulated strategies.

Scenarios analysis for 2006 (base year)

This section presents results for the 2006 (base year) simulations (Figures 2-5). With regard to the total (passenger and truck) vehicle demand (Figure 2), hourly volumes in the morning (5,200 vph), midday (5,000 vph) and afternoon (4,900 vph) peak decrease for each of the four proposed strategies. These demand shifts can be obtained by implementing gate appointment systems and extended gate hours at the Port Newark/Elizabeth, reducing peak hour truck arrivals by shifting those arrivals to non-congested periods. Figure 3 indicates more effectively the shifts in commercial vehicles for each one of the four gate strategies considered. We note that demand distribution for strategies WD_70 and WD_80 was

[3] Also referred to as commercial vehicles throughout the remainder of the paper

assumed to be uniform rather than random as the demand of commercial vehicles shifted to AM and PM off peak periods was not significant to deteriorate LOS.

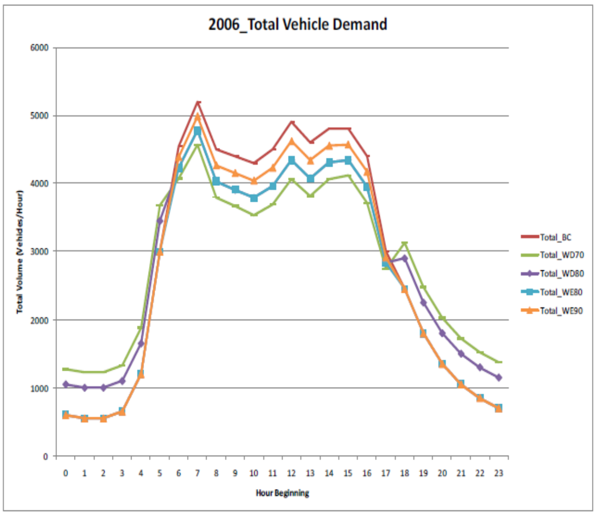

Figure 2 – Year 2006 total vehicle demand

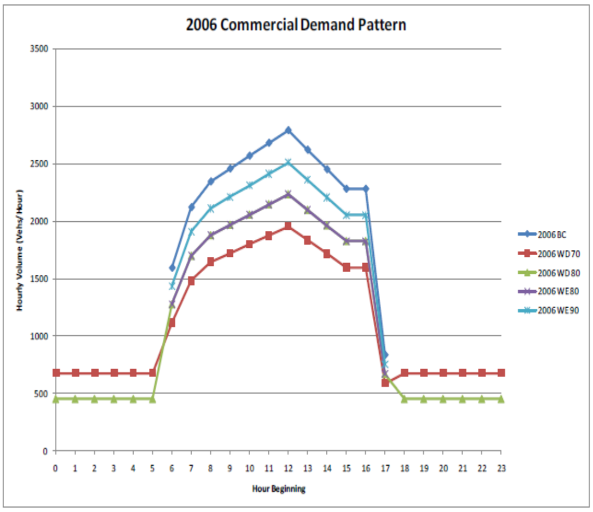

Figure 3 – Year 2006 commercial demand pattern

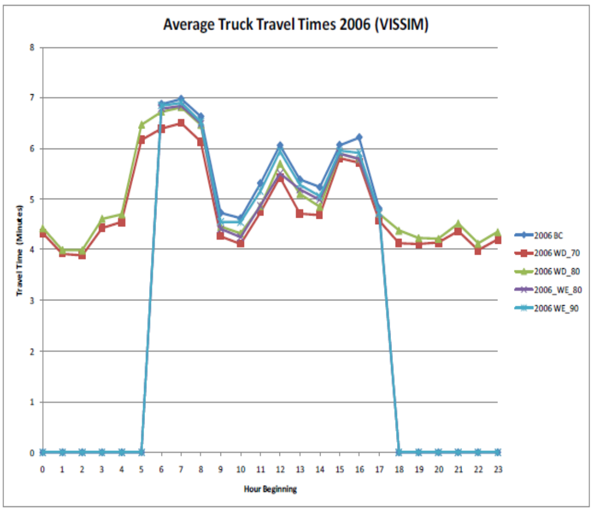

Figure 4 – Year 2006 average truck travel times

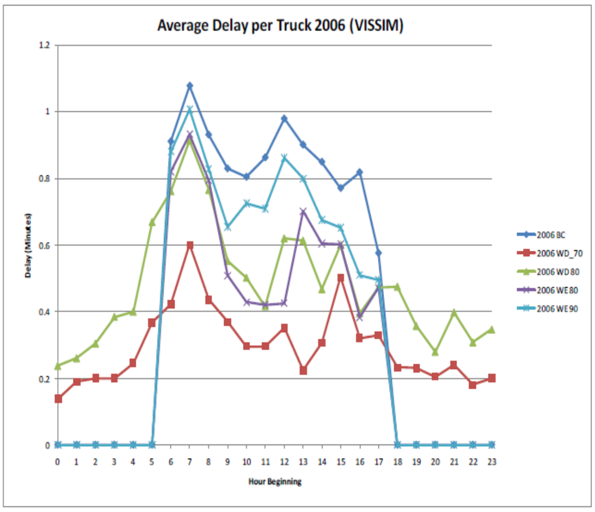

Figure 5 – Year 2006 average truck delay

Average truck travel times (Figure 4) peak between 7am and 8am reaching approximately 7 minutes while the midday and afternoon peaks are slightly over 6 minutes. When comparing all demand shifting scenarios, little variance in average truck travel times can be detected. This indicates that the network level of service in 2006 is sufficient and shifting demand to off peak hours does not have a significant impact on truck travel times. Although field observations showed that truck queues are present during peak hours at all three major terminal gates (APM, Maher and PNCT), these queues were not large enough to impact the traffic on the roadside network. Field observations also confirmed the existence of minor delays at the port throughout the day, given current conditions, and consequently the insignificant changes in average travel times due to demand shifts on the network. However the network was found to be on the cusp of reaching capacity and an increase in truck queues at the gate will spill over on the roadside network causing significant delays in future years if no action is taken in order to accommodate the increasing truck traffic. This observation will become evident in the future demand scenarios.

Average truck delay (Figure 5) is estimated as the difference between average truck travel time and free flow truck travel time for each hour of the simulation not including any delays at the terminal gates. Although a difference for each scenario can be detected, the delay is not significant for the base case or any demand shifting scenario. This also correlates to the field observations previously discussed. Figure 5 does however show a slight but insignificant decrease in delay per truck when demand is shifted to off-peak hours or weekend.

Scenarios analysis for 2011

Infrastructure improvements were undertaken on the port roadside network between 2006, when the Synchro model containing the port network was created, and 2010 when this study was conducted. A number of adjustments were made to the VISSUM network to ensure that the simulation captures these improvements and produces accurate results. The infrastructure improvements allowed higher truck volumes to enter or exit the port roadside network without however, significant impacts to the LOS and productivity at the port. Therefore, the 2011 results show only minor increase in average truck travel times and delay when compared to the 2006 results. It should be noted at this point that the updated VISSIM network file was also used for the 2016 and 2021 simulations.

