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I am submitting herewith a thesis written by Adebola Adebisi Adelakun entitled “Simulating Truck Lane Management Approaches to Improve Efficiency and Safety of Highways in Knoxville, Tennessee.” I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

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Simulating Truck Lane Management Approaches to Improve Efficiency and Safety of Highways in Knoxville, Tennessee

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Abstract

Increased globalization has caused large increases in truck traffic on the nation's interstate system, with much additional growth expected in the coming years. This growth has elevated interest in developing new strategies to address rising levels of truck traffic, especially in dense and congested urban areas. This thesis focuses on the evaluation of several alternative lane management configurations as they compare to the current lane configuration in search of the best fit for operational improvement. This task was performed in two ways – survey and simulation. A survey of 500 long-haul truck drivers was administered in Knoxville, Tennessee, at the crossroads of major north-south and east-west interstate highways. The dataset was evenly divided between owner-operators and truck-company employed drivers. The survey suggested the alternative truck lane management configurations and most of the respondents supported moving truck lanes to the inside travel lanes to avoid merging and lane changing cars, either through traditional truck lanes restrictions or truck only lanes. The alternative lane configurations and the current lane configuration were simulated in VISSIM. Parameters such as speed, travel time, delay, and lane change were used for evaluating the configurations during simulation. A statistical test was applied to the results of the simulations. Each configuration yielded significantly different results in most cases and a few insignificant changes in other cases. One of the configurations – the optional truck only lane configuration, stood out as the best fit for operational improvements by offering high speeds, shorter travel times, smaller delay times and greater delay cost savings, and increased highway safety. Such configuration could potentially address the challenges faced by increasing truck traffic in congested urban areas.

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1.0 Introduction

1.1 Background

Truck freight transportation in the United States is currently expanding. There are more trucks on US highways than ever before as a result of increased commercial activities on both local and international levels. According to the Federal Highway Administration, truck traffic increased by over 90 percent between 1980 and 2000. Also, truck traffic is expected to continue to grow by 3 percent each year through 2020. The fact is that the demand for highway capacity has become greater than the supply during peak hours in most cities. These increases in truck traffic reduce capacity of urban expressways, reduce safety of transportation facilities due to differences in vehicle mix and performance, and impact many other factors like pollution and exposure to hazardous waste. Many states have acknowledged this growing problem and some are in the process of addressing it. The state of Tennessee is no exemption.

Knoxville is the largest city in the east Tennessee region. It is at the crossroads of the I-40 corridor, running east and west and the I-75 corridor, running north and south. These freeways combine through a large portion of west Knoxville, forcing large volumes of truck traffic traveling in all directions through Knoxville's urban area. Knoxville's roadways handle 22 million truck trips yearly, moving 338 million tons of freight. Over 67% of all truck traffic on Knoxville's highways is passing through, with neither origin nor destination in the region (Knoxville Regional Transportation Planning Organization 2007). High levels of suburban housing and retail development in the west has resulted in congestion and competition for capacity between freight movements and urban commuters. Increasing truck traffic also compromises highway safety. While truck crash rates may not be as high as car crash rates, fatal crash rates are higher for trucks (Douglas 2003).

The trend that increased truck traffic on the urban freeways is moving through the urban area has prompted plans for major infrastructure and management initiatives to divert through truck traffic and/or more efficiently move through traffic out of the urban area. A major capital project that has been proposed is the Knoxville Parkway which would also be known as State Route 475. The proposed Knoxville Parkway would

connect I-40/I-75 southwest of Knoxville to I-75 north of Knoxville. This route is envisioned to allow vehicles to travel between either I-75 south or I-40 west and I-75 north without having to travel on the congested sections of these two routes that lead into downtown Knoxville (Tennessee Department of Transportation 2008).

1.2 Research Objectives

An operational strategy that several states including Tennessee, have implemented is truck lane restrictions. Through the urban area of Knoxville, trucks are currently restricted to the right two lanes. In many areas during peak hours, trucks occupy a large portion of the capacity in those right two lanes, with passenger cars merging through those lanes (see Figure 1-01) to enter and exit the freeway and access the higher speed left lanes. This operation could cause considerable discomfort for car and truck drivers and potentially increase the exposure to collisions. Moreover, cars mixing with more uniform truck traffic could increase congestion by requiring trucks to frequently regulate speeds to mix with heterogeneous entering and exiting traffic flows typical of urban areas.



Figure 1-01. Merging Problems caused by Trucks on I-40/75 at Papermill

This research is going to test the hypothesis that the current lane configuration is less safe and/or efficient than one or more alternatives. To test this hypothesis, the researcher will evaluate several lane management options and ultimately come up with a safer and more efficient option that would reduce congestion and conflicts on Knoxville highways, and potentially highways in other urban cities with high truck volumes.

This research identifies several low cost lane use rules and operational improvement strategies that could be implemented to reduce the previously stated conflicts and potentially allow trucks to bypass recurring peak hour congestion in Knoxville and other cities.

These strategies are evaluated using a microsimulation tool called VISSIM in order to get statistically sound results from which recommendations will be made. This research will be evaluating 32.5 miles of highway along the corridors of I-40 and I-640 through Knoxville (see Figure 1-02). The section of I-40 through downtown Knoxville is not included because of the “SmartFix 40” construction underway. The SmartFix40 project involves the closing of a short section of I-40 between James White Parkway (exit 388A) and Hall of Fame Drive (exit 389) for reconstruction.



Figure 1-02. I-40/640 Corridor to be Evaluated

This research also incorporates a survey that looks at the views and perceptions of truck drivers as they deal with the consequences and challenges of increasing truck traffic along with interaction with passenger vehicles on urban highways. These perceptions are generated from a survey that was conducted on 500 truck drivers and gathered information about their perceptions of the safety and congestion problems in Knoxville, their preferences on lane configurations to alleviate those problems, and their willingness to pay tolls to improve their efficiency. These improvements could be either by expanded infrastructure, or improved priority, such as converting existing lanes to managed lanes.

The findings of this research will benefit the Tennessee Department of Transportation and other state DOTs by providing an understanding of which strategies are the most effective at mitigating the impacts of increasing truck traffic.

1.3 Thesis Outline

This thesis is comprised of seven chapters including background and research objectives in Chapter 1. Chapter 2 reviews relevant freight transportation literature, including a background on truck lane configurations, statistics on the problems with truck traffic, some microsimulation approaches, and existing surveys. Chapter 3 describes the survey methodology and also discusses the survey results. Chapter 4 discusses the simulation methodology. It includes the data collection method, an overview of the VISSIM microsimulation tool, and the method for analyzing the results. Chapter 5 contains the microsimulation analysis. The comparison of the results from the microsimulation analysis is contained in Chapter 6. Chapter 7 presents the conclusions and recommendations drawn from this research.

2.0 Literature Review

This section reviews truck lane configurations or special truck treatments, the problems with increasing truck traffic in urban areas, other microsimulation approaches at this issue of dealing with increasing truck traffic, and existing surveys about trucks and the survey methods.

2.1 Truck Lane Configurations

Truck lane configurations could also be referred to as special truck treatments on freeways. There has been extensive study on special truck treatments on freeways. Middleton, Venglar et al. (2006) presented a table that describes the various special truck treatments in detail and also includes examples of cities that have implemented one or more of these truck treatments (Table 2-01).

Cate and Urbanik (2004) noted that more agencies are turning to the managed-lanes concept rather than utilizing physical expansion of roadways. They explain that the managed-lanes concept involves the assignment of special operating conditions to specific lanes of a roadway in order to improve efficiency and/or safety of the roadway. Furthermore, Collier and Goodin (2004) defined managed lanes as a limited number of lanes set aside within an expressway cross section where multiple operational strategies are utilized, and actively adjusted as the need arises, for the purpose of achieving pre-defined performance objectives. Based on review of the work of various researchers (Middleton, Venglar et al. 2006, Cate and Urbanik 2004, Kiattikomol 2002), the most commonly implemented strategy under the managed-lanes concept are truck lane restrictions. Nevertheless, exclusive truck facilities have recently received much attention.

Exclusive Truck Facilities: these are facilities specially designed for the use of trucks only. Truck only lanes are lanes that are separated from the remaining roadway lanes by a physical barrier and equipped with their own access and exit ramps (Rakha, Flintsch et al. 2005). They are designed to accommodate longer and heavier trucks because trucks have very different accelerating, turning, and braking characteristics when compared to passenger vehicles (Rakha, Flintsch et al. 2005). In recent years, three states

Table 2-01. Special Truck Treatments (Middleton, Venglar et al. 2006)

Special Truck Treatments	Description	Examples
Lane restrictions	Trucks are restricted to specified lanes. Other vehicles may travel in any lane. Restricted Lanes are not separated from mainlines.	Capital Beltway, Virginia; Houston, Texas; California, and many others
Exclusive Lanes	Trucks use only specified lanes that are designated for their exclusive use. Other vehicles may not travel in the exclusive lane. Exclusive lanes are not physically separated from mainlines.	None implemented in the U.S.
Exclusive Facilities	Trucks use a facility or lanes that are designated for their use only. These lanes are generally separated from the mainlines by barriers or medians.	No freeway examples implemented in the U.S.
Reserve Capacity Lanes	Trucks are provided access to reserve capacity lanes - i.e., high occupancy vehicle (HOV) lanes - in order to relieve congestion on mainlanes.	None implemented in the U.S.
Separation and Bypass Facilities	Separation or bypass lanes are treatments used for a specific section or segment of roadway. The bypass lanes allow truck traffic to bypass or be separated from other traffic on the targeted segment. This treatment often addresses a roadway segment that has the following characteristics: weaving area, a significant grade, high percentage of truck traffic, and/or congestion.	Portland, Oregon; Los Angeles, California; and Paris A86 Ring.
Dual Facilities	Dual facilities have physically separated inner and outer roadways in each direction. The inner roadway is reserved for light vehicles or cars only, while the outer roadway is open to all vehicles.	New Jersey Turnpike
Multimodal Capacity Improvements	Uses two or more transportation modes, generally a roadway and rail combination, to improve operations and capacity.	Alp Transit St. Gotthard (under construction)
Time of Day Restrictions or Peak Period Bans	Time-of-day restrictions restrict all trucks or specified trucks from either designated lanes or routes during specific times of the day, usually peak hour traffic.	New York City
Route Restrictions	Route restrictions restrict either all trucks or specified trucks from traveling on certain routes or freeway sections.	Atlanta
Speed Restrictions	Differential speed limits are imposed for trucks and other vehicles. The speed limit differentials vary from 5 mph to 10 mph, with truck speeds always being the lower speed.	Texas, Tennessee

have demonstrated interest in truck-only lanes and plans have begun to build these facilities.

The SR-60 freeway in California is one of the three freeways being studied for the possibility of truck-only lanes parallel to it. The study recommended two truck-only lanes in each direction and the project is estimated to cost \$4.3 billion in construction costs (Middleton and Venglar, 2005). The I-81 freeway in Virginia is also one of the freeways to be expanded to include truck-only lanes. This concept was introduced in 2004. There will be two lanes in each direction for trucks, which will be 325 miles in length. The project is expected to be completed in fifteen years (Middleton and Venglar, 2005). In 2002, the Trans Texas Corridor (TTC) concept was introduced. It is a proposed multi-use, statewide network of transportation routes that will incorporate existing and new highways. In this project, there will also be two truck-only lanes in each direction (Middleton and Venglar, 2005).

2.2 Problems with Increasing Truck Traffic in Urban Areas

There are various problems associated with increasing truck traffic on urban freeways. Previous research has investigated truck traffic in urban areas and generally concludes that truck traffic can affect safety and efficiency significantly. The safety of all drivers, both passenger vehicles and trucks, is highly important as more trucks mix with passenger vehicles on our highways. Also, traffic congestion continues to worsen on our freeways as a result of this vehicle mix. This section will look at these two major problems in more detail.

Safety

With passenger cars driving along the side of trucks on the freeways, safety will always be a concern. The significant difference in size and mass usually puts the occupants of a passenger car at a great disadvantage during collisions (Forkenbrock and March, 2005). Nationwide statistics indicate that total crash rates for large trucks are lower than for passenger vehicles; however the fatal crash rates are higher. In 2005, large trucks were involved in 189 total crashes per 100 million vehicle-miles (MVM) and 2.03 fatal crashes per 100 MVM while passenger vehicles were involved in

216 total crashes per 100 MVM and 1.26 fatal crashes per 100 MVM (Federal Motor Carrier Safety Administration 2007).