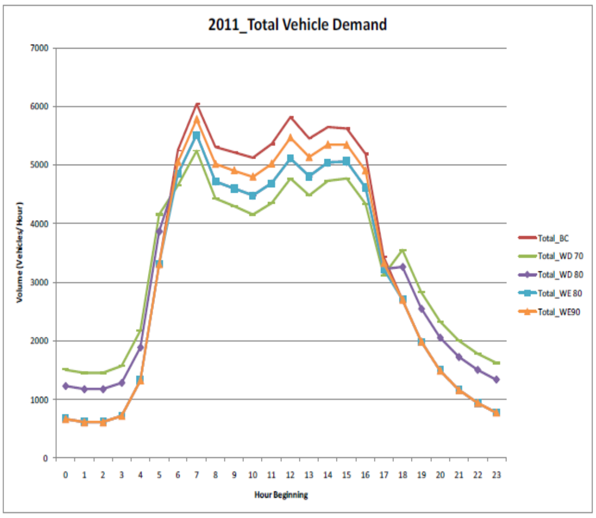

Figure 6 – Year 2001 total vehicle demand

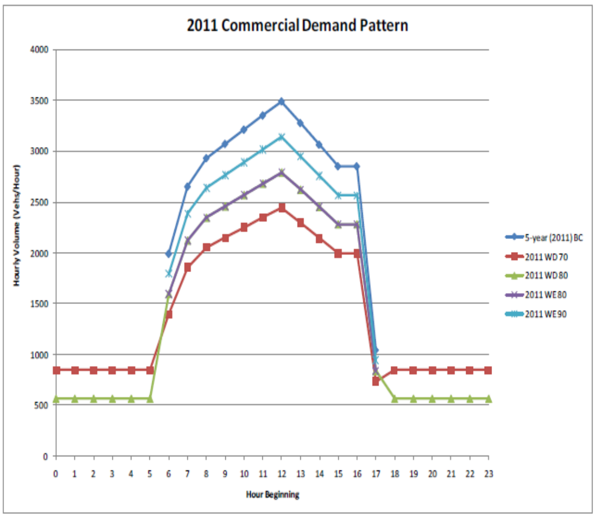

Figure 7 – Year 2011 commercial vehicle demand pattern

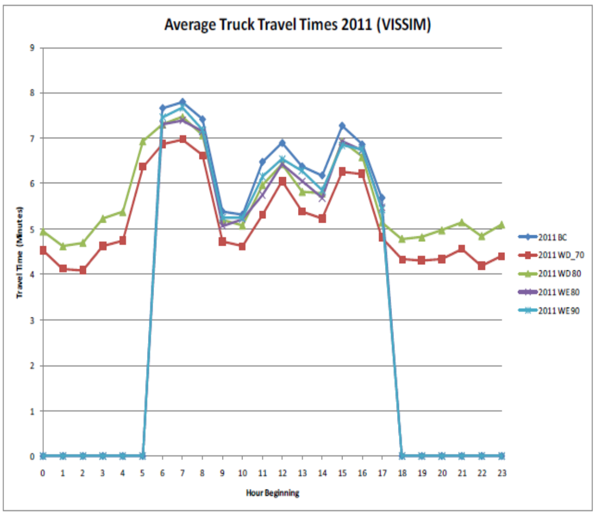

Figure 8 – Year 2011 average truck travel times

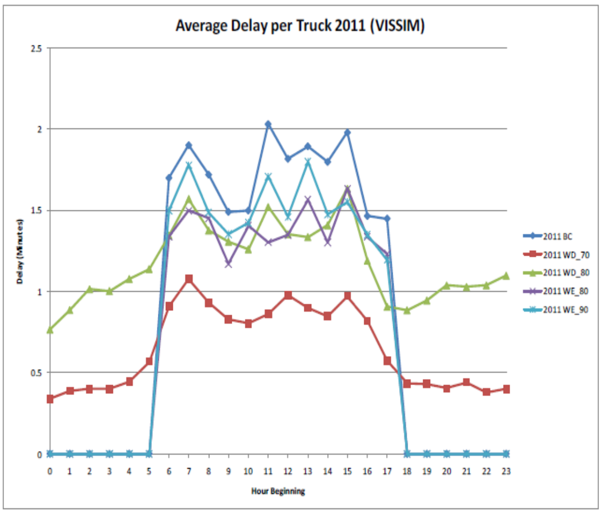

Figure 9 – Year 2011 average truck delay

The total vehicle demand in 2011 (Figure 6) presents a slight increase compared to 2006 as it was assumed that vehicle traffic increases approximately by 2% and truck traffic by 5% per year. Same is the picture, however, for the hourly volumes in the morning (6,000 vph), midday (5,800 vph) and afternoon (5,600 vph) peaks which decrease for each of the strategy. Slight demand increase can be also detected for the commercial demand pattern for 2011 (Figure 7) compared to 2006 (midday peak 3,500 trucks/h) with strategy WD_70 and WD_80 presenting again a uniform shift in demand for the same reasons as in the base case.

Average truck travel time for 2011 (Figure 8) peaks between 7am and 8am reaching approximately 8 minutes, only 1 minute higher than the average truck travel time in 2006, while truck travel times average slightly below and over 7 minutes for the midday and afternoon peak hours respectively. Similarly to 2006, there is little variance when comparing all demand shift strategies. However, Figure 8 indicates that the WD_70 strategy has a deeper impact on truck travel times reducing average truck travel times by approximately 1 minute for all 3 peak hours of the simulation. This indicates that the increase in vehicle demand is