According to the National Safety Council, “in truck/automobile collisions, the car driver is 49 times as likely to be killed as the truck driver because of the difference in mass” (Rakha, Flintsch et al. 2005 Pg 4). Also, “according to the Federal Motor Carrier Safety Administration’s Large Truck Crash Facts 2003, published February 2005, of all crashes involving large trucks and passenger vehicles, 84 percent of the fatalities in 2003 were passengers in vehicles other than the large truck” (Forkenbrock and March, 2005). Each year more than 40,000 people die as a result of highway crashes, and 1 in 8 of those crashes involve commercial motor vehicles (Middleton, Venglar et al. 2006).

In addition to managed lanes, truck-only lanes have also been studied as an alternative to the solutions to the challenges caused by truck traffic on freeways. Results from these studies indicate that truck-only lanes increase safety because the trucks are physically separated from the passenger vehicles by a concrete barrier (Rakha, Flintsch et al. 2005). These studies also show that truck-only lanes could improve driver comfort and convenience and the issue of truck size intimidating drivers of passenger vehicles could also be eliminated (Forkenbrock and March, 2005). Safety of vehicles on freeways is paramount today and based on statistics the number of truck-passenger vehicle crashes is not getting any smaller as a result of the increasing number of trucks on our freeways.

Efficiency

Freeway operating efficiency refers to the level of service, delay, density, congestion, and speed to name a few. All of these components are directly related to one another; however the most obvious efficiency problem to a driver of a passenger vehicle is congestion. Increasing truck traffic can cause traffic congestion because trucks are longer, thereby using more highway space than passenger vehicles, and they have slower rates of acceleration and deceleration (Douglas 2003). For instance, the passenger car equivalent for trucks on upgrades that are half a mile long with grades of 3 to 4 percent in rolling terrain is 2.5 (Ingle, Anthony 2004). Many researchers have evaluated various management strategies as it relates to efficiency and congestion. These management strategies are truck lane restrictions and truck only lanes. Hanscom studied three

interstate sections in Wisconsin and Illinois using truck lane occupancy, delay to following vehicles, proportion of trucks impeding followers, and adjacent lane speed differential to measure effectiveness. The study evaluated tests before and after lane restrictions were implemented. Two of the three sites had three lanes in each direction while the third site had two lanes in each direction. At the sites with three lanes in each direction of travel, trucks were restricted to the two right lanes and at the site with two lanes in each direction of travel, trucks were restricted to the left lane only due to deteriorating pavement in the right lane. The study observed a high level of compliance with the lane restrictions. For the two sites with three lanes in each direction, he recorded a decrease in the number of vehicles impeded by trucks. For the site with two lanes in each direction, the restriction had negative effects caused by the crowding of trucks in the left lane which limited passing for passenger vehicles following noncomplying trucks in the right lane. He concluded that truck lane restrictions implemented on freeway sections with three or more lanes generates the best results in terms of traffic flow and congestion (Hanscom 1990).

Furthermore, other findings that address the benefits of truck lane restrictions are as follows (Cate and Urbanik, 2004, Kiattikomol, 2002, Rakha, Flintsch et al. 2005):

- restricting trucks from the left lane with steep grades causes an increase in the speed differential, decreases density and decreases the number of lane changes
- restricting trucks from the right lane increases the number of lane changes for sites without entry and exit ramps
- trucks should be restricted from the left lane on sections with grades of 4 percent or higher
- site characteristics have an impact on the effects of truck lane restrictions
- prohibiting trucks from the leftmost lane on sections of highway with three or more lanes of travel in each direction has no negative effect on efficiency
- and as the severity of uphill grade is increased, passenger vehicles begin to see significant operational benefits

It is important to keep in mind that truck lane restrictions do not completely separate passenger vehicles from trucks, however it at least provides one lane on the freeway that is free of trucks. This tends to give drivers some measure of relief knowing

that they could drive without truck interference in that lane (Middleton, Venglar et al. 2006). A study conducted by the federal highway administration to determine why 26 states in the United States implemented truck lane restrictions revealed the most common reasons to be improved highway operations and reduced crashes (Middleton, Venglar et al. 2006).

In the case of truck-only lanes or exclusive truck facilities, studies have demonstrated that this truck treatment offers the maximum benefits in terms of efficiency through improved speeds, reduced congestion, reduced delay, and shorter travel times (Rakha, Flintsch et al. 2005). The benefits of this strategy also extend to lower maintenance costs on general-traffic lanes (Forkenbrock and March, 2005). The largest obstacle to implementing truck-only lanes is construction costs. Poole and Samuel (2004) state an approximate cost of \$2.5 million per lane mile to construct a truck-only facility alongside and existing rural interstate. This figure does not include land acquisition costs. The cost would also vary depending on right-of-way availability, topography, the need for overpass reconstruction for heavier gross vehicle weights, number of entrance and exit ramps needed, and other factors. Also a cost estimate done by Middleton, Venglar et al. (2006) for a two lane exclusive truck roadway came out to be approximately \$5.5 million per mile. This estimate is consistent with the Poole and Samuel (2004) estimate.

2.3 Applied Microsimulation Approaches

Microsimulation programs have been developed to model the flow of individual vehicles on road segments and networks. Some of these software applications include VISSIM, CORSIM, PARAMICS, INTEGRATION, and SimTraffic.

Middleton and Venglar (2005) used the VISSIM microsimulation tool to evaluate the operational aspects of exclusive truck roadways. The research team developed VISSIM simulation models of generic rural freeway sections as a starting point for determining capacity of an exclusive truck facility. They then created variations on this basic model to explore capacity impacts of grades and entrance and exit ramps. A 20 mile segment of a truck-only freeway was modeled to ensure adequate measurements of capacity effects. Capacity under prevailing operating conditions was determined by increasing the input flows in each of ten model runs until output flow reached its

maximum value. Capacity was the average maximum flow rate at the most extreme downstream point on the simulated network. The other VISSIM outputs from this analysis were delay, fuel consumption, and emissions for mixed flow versus separated facilities for computing the operational costs (delay time value and cost of fuel consumption) of each design under the extensive range of operating conditions scrutinized in the research.

Cate and Urbanik (2004) also used VISSIM to model freeway operations relating to truck lane restrictions. A series of simulations was performed to test the effect of truck lane restrictions on performance measures such as density, travel time, and number of lane changes. There were about 13 scenarios, and for each scenario two simulations were performed. In scenarios without ramps, the model consisted of a single 5 mile long segment with three lanes. In scenarios with ramps, the initial segment is 2 miles long with three lanes. At the 2 mile mark, the entrance ramp joins the freeway's main lanes with a 1,320 ft long (0.25 mi) acceleration lane. At the 3 mile mark, the exit ramp diverges from the freeway and the final freeway segment continues for another 2 miles making a total length of 5 miles. The output files generated by VISSIM are used to calculate the performance statistics such as vehicle density and level of service for each distinct freeway segment, average travel time for individual vehicle types and routes, and the number and description of each lane change over the simulation period. The comparisons made between the before and after conditions were used to quantify the impact of the applied lane restriction.

Yang and Regan (2007) used Paramics to determine the impacts of left lane truck restrictions on urban freeways. There were three scenarios. The first was a do-nothing scenario. The second was restricting trucks from the far left lane. The third was restricting trucks from the two far left lanes. This simulation evaluated parameters such as average speed, average travel time, and frequency of lane changes.

Rakha, Flintsch et al. (2005) used the INTEGRATION software to evaluate alternative truck management strategies along I-81 in Virginia. The simulation network was built using an AutoCAD design to define the horizontal profile. Roadway grades were generated by driving a vehicle equipped with a Global Positioning System (GPS) along the study section. Nine scenarios for improving traffic flow were modeled. The

first scenario was a do-nothing scenario. The second was two truck only lanes in each direction. The other six were different variations of additional lanes and climbing lanes. The simulation of the model evaluated performance parameters such as average speed, travel time, delay, and vehicle emissions for all nine scenarios. These results were used to quantify road user costs (fuel and vehicle maintenance cost), travel time savings, and environmental benefits.

2.4 Surveys and Methods

Several researchers have conducted surveys to identify concerns and perceptions of truck operators and freight transportation managers. The National Cooperative Highway Research Program (NCHRP) sponsored a survey in 2001 that was designed to identify the strategies being implemented in order to address the challenges associated with increasing truck traffic. The survey was intended for transportation organizations, particularly State Departments of Transportation (DOTs) and Metropolitan Planning Organizations (MPOs) to identify strategies they had in place to address truck traffic. The strategies were grouped into eight categories which include improved highway design, roadway facilities for trucks, operational strategies, intelligent transportation systems, signing, vehicle size and configuration, enforcement and compliance, and investments in alternative infrastructure.

The researchers received responses on the survey from twenty-five states and eight MPOs. The strategies under the “roadway facilities for trucks” category include dedicated roads for trucks or commercial vehicles, special use lanes for trucks or commercial vehicles, truck climbing lanes, and dedicated truck ramps. The survey found that more than 75 percent of the states responding have climbing lanes, 20 percent are developing special use lanes or dedicated ramps, and only one state reported approval of a dedicated road for trucks. The strategies under the “operational strategies” category include lane restrictions, time-of-day restrictions, roadway restrictions or prohibitions, parking restrictions or prohibitions, incident management, and improvements in intermodal operations. The survey found that with the exception of time-of-day restrictions, most of the states have implemented one or more options under the

operational strategies category with incident management being the most implemented (19 of 25 states) (Douglas 2003).

The Washington State DOT and the federal government funded a six-year study called Eastern Washington Intermodal Transportation Study. One of the reports generated from this study was based on a survey conducted to determine Washington state truck origin and destination volumes. The method used to conduct this survey was via intercept survey interviews. The targeted population was truck drivers. The interview personnel conducted about 28,000 interviews in a year. The application of the freight truck origin and destination data are corridor planning, intermodal systems planning, pavement management, and congestion management and safety (Gillis and Casavant, 1994).

Furthermore, the American Transportation Research Institute conducted a survey of motor carrier opinions on potential optional truck only toll (TOT) lanes on Atlanta interstate highways. Atlanta highways have a serious congestion problem resulting from recent economic and population growth. In the freight perspective, nearly 300 million tons of freight are transported annually and 12.9 billion miles are traveled by truck annually in Georgia alone. This survey was conducted as a result of the idea that tolls would address the congestion problem to a certain extent. The results indicated that Georgia carriers have a staggering interest in using optional truck-only lanes when no cost exists. However, a pricing mechanism could ensure that the TOT lanes are kept at a free-flow level (Short, 2007).

The Center for Transportation Research of the University of Texas at Austin published a truck data collection guidebook that discusses how to conduct truck surveys. The guidebook discusses roadside intercept surveys, data collection and sampling, recruiting survey personnel, survey equipments, interview procedure, and questionnaire design (Prozzi, Wong, and Harrison, 2004).

2.5 Summary

The increase in truck traffic is in part a result of globalizing economic conditions requiring more movement of freight. While freight movement is a significant contributor to the economy, increasing truck traffic can be devastating on freeways because the

volume of truck traffic is outgrowing highway capacity increases. While the cost of building additional lanes is very high and constantly increasing, it takes years to build the additional lanes required. Moreover, right-of-way in dense urban areas is difficult and expensive to acquire. This is one of the reasons transportation agencies are conducting several studies to determine how feasible other strategies are that can address the challenges of increasing truck traffic. Safety and efficiency are important issues that are significantly affected by truck traffic. Researchers have done extensive work using microsimulation analysis and surveys to identify the impacts of increasing truck traffic on the two factors (safety and efficiency) mentioned previously and useful conclusions are being reached through this collective effort.

3.0 Truck Driver Perception Survey

3.1 Methodology

The truck driver perception survey was a part of this research to ensure the involvement of truckers in the process. Truck drivers have to drive on this infrastructure and their input on the lane configurations count. Therefore it was imperative that the alternatives that were acceptable to truckers were part of the alternatives that were tested.

Site Selection

Site selection is driven by the types of drivers we would like to survey. This study is focusing on providing infrastructure or priority rule changes for truck drivers traveling through the Knoxville urban area. For surveys dealing with truck freight, many studies have utilized permanent weigh stations as the primary site for data collection. This option was evaluated; however it was not the best for this study for a number of reasons, primarily associated with sampling. The type of site that was selected for data collection was a truck stop or travel plaza, which is a location along the highway that combines the services of a gas station for trucks, convenient store, restaurant, and a parking lot in one stop along I-40 and I-75 (exit 369) in Knoxville, Tennessee. This selection was based on the high truck volumes generated at this truck stop, its service of I-75 and I-40 traffic simultaneously, and its proximity to Knoxville to reduce the amount of drivers with destinations in the urban area, ensuring the target of through traffic.

Survey Method

The survey method chosen was an intercept survey. Interviews were conducted with 500 truck drivers at the site location, generally during the refueling/vehicle inspection process.

Questionnaire Design

The questionnaire is an important element in intercept surveys. The questionnaire for this survey was designed in a manner that ensures that the truck drivers are not overwhelmed by the interview process. The questions were worded in a manner that ensures easy understanding that would generate correct responses. This survey collected

information on operator status, years of driving experience, origin and destination, Knoxville area destinations, how often the Knoxville highways are travelled, perception of congestion in Knoxville, schedule adjustments, perceptions on lane configurations, factors that reduce efficiency and safety, effect of smaller vehicles, and willingness to pay tolls.

The questionnaire was designed to be completed within 3 to 5 minutes to encourage truck driver participation. Check boxes were used to enhance interview completion by reducing writing tasks. Finally, the questions could be read out to the driver while he or she is engaged in other activities like fueling up, or the questionnaire could be filled-out by the truck driver him/herself within the predicted time frame of 3 to 5 minutes. The survey questionnaire is shown in Appendix A.

Interview Dates

The time frame limit was 5 weeks with the first set of interviews conducted on the 26th, 28th, and 31st of March, 2008. The second set of interviews was conducted on the 23rd, 25th, 28th, and 29th of April, 2008. The three week gap between the first and second set was due to unforeseen circumstances. There were rumors about a truck operator strike provoked by the high diesel prices during the first week of April. The interview process was then put on hold in order to avoid getting a biased sample. The interview process was resumed two weeks after the rumors when truck movements seemed back to normal. Overall, a 90 percent response rate was achieved during the intercept interviews.

3.2 Discussion of Survey Results

The results discussed in this chapter are based on a survey of 500 truck drivers in an effort to gather the views and perceptions of truck drivers as they deal with the consequences and challenges of increasing truck traffic along with interaction with passenger vehicles on urban highways.

Driver and load background

Since the survey location was located at the crossroads of two major corridors, the origins and destinations of the load were distributed throughout the country, though they

are centered in the Southeast. Table 3-01 shows the ten States with the most common origins and destinations.

The dataset was evenly split, with 47% independent-operators and 53% employed by a corporate motor carrier. Among the descriptive questions related to trip length, experience and trip making frequency, the two types of drivers varied significantly. One noteworthy instance is distance traveled between origin and destination, with independent-operators representing 20% longer trips. The distances traveled along the freeway network, from the origin, through Knoxville, to the destination were calculated, resulting in a bi-modal distribution (Figure 3-01).

The first peak on both of these cases is generally traffic originating and destined on the East and Midwest, with the second peak representing West coast traffic. Inversely related to distance is the frequency of trips, with independent-operators making fewer trips through Knoxville (4.8 trips/month) compared to company drivers (6.4 trips/month). Only 3% of the sample planned on stopping in Knoxville. Driver experience varied by employment status, with independent-operators averaging 18.7 years of experience and company employed operators averaging 16.5 years of experience.

Table 3-01. Common Truck Origins and Destinations

Most Common Origin	% of trips	Most Common Destination	% of Trips
TN	19	TN	11
NC	7	GA	10
CA	7	TX	8
Canada	6	NC	8
GA	6	NJ	5
OH	6	Canada	5
TX	6	AL	5
AL	4	PA	5
PA	4	CA	4
FL	3	OH	4

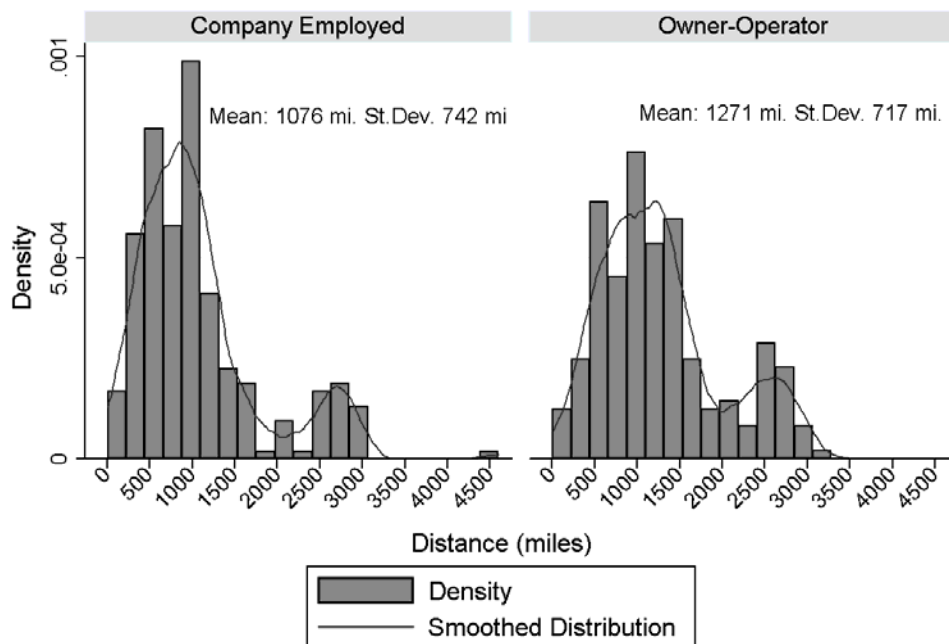


Figure 3-01. Truck Trip length by employment status

Local Perception of Congestion

Differences between types of truck drivers generally influence travel patterns and demographics. When asked of perceptions of congestion and safety, both sets of drivers tend to agree. When asked if they experience severe congestion in Knoxville, 75% answered affirmatively, mostly during peak periods. However, 42% of the respondents do not change their itinerary by time or route to avoid congestion. Of the total dataset, 31% stated that they experience severe congestion and they don't make any schedule or route adjustments to avoid it. This is an indication that the cost of making adjustments (due to schedule inflexibility or lack of sufficient alternative routes) is greater than the perceived costs associated with congestion. Still, 37% of respondents drive earlier, 43% travel later, and 27% use a bypass to avoid congestion (Figure 3-02)(note: respondents could choose more than one adjustment). Independent operators have a higher tendency to use a bypass, with 33% stating that they bypass, compared to only 18% of company employed drivers, perhaps because of their longer routes.

Drivers were asked two specific questions related to interactions with personal cars. The first question asked drivers to pick two factors from a list that reduce their efficiency and safety most significantly. Figure 3-03 shows the distribution of responses.

Clearly, aggressive drivers, congestion, vehicle lane changing behavior and on-ramp entering vehicles stand out as the most problematic factors from the respondents' perspective.

A similar follow-up question asked to what extent small vehicles traveling at faster speeds affected their driving task, yielding the responses illustrated in Figure 3-04. The response seems somewhat inconsistent with responses in the previous question. Nearly 50% of the respondents said that small cars moving at faster speeds do not affect their driving task, while aggressive drivers seem to dominate in Figure 3-03. This indicates that speed differential might not be as important as erratic driving, lane changing, or merging. Still, some 35% of respondents indicated that faster car drivers do make their task uncomfortable or very difficult.

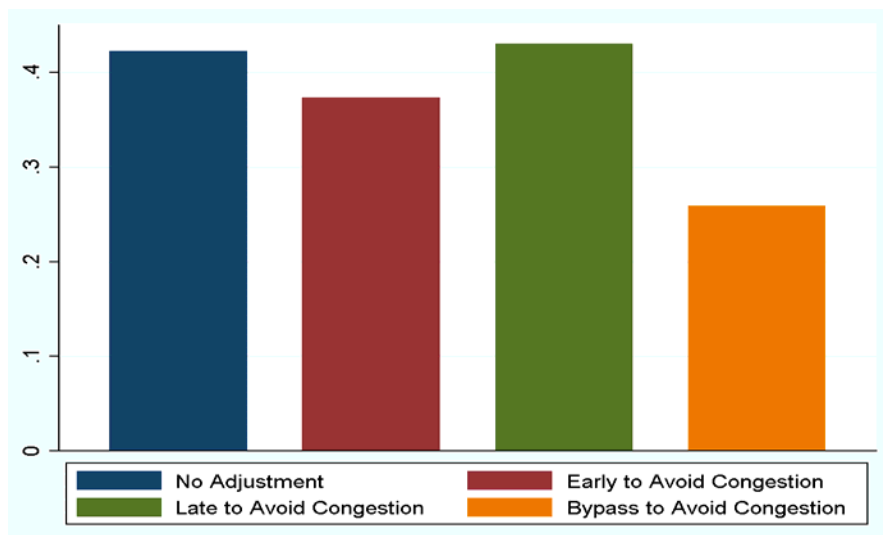


Figure 3-02. Do you adjust your schedule or route to avoid congestion?

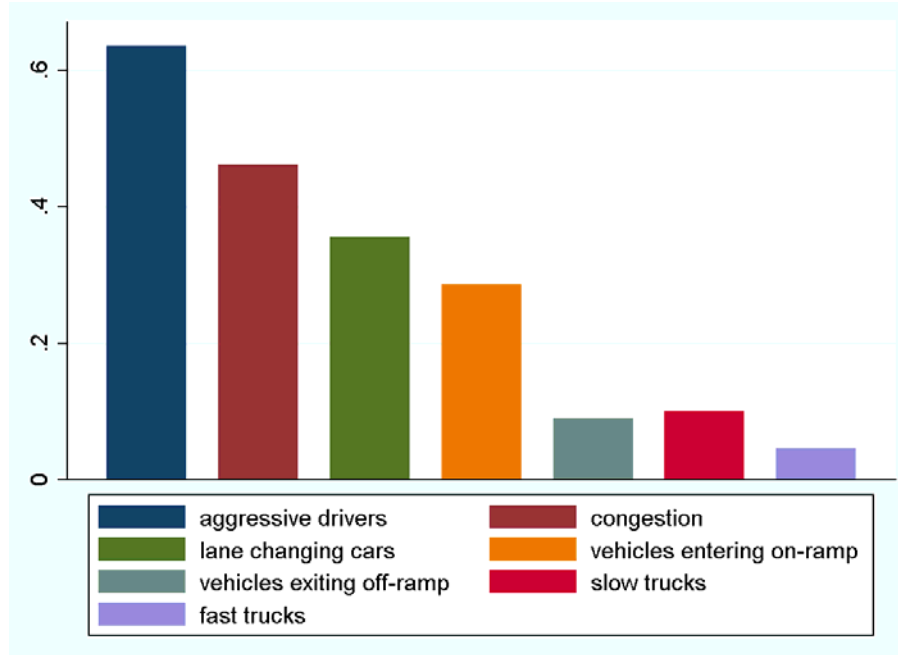


Figure 3-03. Factors that Most Affect Safety and Efficiency of Trucks

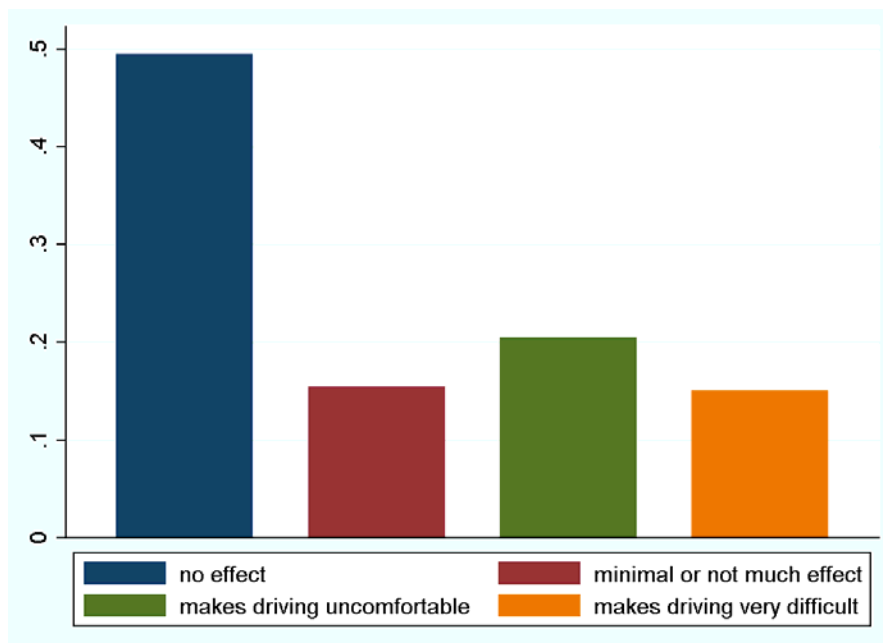


Figure 3-04. Effect of Faster Cars on Truck Driving Task

Lane Preferences

Some solutions to these challenges include managing the truck lanes more effectively, including moving trucks away from the outside lanes. In order to gauge truck drivers' interest in various lane rule changes or exclusive right of way options, they were asked to rank each of the following configurations (Figure 3-05) on a scale from 1-4, with 1 being unacceptable and 4 being most acceptable. These are the same configurations that were simulated in VISSIM.