beginning to impact the roadside network LOS, although not to a significant degree. Average truck delay for 2011 (Figure 9) also shows insignificant increase, as compared to 2006. Differences can be detected among the different strategies but it is not considered as a significant one. It should be highlighted, at this point, that the significant vehicle demand increase between 2006 and 2011, was accommodated by the additional capacity from infrastructure improvements. These improvements lead to insignificant increases in truck travel times and average delays.

Scenarios analysis for 2016

Results of the 2016 simulations indicate significant impacts on truck travel time and delay since no additional infrastructure has been provided to handle the increase in vehicle demand. The total vehicle demand (Figure 10) has increased compared to the 2011 demand profile with hourly volumes in the morning, midday, and afternoon in the range of 6,800 vph.

As previously stated it was assumed that vehicle traffic increases approximately by 2% and truck traffic by 5% per year.

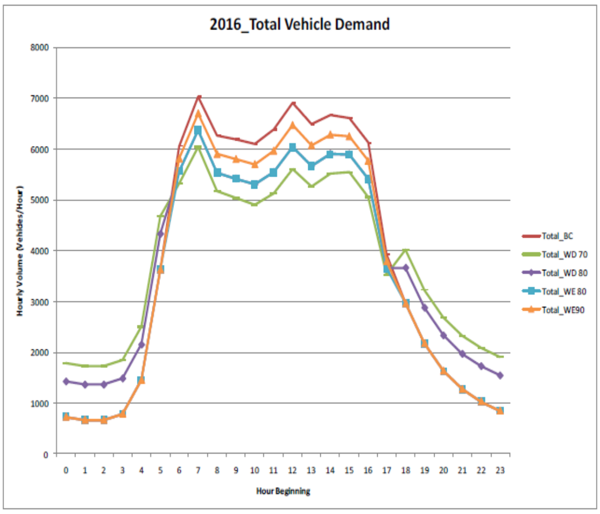

Figure 10 – Year 2016 total vehicle demand

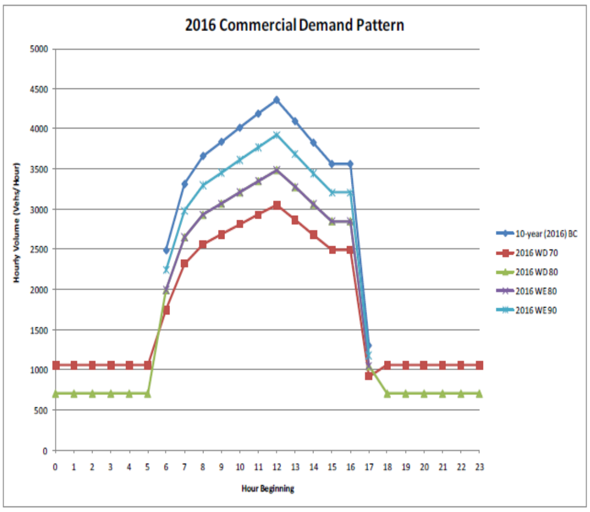

Figure 11 – Year 2016 commercial demand

Slight increase can be also detected for the commercial vehicle demand pattern for 2016 (Figure 11) as compared to 2011 (midday peak at 4.400 tph) with strategies WD_70 and WD_80 presenting again a uniform shift in demand in the morning and night shifts as the number of commercial vehicles shifted was not significant enough to affect the port roadside network LOS.