The configurations with the highest approval were Configuration B and C, with 60% and 74% of respondents giving a 3 or 4 to those options, respectively (Figure 3-06). Configuration A was least attractive as might be expected as it is the most restrictive. Finally Configuration D, the status quo, had polarized responses with many thinking that it is most acceptable and many stating that it is unacceptable.

To understand what attributes truckers valued in relation to the lane configurations below, truckers were asked an open ended question about what influenced their highest rating. The answers to this open ended question followed several themes, which were grouped into categories. These categories and their response rate are shown in Figure 3-07.

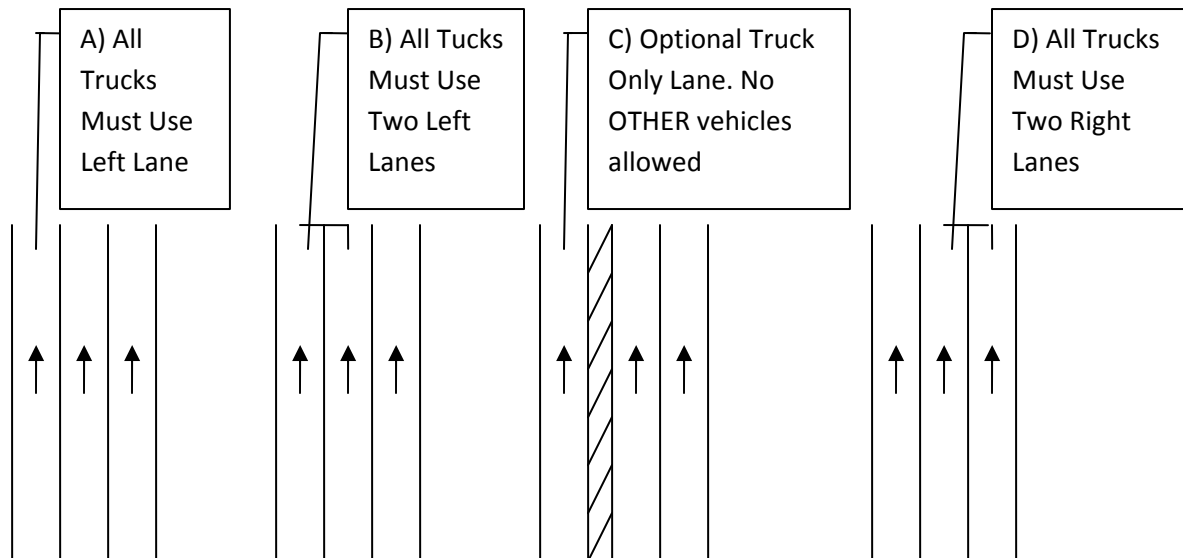


Figure 3-05. Rate these truck lane configurations

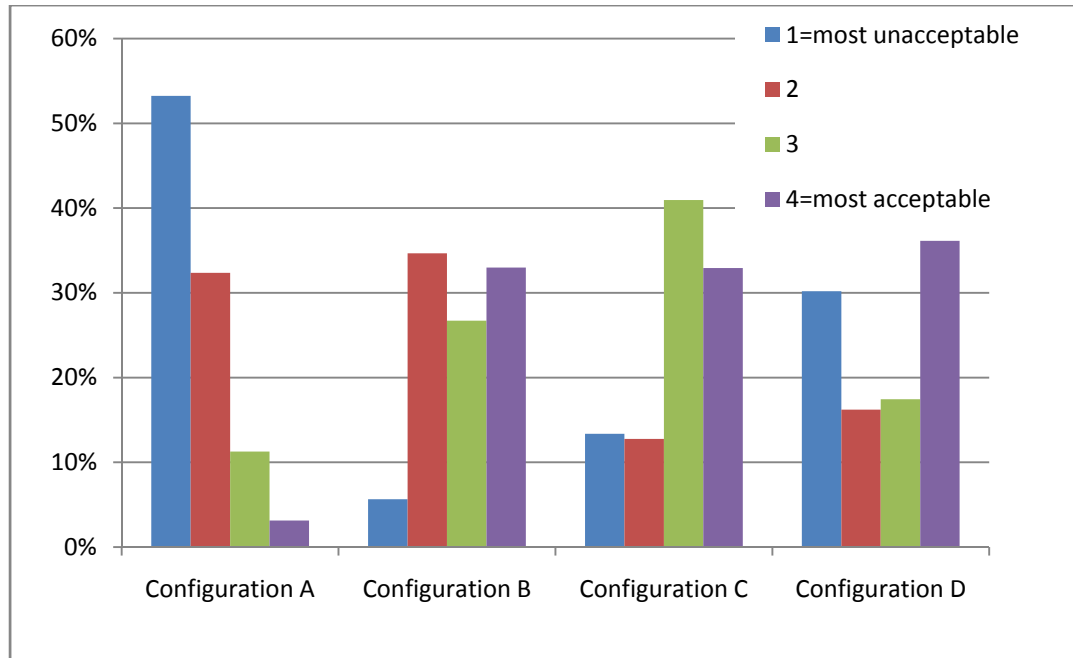


Figure 3-06. Road configuration rating from Figure 3-05

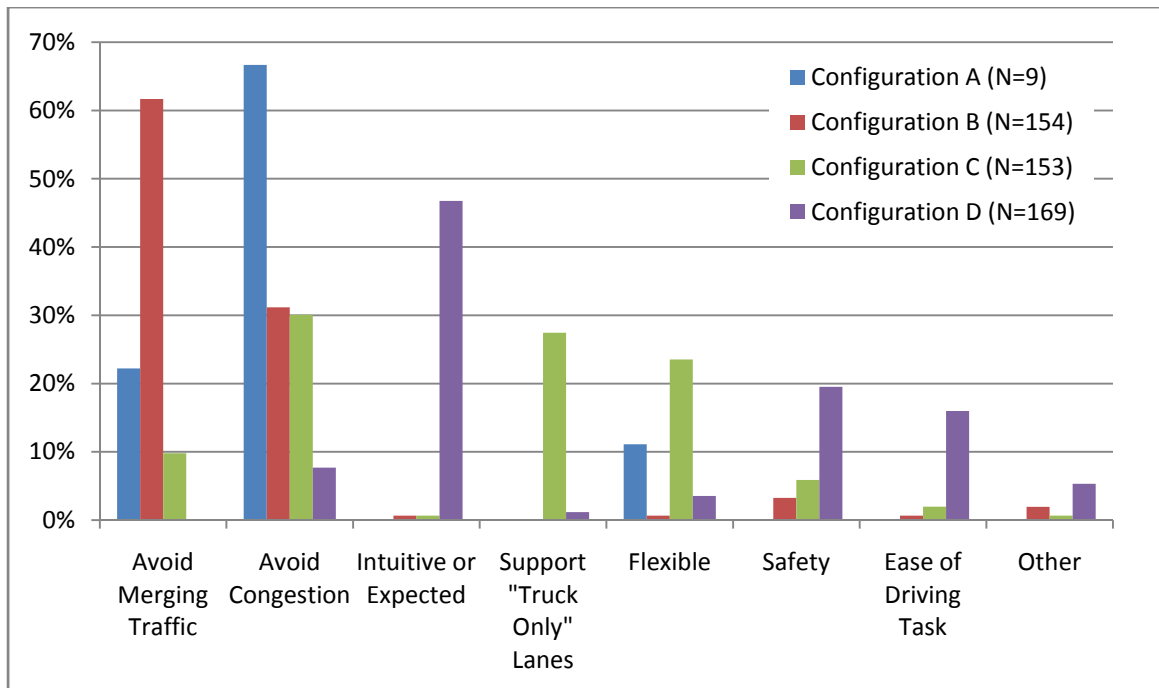


Figure 3-07. Reasons for giving a "most acceptable rating" on chosen configuration

Only nine respondents rated Configuration A (trucks must use left lane) as the most acceptable and two thirds of them responded that they chose that configuration to avoid merging traffic. Configuration B (left two lanes must be used by trucks) was the second most popular response. Over 60% of those who chose Configuration B did so because they would like to avoid merging traffic, which is a strong indicator of the perceived challenge of increased truck traffic and conflicts with merging auto traffic. Another 30% stated that they prefer Configuration B to avoid congestion. Configuration C (optional truck only lane) is perhaps the most preferred alternative, with a high number of “3” and “4” ratings. Nearly 1/3 of those that rated it “4” stated that they chose this alternative to avoid congestion. Nearly 30% stated that they chose this alternative because they support “truck only” lanes, but did not elaborate on what aspect of truck only lanes they support. The next most common responses were flexibility, avoiding merging traffic, and safety. Finally, Configuration D (trucks must use right two lanes) is the current system. This configuration had the most affirmative responses rated “4”, but also had more unacceptable responses, rated “1”, than configurations B and C. The most common responses fell under the category of “Intuitive or Expected”, indicating that drivers do not necessarily see it as advantageous from an operations perspective, but they are averse to changes in operating conditions or rules that are inconsistent with general “rules of the road”, such as slower traffic belongs on the right side of the traffic stream. Several respondents stated that they chose this configuration for safety reasons or because it made the driving task easier.

Willingness to Pay for Improvements

All of the configuration will require some infrastructure investment, from simple lane reassignment to perhaps greater investment in truck only facilities such as exclusive ramps and barrier separated lanes. Each of these configurations will have different costs and benefits in terms of expected delay reductions and safety improvements. It is expected that most respondents would be willing to pay primarily for delay reduction. Respondents were asked how much they would pay to reduce expected delay by ten minutes traveling through Knoxville’s urban area. Some 70% of the respondents were unwilling to pay any amount to save ten minutes of travel time. This is somewhat

unexpected but consistent with a previous study (Short 2007). On the other extreme, one respondent said he would pay \$100 to save ten minutes. The average willingness to pay of all respondents is \$2.17 (standard deviation \$7.70). Removing the \$100 “outlier” results in an average willingness to pay of \$1.75 (standard deviation \$4.20) to save 10 minutes. Including only those willing to pay some amount (removing those unwilling to pay), the average willingness to pay is \$5.92 (standard deviation \$5.90).

It was the authors’ hope that variables gathered in the survey, such as independent-operator status, route distance, frequency of travel through Knoxville, perception of congestion and conflict, or preference for truck only infrastructure; would be able to reveal relationships between a drivers’ willingness-to-pay a toll and those variables. Several regression-based model specifications did not reveal any significant relationships, indicating that willingness-to-pay a toll is not significantly related to any of the information gathered in this particular survey, at least in this study.

4.0 Simulation Methodology

4.1 Traffic Data

This research was intended to simulate several highway lane management configurations using current and future traffic patterns of the study corridor. This ensures that the results of the simulated lane management configurations are applicable to the study corridor. The collection of current traffic data was required so that the simulation model could be loaded with the same traffic patterns as existing in order to calibrate a representative model. Traffic data was collected before the SmartFix40 project begun in May, 2008. Therefore the network was modeled as if it were under normal traffic conditions.

The types of data that were collected were vehicle counts and average speed. The data were subdivided into four vehicle classes. These vehicle classes are car, single-unit truck, tractor-trailer, and bus.

4.2 Traffic Data Collection

A total of eight points along the highway section were selected for traffic data collection. Traffic data was collected using Tennessee Department of Transportation (TDOT) SmartWay cameras. These eight data collection points (DCP) are illustrated on the Figure 4-01 below.

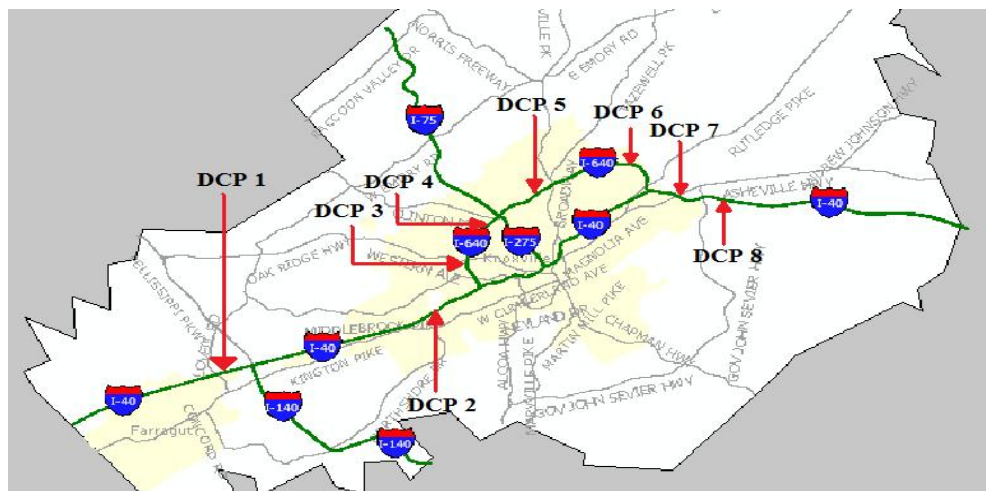


Figure 4-01. Graphical Locations of Data Collection Points (DCP)

The location of the above DCPs are as follows:

DCP 1: I-40 at Parkside Drive

DCP 2: I-40 at Papermill Road

DCP 3: I-640 at Western Avenue

DCP 4: I-640 at Wilson Road

DCP 5: I-640 at Dutch Valley Road

DCP 6: I-640 at Millertown Pike

DCP 7: I-40 at Asheville Highway

DCP 8: I-40 East of Holston River Bridge

Data were collected in April, 2008 using the TDOT SmartWay cameras. The SmartFIX40 project which involved the closing of a short section of I-40 through downtown Knoxville was scheduled for May 1st, 2008. Therefore the data collection was done before May to avoid potential traffic pattern complications and biases. At the time of data collection, the TDOT cameras provided a new image of the highway every minute. Figure 4-02 shows an image from a TDOT camera at one of the DCPs. The rush hour period from 5 to 6 pm was chosen for data collection; therefore 60 images were gathered at each DCP. A section demarcated by landmarks was identified in each image, so traffic counts were recorded for all vehicles that were within that section of the highway. The exact length of this section was measured in Google Earth using the same landmarks.

With known traffic volumes over a specified length of roadway, density could be calculated. A moving average analysis was done for the 60 traffic counts at each DCP location to get a representative average number of vehicles over a particular highway section with known length. Also, the traffic counts were for three or more lanes of highway, so the average number of vehicles was divided by the number of lanes to get “per lane” figures. Density was calculated using the following formula.

$$k \text{ (veh/ln/mi)} = \left(\frac{\left(\frac{\text{Avg \# of Veh}}{\text{\# of Lanes}} \right)}{\text{Section Length (ft)}} \right) \times 5280$$



Figure 4-02. Image from TDOT SmartWay Camera at Asheville Highway

Flow was calculated using density and speed. Average speed values were estimated from the speed groups reported by the TDOT SmartWay information system. Flow was calculated using the following formula.

$$q \text{ (veh/hr/ln)} = k \text{ (veh/ln/mi)} \times v \text{ (mph)}$$

In summary, density and flow were derived from the vehicle counts and average speed data collected.

4.3 Microsimulation Tool

Microsimulation software is a traffic analysis tool used in transportation analyses to model and analyze the operation of complex transportation systems under different conditions. This analysis helps predict potential behaviors and patterns relating to roadway and traffic operations under the different conditions that are introduced. Although microsimulation models are valuable tools, they have advantages as well as disadvantages.

Advantages of Simulation Models

Traffic simulation can be used to investigate and estimate the impacts of making modifications to the network, such as road geometry, traffic control, and traffic levels. Traffic simulation can assess these impacts without disrupting traffic operations, implementing costly measures, or causing unsafe conditions to motorists before a design is finalized. With simulation models, time can be compressed to allow for investigating the system operations over a long period in a short time interval. Another big advantage of traffic simulation is the ability to present proposed transportation alternatives to the public. The animated output produced by traffic simulation provides an effective tool to present technical data (in engineering terms) in an easy to use format for the average citizen. The use of traffic simulation can therefore support various decisions levels, such as operations, planning, and design (Upper Great Plains Transportation Institute 2002).

Disadvantages of Simulation Models

Simulation models can be costly to execute and maintain. Since these models typically provide a high level of detail, they have significant data requirements. Personnel

time and experience are also significant for collecting the required data and executing the model. Additional time is needed to troubleshoot and calibrate the model to represent an accurate depiction of the system. Simulation results may be difficult to interpret especially since they rely on random variables. In addition, traffic simulation models generally require high computing resources for processing and data management (Upper Great Plains Transportation Institute 2002).

VISSIM

The microsimulation tool used in this research is called VISSIM from PTV. VISSIM is a microscopic, time step and behavior based simulation model developed to model urban traffic and public transit operations (Planung Transport Verkehr 2007). The program can analyze traffic and transit operations under constraints such as lane configuration, traffic composition, traffic signals, transit stops, etc., thus making it a useful tool for the evaluation of various alternatives based on transportation engineering and planning measures of effectiveness.

Construction of the VISSIM Model

In building the network, the first task was to develop the highway network using background images. To get the background image, a plain gif image of the Knoxville highway network to be used was overlaid in Google Earth to match the corresponding road network. The Google Earth images were then saved for use in VISSIM. About 200 images made up the entire highway network to be evaluated. These images were brought into VISSIM and the links and connectors were drawn. Figure 4-03 below shows the entire highway network to be evaluated, a total of 32.5 miles made up of links and connectors in VISSIM. Several areas were modified to reflect recent highway modifications. This includes highway sections that used to be two lanes in each direction and now has three lanes in each direction to accommodate the “Smartfix40” project.

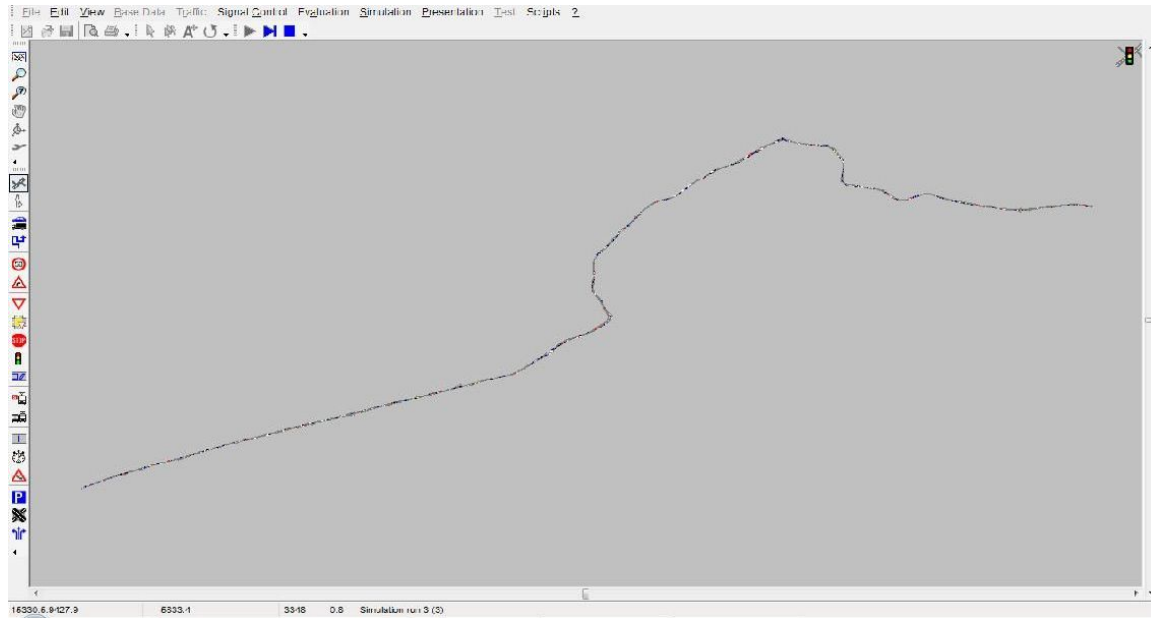


Figure 4-03. VISSIM Network

The next task was setting the simulation parameters. A period of 7200 simulation seconds was chosen. This represents 2 hours of simulation. For the simulation resolution, five time steps per second was selected, meaning that calculations in the simulation are conducted every 0.2 s. This value was within the range of recommended values by PTV. The random seed was set at one, although several simulations were run with different random seeds with an increment of 1. Finally the simulation speed was set at maximum. This makes the simulation run as fast as possible without affecting the parameters calculated during the simulation.

Next, four speed distributions were created. These represent stochastic distributions of desired speeds which will be defined for each vehicle type within the traffic composition. For each of these four speed distributions, there is a minimum and a maximum value. The vehicle types to be on the network were then chosen and their characteristics were edited. There are four vehicle types on this network – cars, single-unit trucks, HGVs (tractor-trailer), and buses.

Sixteen traffic compositions were defined – one for each direction (eastbound or westbound) at each data collection point. A traffic composition defines the vehicle mix

that will be delivered to the network from a particular input flow. Each traffic composition incorporated relative flows of each vehicle type and speed distributions.

Traffic volumes were then entered at the network endpoints and entrance ramps. Vehicle flow values were entered in vehicles per hour for each of the entrance ramps and the two end points and a traffic composition was selected for each input.

Calibration of the VISSIM Model

In order to ensure that the simulation model would be representative of field behaviors and patterns, it had to reflect field measured parameters. Link evaluations were done at each of the eight data collection points. These evaluations reported simulation results for average speed in miles per hour, vehicle density in vehicles per mile, and volume in vehicles per hour. The model figures reported for these three parameters seemed close to the field measured figures; nevertheless a statistical test was done to determine if the model's performance is within an acceptable range of field conditions. The GEH statistic (Dowling, Skabardonis, and Alexiadis 2004) was developed just for this purpose. The formula gets its name from Geoffrey E. Havers, a London transport planner who invented it in the 1970s. It is computed using the following formula:

$$GEH = \sqrt{\frac{(E - V)^2}{(E + V)/2}}$$

Where:

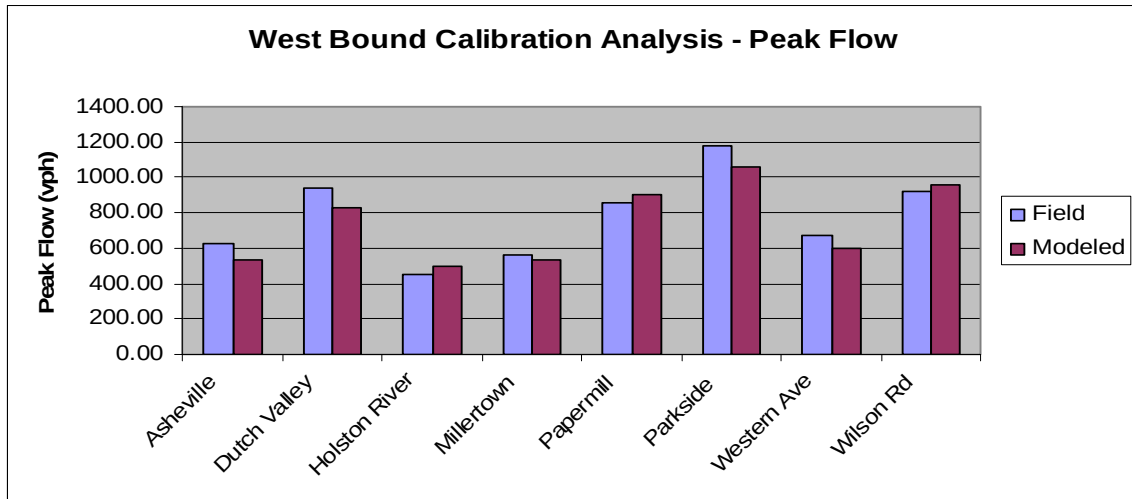
E = model estimate volume

V = field count

With the GEH statistic, there are two sets of requirements for a calibrated model – a) for individual link flows, 85 percent of the cases should report a GEH statistic of less than 5, and b) for the sum of all link flows, the GEH statistic should be less than 4. In the case of this simulation model, all individual link flows evaluated reported a GEH statistic of less than 5. Also, all individual link speeds reported a GEH statistic of less than 5. The GEH statistic figures for the sum of all link flows and speeds in both directions are presented in Table 4-01 below. Figure 4-04 below shows the comparison of modeled versus field measured parameters (flow and speed) for both directions at all data collection points on the network.