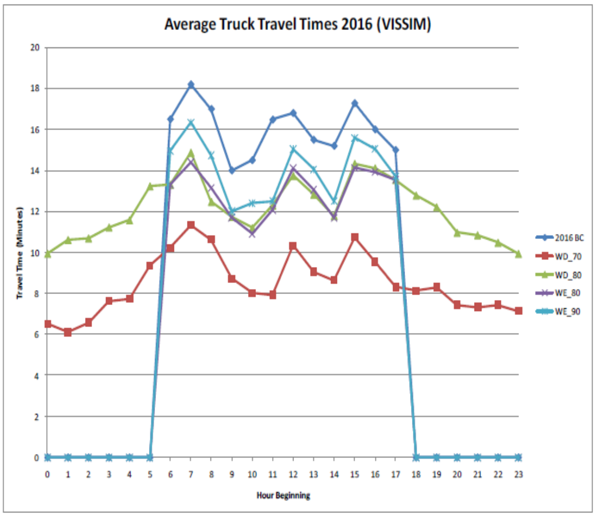

Figure 12 – Year 2016 average truck travel times

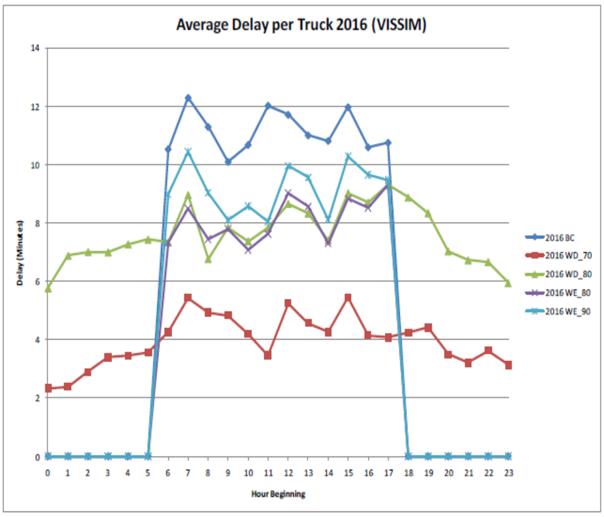

Figure 13 – Year 2016 average truck delay

Average truck travel time for 2016 (Figure 12) peaks between 7am and 8am reaching approximately 18 minutes, a significant 11 minute increase from the 2006 base year, while truck travel times average slightly over 16 minutes for the midday and afternoon peak hours. Unlike results from the 2006 and 2011 simulations, significant changes in average truck travel times can be detected for the different demand shifting strategies. For strategy WE_90 a decrease of 2 minutes is detected in the morning and midday peak periods and nearly 1 minute in the afternoon period. However this decrease is not significant enough to allow for a sufficient roadside network LOS. Strategies WD_80 and WE_80 have similar average truck travel times, slightly below those of WE_90, which are acceptable during off-peak hours with high travel time and delays however during the three peak periods. Strategy WD_70 presents significant improvements in average truck travel times, which for the three peak periods proves to be only slightly higher, as compared to 2006 and 2011. This indicates that WD_70 strategy could potentially contribute towards achieving an acceptable port roadside network LOS. To this end, a combination of gate strategies (most likely extended gate hours and gate appointment system) should be adopted to achieve the truck demand shift.

Similar to the average truck travel times, a more significant decrease in truck delays is detected for each demand shifting strategy (Figure 13). Delays for the 2016 base case are much higher than 2006 and 2011 for the hours between 6am and 6pm, reaching just above 12 minutes in the morning peak and nearly 12 minutes during the midday and afternoon peak. Average truck for the WE_90 strategy is approximately 10 minutes during the 3 peak periods. For both WE_80 and WD_80 strategies, average truck is close to 8.5 minutes. Furthermore, a significant reduction in average truck delay for all hours of the day is reported for the WD_70 strategy, indicating it as the one leading to an acceptable port roadside network LOS.

Scenarios analysis for 2021

The large increase in vehicle demand due to the increasing international trade will significantly impact conditions on the port roadside network in 2021. Total vehicle demand (Figure 14) has increased, as compared to the 2016 demand profile, with peak hour volumes in the vicinity of 8,000 vph. Significant increase is also observed for the commercial demand pattern for 2021 (midday peak 5.400 tph-Figure 15), when compared to 2016, with strategies WD_70 and WD_80 presenting again a uniform morning and night demand shift.