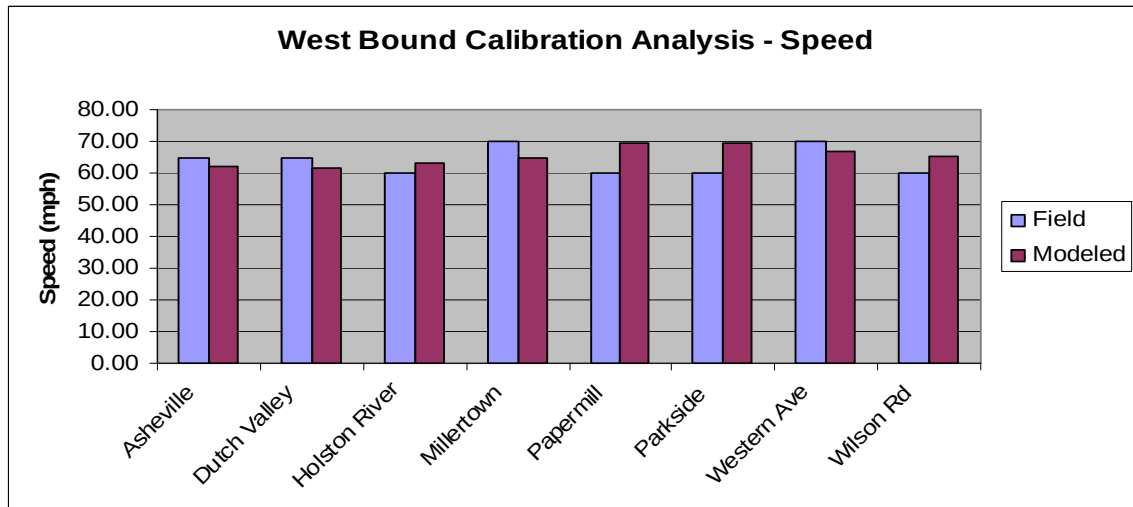
Table 4-01. GEH Statistic Values for the Sum of all Link Flows and Speeds

	GEH statistic	
	WB	EB
Target	<4	<4
Peak-Flow (vph)	3.84	2.64
Speed (mph)	0.59	1.64



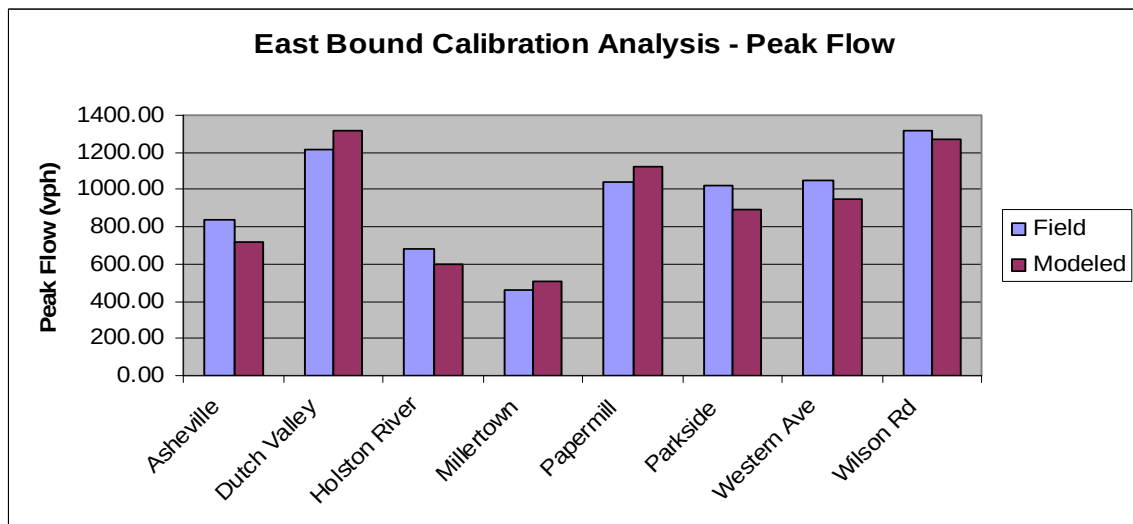
(a)

Figure 4-04. Comparisons of [a&c] Flow and [b&d] Speed: Modeled versus Field Measured



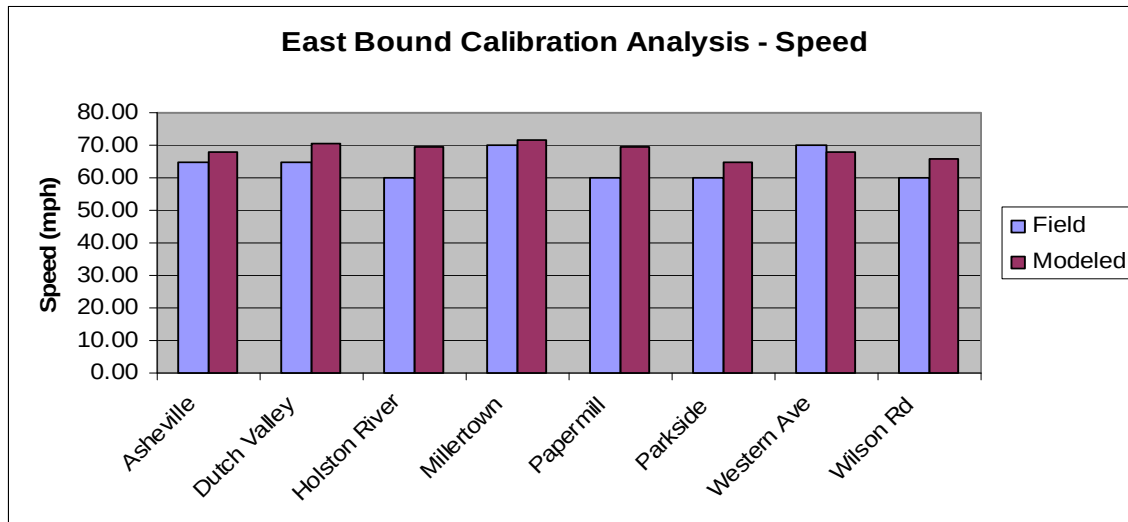
(b)

Figure 4-04 Contd.



(c)

Figure 4-04 Contd.



(d)

Figure 4-04 Contd.

Alternative Truck Lane Configurations

After the model was calibrated to yield acceptable flow and speed for the existing network, it was used to evaluate alternative truck lane configurations for the purpose of operational improvements. Some solutions to the challenges of increasing truck traffic include managing the truck lanes more effectively, including moving trucks away from the outside lanes. Three alternatives to the current lane configuration were proposed and are presented in figure 4-05 below.

Configuration A restricts through trucks to the left lane only and would operate in a way so that cars could use the lane if capacity exists. This is the most restrictive configuration. Configuration B would be similar to the existing truck lane rules, mandating that trucks use the left two lanes through the urban area, instead of the right two lanes. This design is meant to mitigate problems associated with entering and exiting vehicles crossing lanes that are dense with truck traffic. Configuration C develops a barrier separated optional truck only lane that would operate much like a high occupant vehicle lane, where trucks could use the lane if they see a benefit, but also are allowed access to the right lanes.

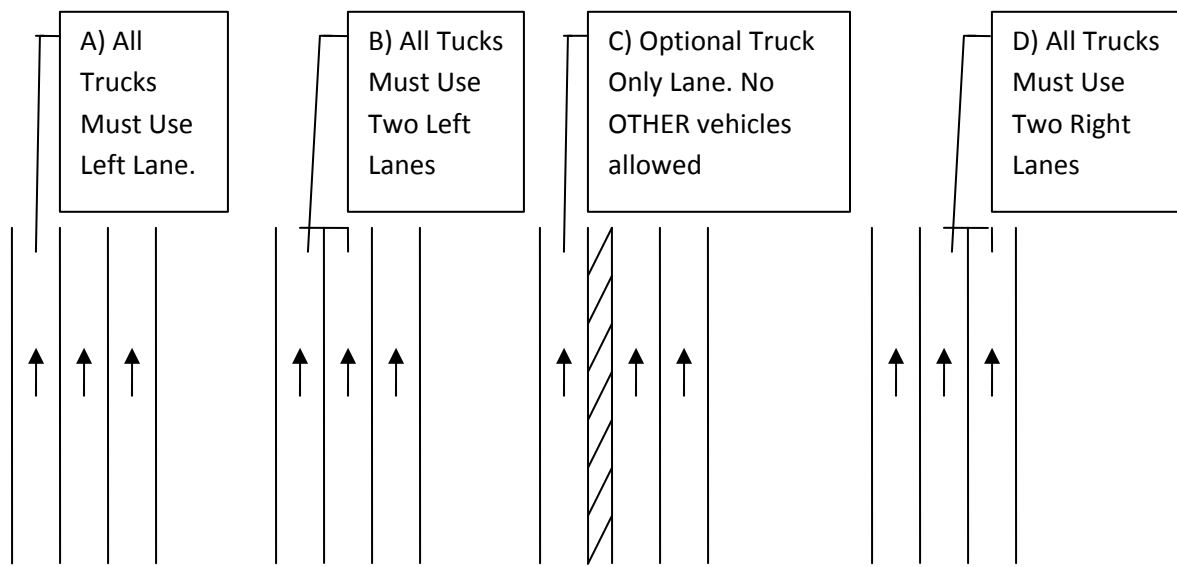


Figure 4-05. Truck Lane Configurations

Finally, Configuration D is the current system where trucks must use the right two lanes. The three alternative configurations (A-C) and the existing configuration (D) were designed in VISSIM to analyze differences in performance of the alternatives.

Furthermore, all four configurations were evaluated under two traffic scenarios – the 2008 analysis year scenario which incorporates 2008 traffic conditions, and the 2020 analysis year scenario which incorporates projected 2020 traffic conditions.

2020 Analysis Year Scenario

The projected 2020 traffic volumes for the car and single-unit truck vehicle classes were computed using traffic data provided in the Knoxville regional transportation plan update (Knoxville Regional Transportation Planning Organization 2007). This data included average daily traffic (ADT) counts for the years 1993 and 2003. These counts were available for certain areas in Knoxville, however not all these areas apply to the study corridor in this research. So two areas that applied to the study corridor – I-40 at Papermill Road and I-640 North of Western Avenue, were selected. An annual growth rate was calculated with these traffic counts using the compound growth equation below. A weighted average of the computed annual growth rates using the 2003 ADTs was calculated. This number was used as the annual growth rate of traffic on the

study corridor. The compound growth equation was applied to the annual growth rate using a base year of 2008 and 12 years as the number of years in order to get the projected growth rate for the 2020 analysis year. Table 4-02 shows the ADTs and the calculated growth rates.

Compound Growth Equation

$$FV = PV(1+i)^n$$

Where FV = Future Value (ADT)

PV = Present Value (ADT)

i = Yearly growth rate

n = number of years

In summary, 2008 traffic volumes for the car and single-unit truck vehicle classes were increased by 32.3% to generate the 2020 traffic volumes. For the tractor-trailer vehicle class, the Federal Highway Administrations' prediction of a 3% annual growth rate through 2020 was employed. This annual growth rate was used because it reflects the increasing truck traffic trends more accurately. Applying the compound growth equation to this annual growth rate and a 12 year period results in a 42.5% growth rate. Therefore the 2008 traffic volumes were increased by 42.5% to generate the 2020 traffic volumes.

Table 4-02. Calculating 2020 Analysis Year Growth Rate

Area Along Study Corridor	1993 ADT	2003 ADT	Compounded Annual Growth Rate (CAGR)
I-40 at Papermill Road	123610	152129	2.10%
I-640 North of Western Avenue	57232	75954	2.87%
	Weighted Average		2.36%
	12 Year Growth Rate (to apply to 2008 volumes to get 2020 volumes)		32.3%

5.0 Results from Microsimulation Analysis

There are four VISSIM networks built for simulation. The first is the current situation network where no changes were made to the existing situation of the highways evaluated. The second is called Configuration A, where all trucks are restricted to the left lane only. The third network is Configuration B, where all trucks are restricted to the two left lanes of the highway. The fourth and last network is Configuration C, where there is an optional truck-only lane on the leftmost lane of the highway. Only trucks are allowed in this lane and trucks that do not wish to use this lane are allowed to use the other lanes of the freeway. Each of these four networks was evaluated under two scenarios – 2008 analysis year scenario and the 2020 analysis year scenario.

This chapter presents the results from these four VISSIM networks while the next chapter will compare these results. As mentioned in Chapter 4, the parameters evaluated via simulation are speed, delay, travel time, and lane change. The results are based on these four evaluation parameters. In addition, all results are modeled and evaluated separately by vehicle class (car, single-unit truck, tractor-trailer, and bus) to identify mode specific changes in performance. While buses were included in the model, because of their low volumes; only cars, single-unit trucks and tractor trailers were evaluated.

5.1 Current Situation/Do-Nothing Scenario

Speed Analysis

In evaluating speed, the network performance evaluation tool was used. This tool allows the user to have the average speed of all vehicles that enter the network reported. Table 5-01 below shows the average speeds of each vehicle class for the current situation network for the 2008 and 2020 analysis year scenarios.

Travel Time Analysis

In order for VISSIM to evaluate travel time, travel time sections have to be defined. Once these travel time sections are defined, a simulation can be run and travel time will be evaluated based on those travel time sections. Table 5-02 gives a detailed description of the travel time sections that were defined for this network.

Travel time is calculated as the average time it took a vehicle to travel from the beginning of the travel time section to the end of the travel time section. It is measured in seconds. As expected, the car vehicle class had the shortest travel times. This is due to the fact that the car vehicle class had the highest average speed.

For the 2008 analysis year scenario, the car vehicle class had a total travel time of 1697 seconds in the eastbound (EB) direction and 1671 seconds in the westbound (WB) direction. The single-unit truck had a total travel time of 2000 seconds in the EB direction and 2210 seconds in the WB direction. The tractor-trailer vehicle class had a total travel time of 2119 seconds in the EB direction and 2285 seconds in the WB direction. This was expected as the tractor-trailer vehicle class had the lowest average speed. Figure 5-01 shows average travel time by travel time section for the current situation network for the 2008 analysis year scenario.

For the 2020 analysis year scenario, the car vehicle class had a total travel time of 1742 seconds in the eastbound (EB) direction and 1748 seconds in the westbound (WB) direction. The single-unit truck had a total travel time of 2082 seconds in the EB direction and 2240 seconds in the WB direction. The tractor-trailer vehicle class had a total travel time of 2171 seconds in the EB direction and 2286 seconds in the WB direction. Figure 5-02 shows average travel time by travel time section for the current situation network for the 2020 analysis year scenario.

Delay Analysis

Delay is calculated as “the total time it takes a vehicle to travel from point A to point B while other vehicles are on the highway” subtracted from the “total time it takes a vehicle to travel from point A to point B without other vehicles on the highway”.

For delay evaluation, VISSIM used the travel time sections already defined for travel time evaluation. Therefore, delay values were reported per travel time section. The delay values were measured in seconds per vehicle; however delay values are presented in seconds per vehicle and seconds per vehicle-mile. Average delay values by vehicle class were reported for each travel time section. Delay values for the current situation network seemed reasonably low. Table 5-03 shows total delay per vehicle and per mile for the 2008 analysis year scenario. Figure 5-03 shows delay by vehicle class for each of

the six travel time sections for the 2008 analysis year scenario. Table 5-04 shows total delay per vehicle and per mile for the 2020 analysis year scenario. Figure 5-04 shows delay by vehicle class for each of the six travel time sections for the 2020 analysis year scenario.

Lane Change Analysis

Every lane change event that occurred was recorded for the duration of the simulation which is 7200 seconds which included a warm-up period of 1200 seconds. These numbers were converted to present lane changes per hour. The current situation configuration was expected to generate high average lane change rates because the configuration only has the two right lane truck restrictions on the two I-40 sections. The I-640 section of the network has no restrictions therefore trucks can travel in any lane they wish. Table 5-05 shows the rate at which vehicles changed lanes by vehicle class for the 2008 and 2020 analysis year scenarios.

Table 5-01. Average Speed by Vehicle Class for Current Situation

Vehicle Class	2008 Analysis Year – Average Network Speed (mph)	2020 Analysis Year – Average Network Speed (mph)
Car	66.76	63.00
Single-Unit Truck	53.11	51.90
Tractor-Trailer	50.39	49.70

Table 5-02. Description of Travel Time Sections

Section Number	Direction	Section Description	Section Length (miles)
1	East Bound	I-40 at Watt Road to I-40/I-640 Interchange (SW)	14.30
2	East Bound	Beginning of I-640 to End of I-640	9.98
3	East Bound	I-40/I-640 Interchange (NE) to I-40 at Strawberry Plains Pike	6.31
4	West Bound	I-40 at Strawberry Plains Pike to I-40/I-640 Interchange (NE)	6.42
5	West Bound	End of I-640 to Beginning of I-640	10.02
6	West Bound	I-40/I-640 Interchange (SW) to I-40 at Watt Road	14.61

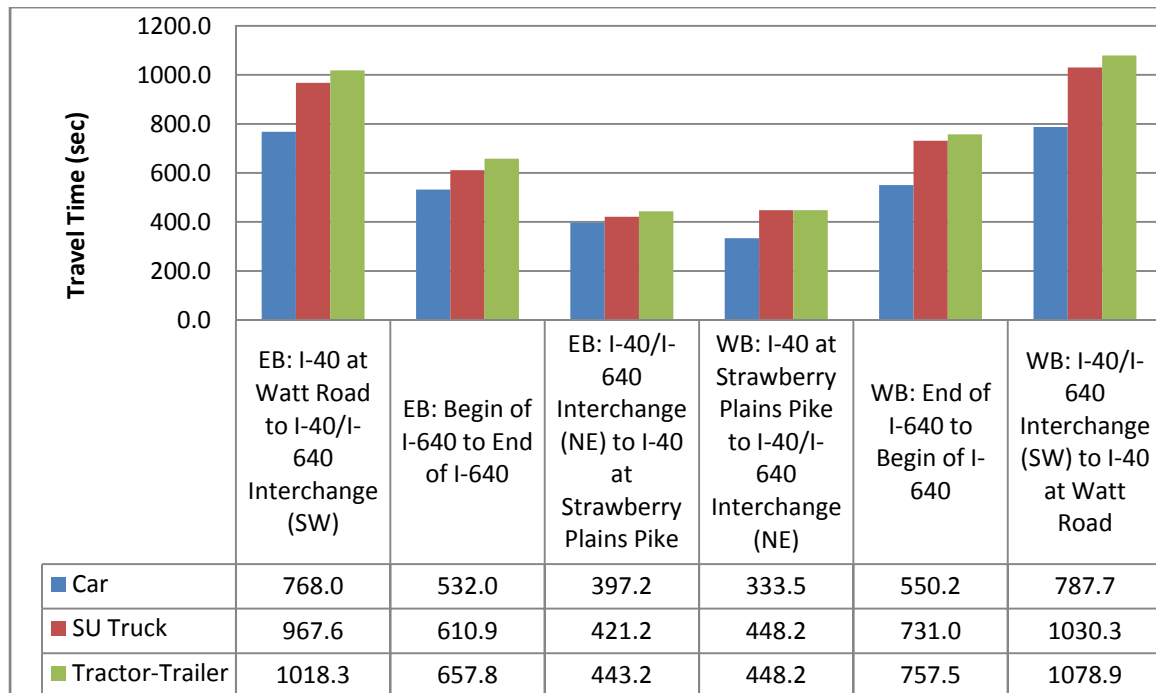


Figure 5-01. Average Travel Time by Vehicle Class for Current Situation – 2008 Analysis Year Scenario

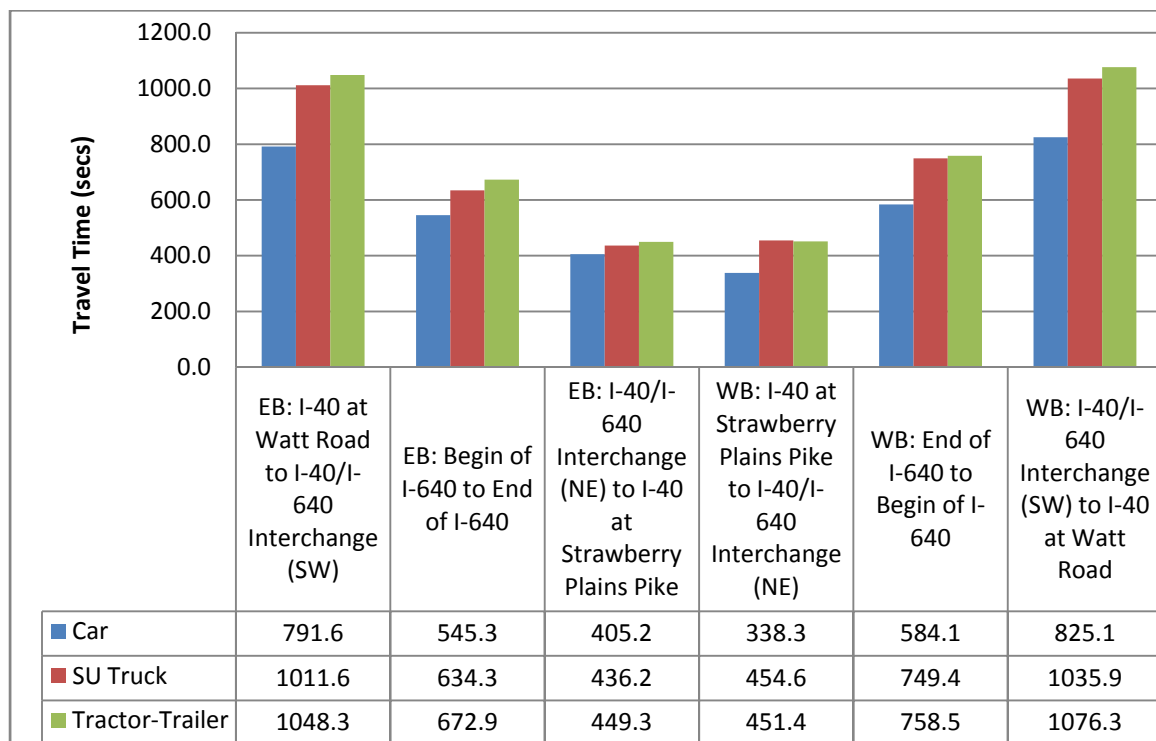


Figure 5-02. Average Travel Time by Vehicle Class for Current Situation – 2020 Analysis Year Scenario

Table 5-03. Total Delay by Vehicle Class for Current Situation – 2008 Analysis Year Scenario

	East Bound		West Bound	
	Delay/veh (s)	Delay/mile (s)	Delay/veh (s)	Delay/mile (s)
Car	119	3.89	82	2.65
SU Truck	174	5.68	282	9.10
Tractor-Trailer	124	4.06	218	7.01

Table 5-04. Total Delay by Vehicle Class for Current Situation – 2020 Analysis Year Scenario

	East Bound		West Bound	
	Delay/veh (s)	Delay/mile (s)	Delay/veh (s)	Delay/mile (s)
Car	161	5.25	157	5.07
SU Truck	215	7.01	302	9.71
Tractor-Trailer	168	5.50	231	7.44

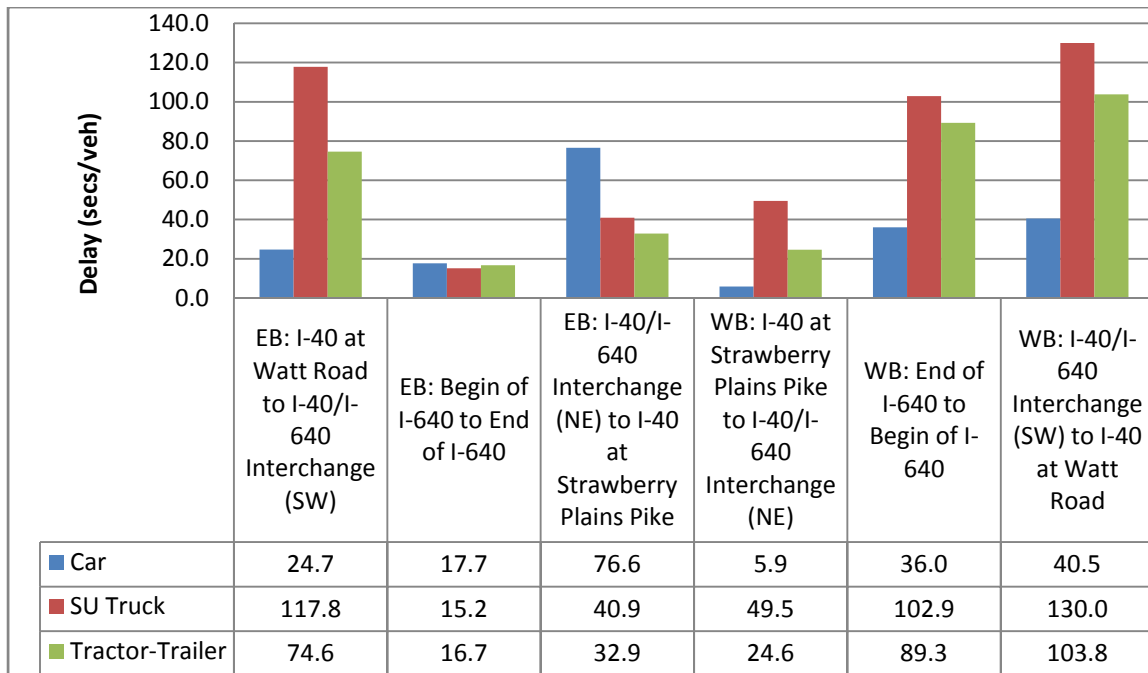


Figure 5-03. Average Delay by Vehicle Class for Current Situation – 2008 Analysis Year Scenario