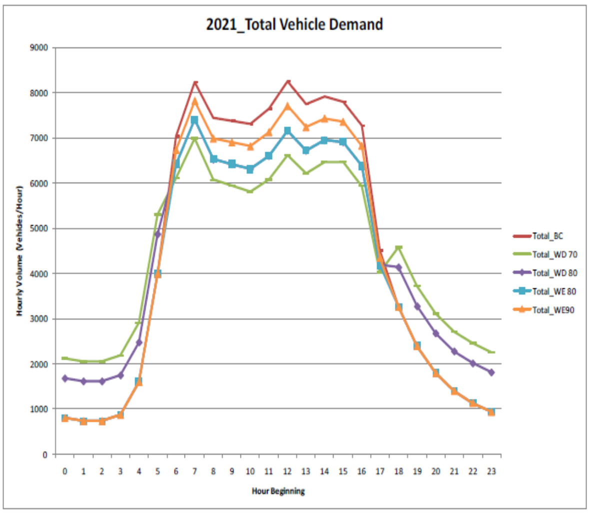

Figure 14–Year 2021 total vehicle demand

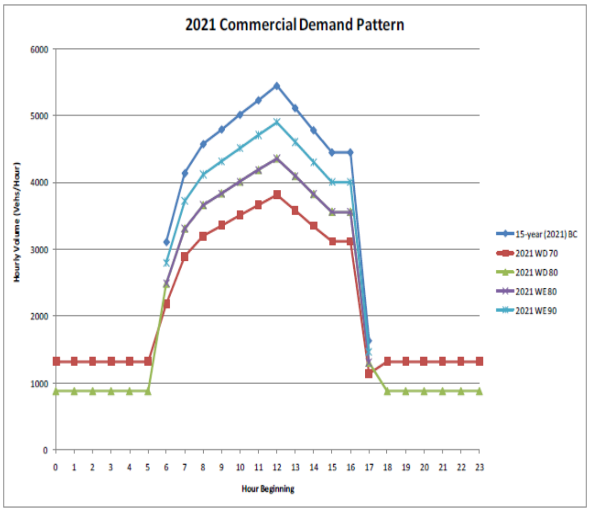

Figure 15–Year 2021 commercial demand pattern

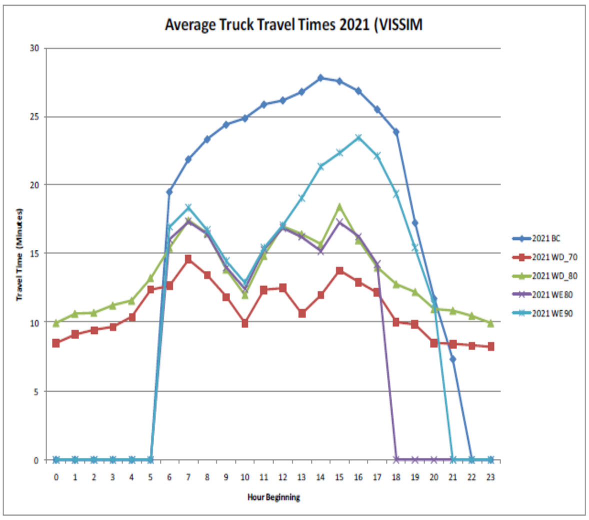

Figure 16 – Year 2021 average truck travel times

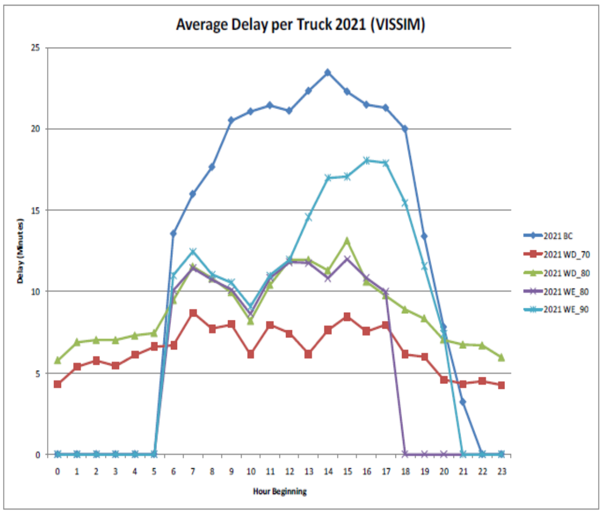

Figure 17 – Year 2021 average truck delay

Average truck travel times, for the 2021 base case strategy, (Figure 16) peak between 7am and 8am reaching approximately 20 minutes (a 2 minute increase from 2016). However, average truck travel times continue to increase, through the midday peak period, reaching an average of 27 minutes as the port roadside network has reached its maximum capacity during the morning peak period. Queues of morning un-served demand spill into the midday and afternoon hours resulting in a continuous increase in average truck travel time. For strategy WE_90, average truck travel time reaches approximately 13 minutes in the morning peak period. Travel time then decrease before the midday peak period when the network reaches its maximum capacity increasing, after 12pm, to a maximum of 24 minutes around 4pm. Strategies WD_80 and WE_80 have similar average truck travel patterns, slightly below those of WE_90 from the beginning of the simulation until the AM peak period. Unlike strategy WE_90, strategies WD_80 and WE_80 reach maximum capacity only during the 3 peak periods (not during off-peak). Roadside network LOS under these 2 strategies is very low and an acceptable level of productivity cannot be reached. The vehicle demand on the network is simply too high. A more significant shift in commercial vehicle demand is needed to allow an acceptable LOS. Strategy WD_70 results in significant improvements in average truck travel times from the 2021 base case. However travel times are over 12 minutes over the entire simulation period. This results in heavy delays not allowing an acceptable level of productivity to be reached. A larger shift in commercial vehicle demand will be needed in 2021 so that average truck travel times can reach a level that will allow terminals to be productive and remain competitive.

Similar to the average truck travel times, major average truck delays are indicated for all five strategies (Figure 17). Average truck delays for the 2021 base case prove to be much higher than the four gate strategies peaking at around 23 minutes between 6am and 6pm. Average truck delay for the WE_90 strategy is approximately 12 minutes, during the morning peak period, reaching however 17 minutes during the midday and afternoon peak. For both WE_80 and WD_80 strategies, average truck delay is close to 11 minutes. Furthermore, a significant reduction in average truck delay for all hours of the day is achieved by WD_70 strategy. Although this strategy was effective in 2016, a larger shift in commercial vehicle demand is needed in 2021 for average truck travel times to be at a level allowing terminals to be productive and remain competitive.

Peak hour travel time

This section presents a comparison of travel times and delays for peak periods. Average truck travel times for all five strategies and simulation years are summarized and compared for each of the three peak periods in Figures 18 (AM peak), 19 (MD peak), and 20 (PM peak). We observe that truck travel times in 2006, for all three peak periods, average slightly over 5 minutes and only a minor variance can be detected between the demand shifting strategies. The 2011 truck travel times did not significantly increase from 2006 due to the infrastructure improvements discussed earlier. However, greater variance can be detected for each of the demand shifting strategies due to the increased demand. A large increase in travel time, nearly 11 minutes for AM and PM and 12 minutes for MD, is indicated between the 2011 and 2016 base cases due to the major increase in travel demand. However, for the 2016 simulation year, a large variance in travel time for each strategy is observed. Reducing commercial demand between 6am-6pm shows significant decreases in average truck travel time during all three peak periods. Shifting 30% of commercial demand to the morning and late night shifts has the potential to reduce average truck travel time by nearly 40% (as compared to the base case).

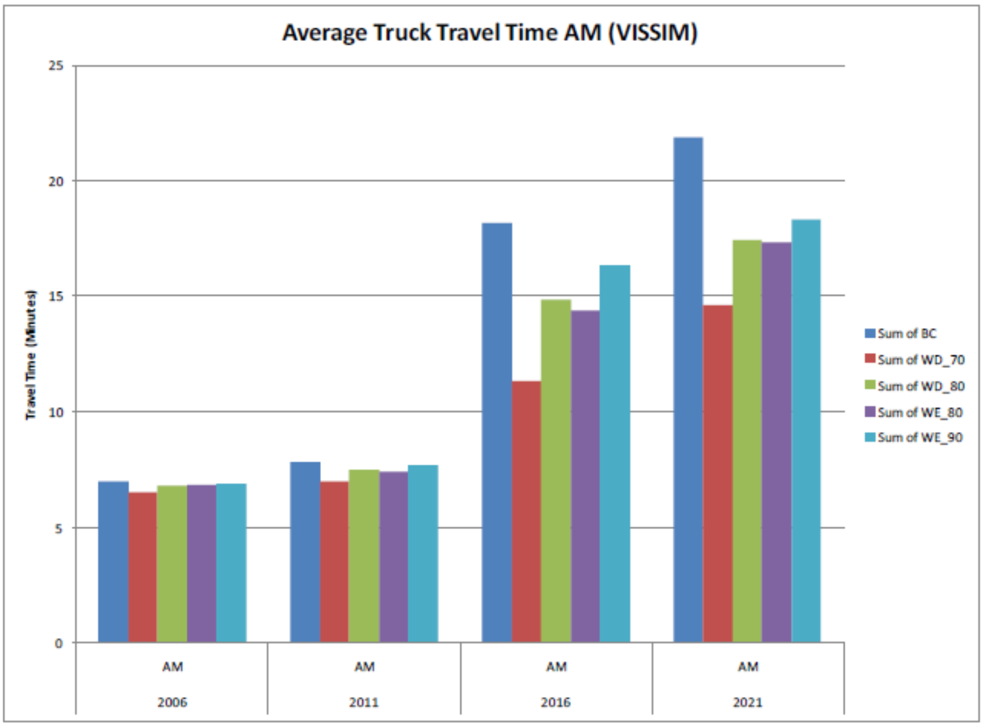

Figure 18 – AM average truck travel time

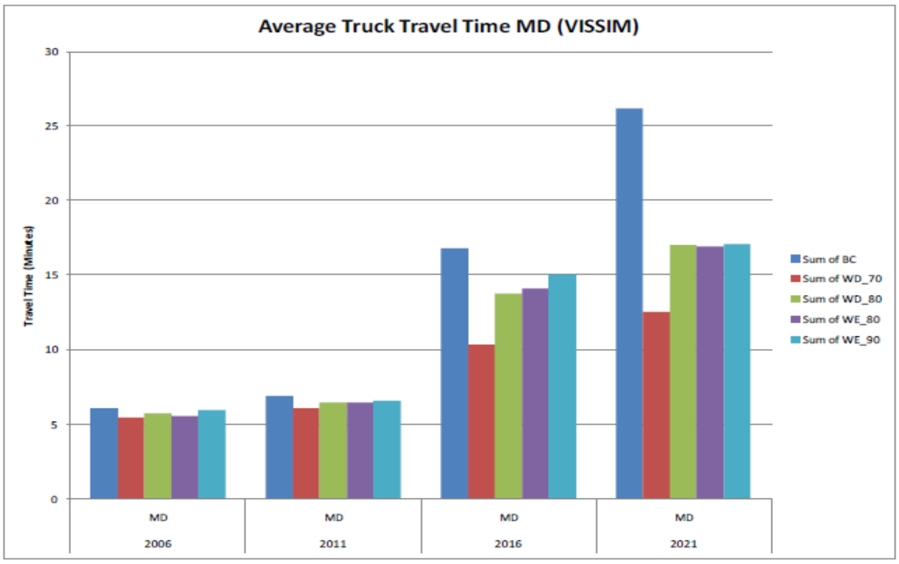

Figure 19 – MD average truck travel time

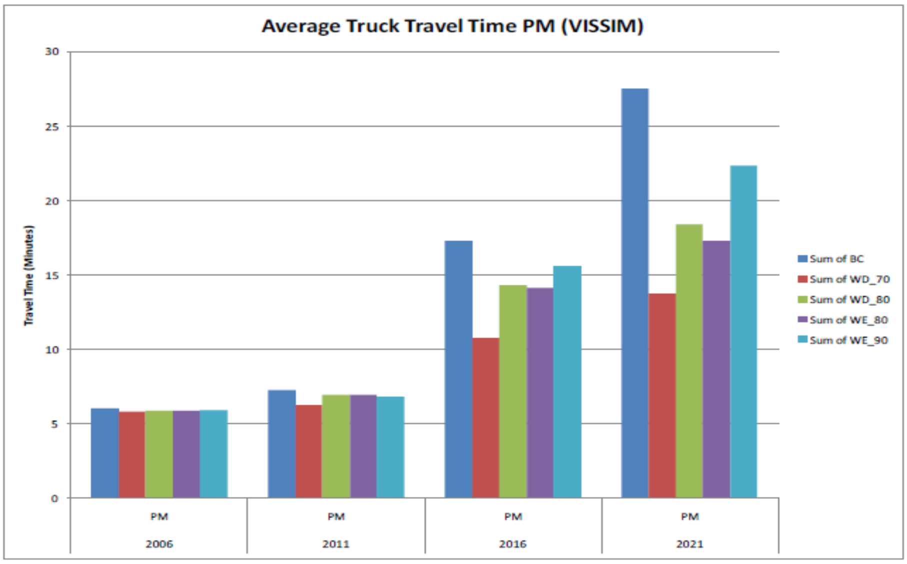

Figure 20 – PM average truck travel time

Peak hour delay

This section presents the total truck delay for all five strategies and simulation years for each of the three peak periods (Figures 21-23). Total truck delay was calculated by taking the difference of the average truck travel time and the free flow of truck travel time and then multiplying the difference by the truck volume for that time period (i.e. delay is measured in truck-hours). Minimal delay is seen in the 2006 AM and PM periods while slightly higher delay is detected in the MD period. All three figures present the base case exponentially increasing for each 5 year simulation. The WD_70 strategy presents the smallest increase in total truck delay for each simulation year, reaching a maximum of 400 total truck hours of delay in the 2021 AM peak period and 500 hours of delay for MD peak period while for the PM peak period this strategy presents the deepest impact on the reduction of the total truck delay.

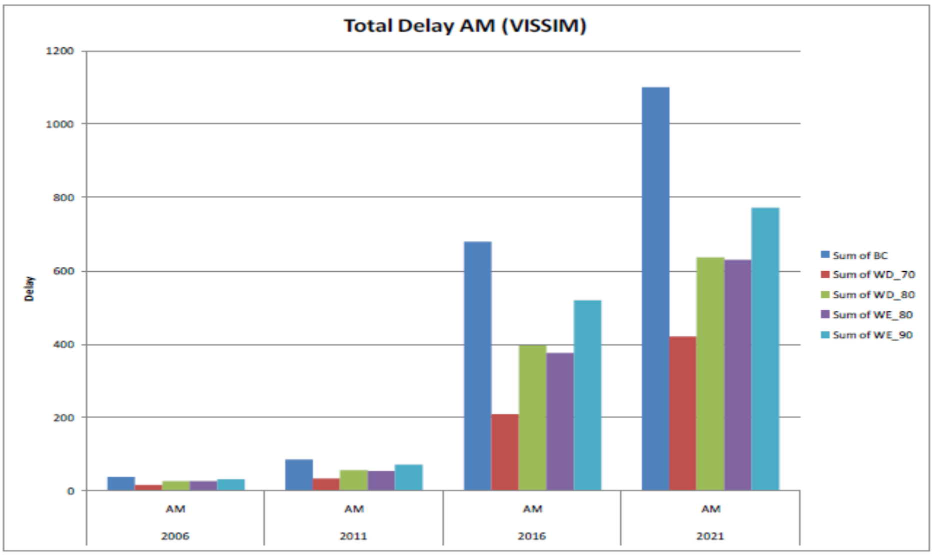

Figure 21 – AM total truck delay

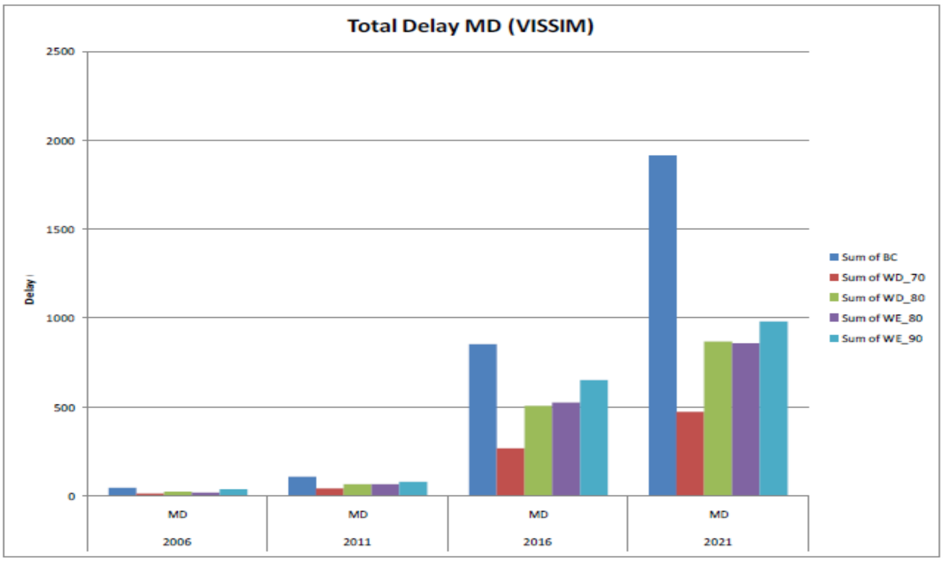

Figure 22 – MD Total truck delay

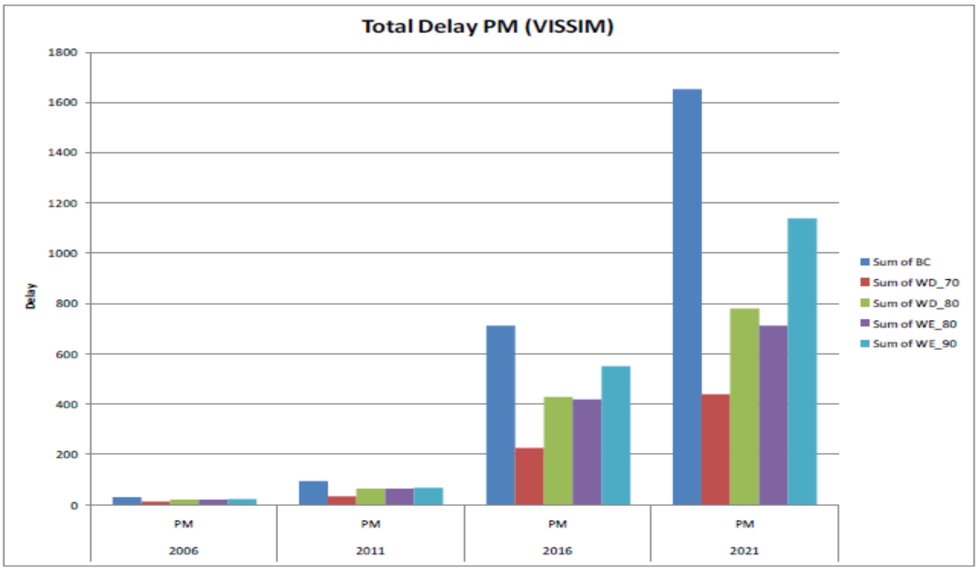

Figure 23 – PM total truck delay

Environmental impact implications

Several scientific articles have highlighted the severe impact that port-related activity may have on the environment, both from the water side and the land side operations. Truck operations related impacts become even more crucial when terminals are located nearby urban areas with residents experiencing high pollutant exposure levels (Lena et al., 2002) and increased health risk (South Coast Air Quality Management District, 2000). To this end, implementing effective solutions for easing congestion on port roadside networks proves to be an important issue with benefits to many different stakeholders (e.g. port workers, nearby residents, truckers, etc.) As indicated in the previous sections, the implementation of gate appointment systems and extended gate hours can assist in reducing truck delays and improve truck travel times thus increasing trucks' average speed and streamlining traffic operations on the port roadside network. Speed improvements of 2.5 mph, 5 mph and 10 mph can provide CO_2 related benefits of up to 25%, 45% and 75% respectively (Bath and Boriboonsomsin, 2008). However, the wide breadth of congestion effects continues to hinder comprehensive investigations of congestion impacts on emissions, indicating it as a research field to be further investigated.

CONCLUSIONS

This paper presented a simulation based approach capable of modelling traffic operations of incoming and outgoing drayage trucks at a container port, using as a case study the Newark / Elizabeth area of the Port of New York and New Jersey. Realistic estimates of truck traffic, travel time, delay and various other performance metrics for a base case scenario (representing current conditions) and several other implementation scenarios, focusing on the two common operational strategies i.e. gate appointment systems and extended hours of gate operation, were produced. Results indicate that recent network improvements are capable of handling increased demand until year 2016 but continuous demand increase can only be addressed by aggressive off-peak demand shifting strategies. To that end, research is needed to establish quantitative relationships between demand shifts and demand shifting pricing mechanisms (e.g. congestion pricing).

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