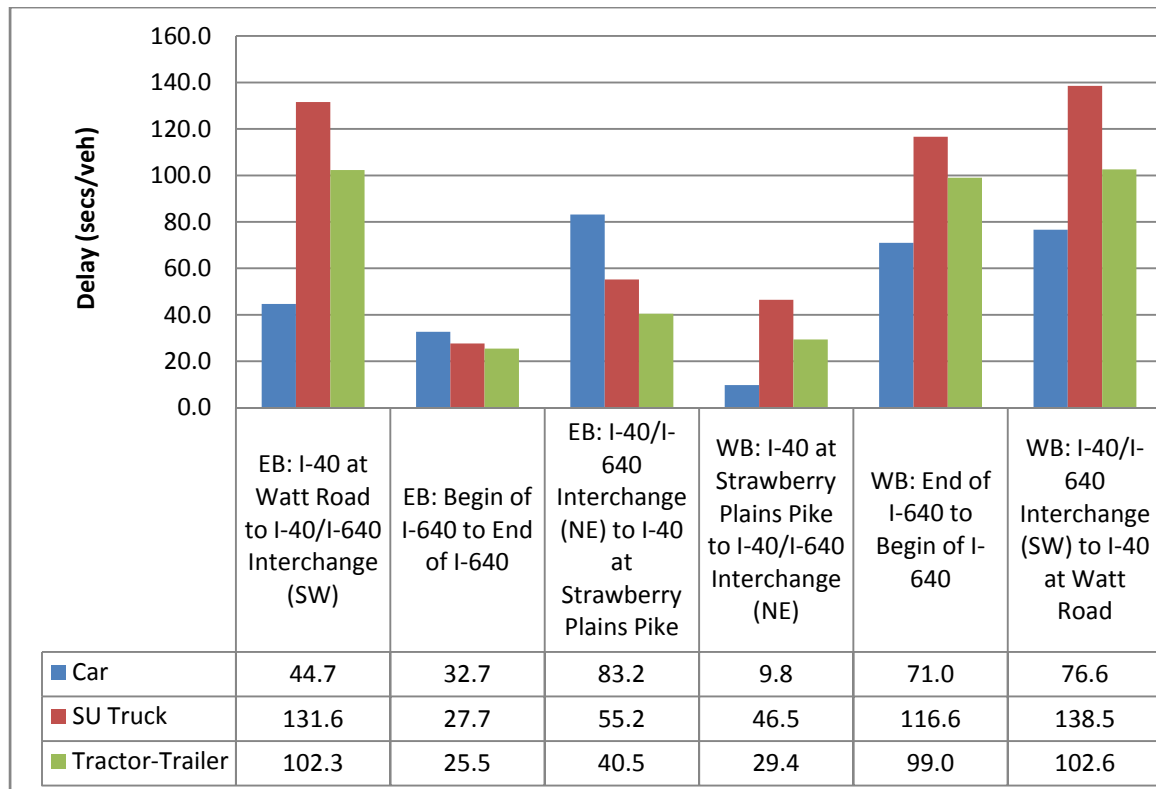


Figure 5-04. Average Delay by Vehicle Class for Current Situation – 2020 Analysis Year Scenario

Table 5-05. Average Lane Change Rate by Vehicle Class for Current Situation

Vehicle Class	2008 Analysis Year – Lane Changes Per Hour	2020 Analysis Year – Lane Changes Per Hour
Car	137975	198969
Single-Unit Truck	3259	3500
Tractor-Trailer	28533	33283

5.2 Configuration A – Left Lane Restriction

Speed Analysis

The average speeds of all vehicles in the network are displayed by vehicle class for the 2008 and 2020 analysis year scenarios in Table 5-06 below. These values are the mean of over a million observed speeds for each vehicle class.

Since all trucks are restricted to the left lane only, it resulted in a low average speed for both single-unit truck and tractor-trailer vehicle classes. This configuration led to high density in the left lane. As shown in the table the car vehicle class has a high average speed compared to the other two classes. This is simply because the cars had the two right lanes to travel on without much truck interference.

Travel Time Analysis

High travel time values were anticipated for the trucks because of the nature of this configuration – all trucks must use left lane only. The EB travel times are significantly longer than the WB travel times. This could be attributed to the fact that the EB traffic volumes are higher compared to the WB traffic volumes. The cars however, were expected to have low to normal travel time values.

For the 2008 analysis year scenario, the car vehicle class had a total travel time of 1713 seconds in the EB direction and 1651 seconds in the WB direction. The single-unit truck had a total travel time of 2882 seconds in the EB direction and 2558 seconds in the WB direction. The tractor-trailer vehicle class had a total travel time of 2953 seconds in the EB direction and 2560 seconds in the WB direction. Figure 5-05 shows average travel time by travel time section for the Configuration A network for the 2008 analysis year scenario.

For the 2020 analysis year scenario, the car vehicle class had a total travel time of 1721 seconds in the EB direction and 1709 seconds in the WB direction. The single-unit truck had a total travel time of 3556 seconds in the EB direction and 2816 seconds in the WB direction. The tractor-trailer vehicle class had a total travel time of 3702 seconds in the EB direction and 2812 seconds in the WB direction. Figure 5-06 shows average travel time by travel time section for the Configuration A network for the 2020 analysis year scenario.

Delay Analysis

Delay results for the configuration A network were as expected. The truck vehicle classes have high average delay values while the car vehicle class has low average delay values. Table 5-07 shows total delay per vehicle and per mile for Configuration A for the 2008 analysis year scenario. Figure 5-07 shows average delay by vehicle class for each of the six travel time sections for the 2008 analysis year scenario. Table 5-08 shows total delay per vehicle and per mile for Configuration A for the 2020 analysis year scenario. Figure 5-08 shows average delay by vehicle class for each of the six travel time sections for the 2020 analysis year scenario. Again, trucks bear significant delay in this configuration.

Lane Change Analysis

Since this configuration restricted all trucks to the left lane, minimal lane change rates were expected for trucks. Furthermore, since the left lane was filled up by trucks most of the time, cars had to use the right two lanes most of the time and this creates one less lane to change lanes in and out of. Table 5-09 contains the rate of lane changes by vehicle class for Configuration A for the 2008 and 2020 analysis year scenarios.

The values in table 5-09 suggest low lane change rates for all vehicle classes as a result of this lane configuration, which is “all trucks must use left lanes”.

Table 5-06. Average Speeds by Vehicle Class for Configuration A

Vehicle Class	2008 Analysis Year – Average Network Speed (mph)	2020 Analysis Year – Average Network Speed (mph)
Car	64.30	61.00
Single-Unit Truck	38.47	32.20
Tractor-Trailer	38.45	31.80

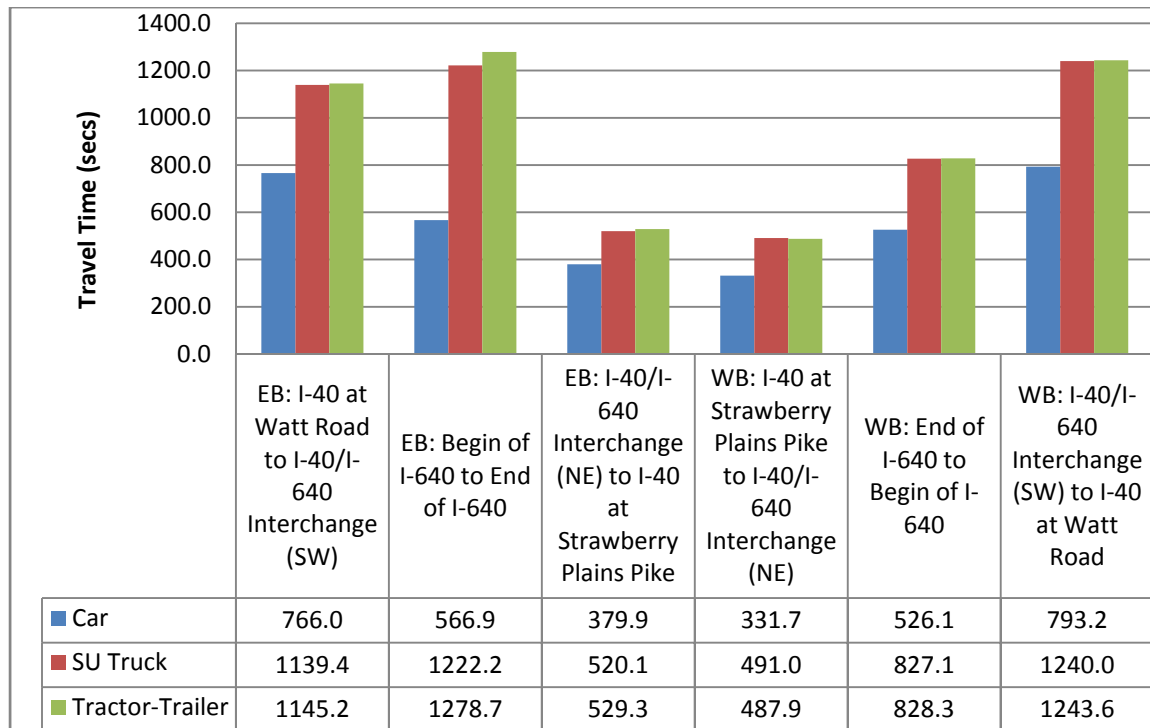


Figure 5-05. Average Travel Time by Vehicle Class for Configuration A – 2008 Analysis Year Scenario

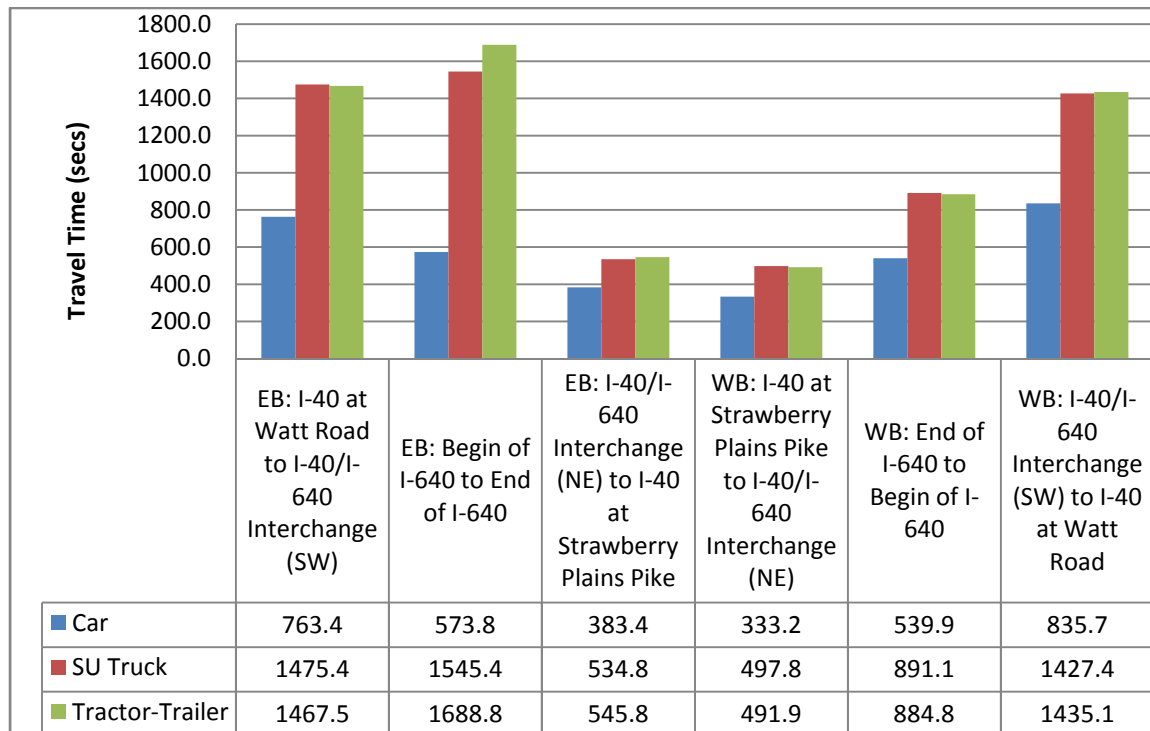


Figure 5-06. Average Travel Time by Vehicle Class for Configuration A – 2020 Analysis Year Scenario

Table 5-07. Total Delay by Vehicle Class for Configuration A – 2008 Analysis Year Scenario

	East Bound		West Bound	
	Delay/veh (s)	Delay/mile (s)	Delay/veh (s)	Delay/mile (s)
Car	131	4.29	70	2.24
SU Truck	1055	34.49	590	18.99
Tractor-Trailer	968	31.63	503	16.21

Table 5-08. Total Delay by Vehicle Class for Configuration A – 2020 Analysis Year Scenario

	East Bound		West Bound	
	Delay/veh (s)	Delay/mile (s)	Delay/veh (s)	Delay/mile (s)
Car	163	5.32	127	4.07
SU Truck	1688	55.17	873	28.13
Tractor-Trailer	1689	55.21	758	24.41

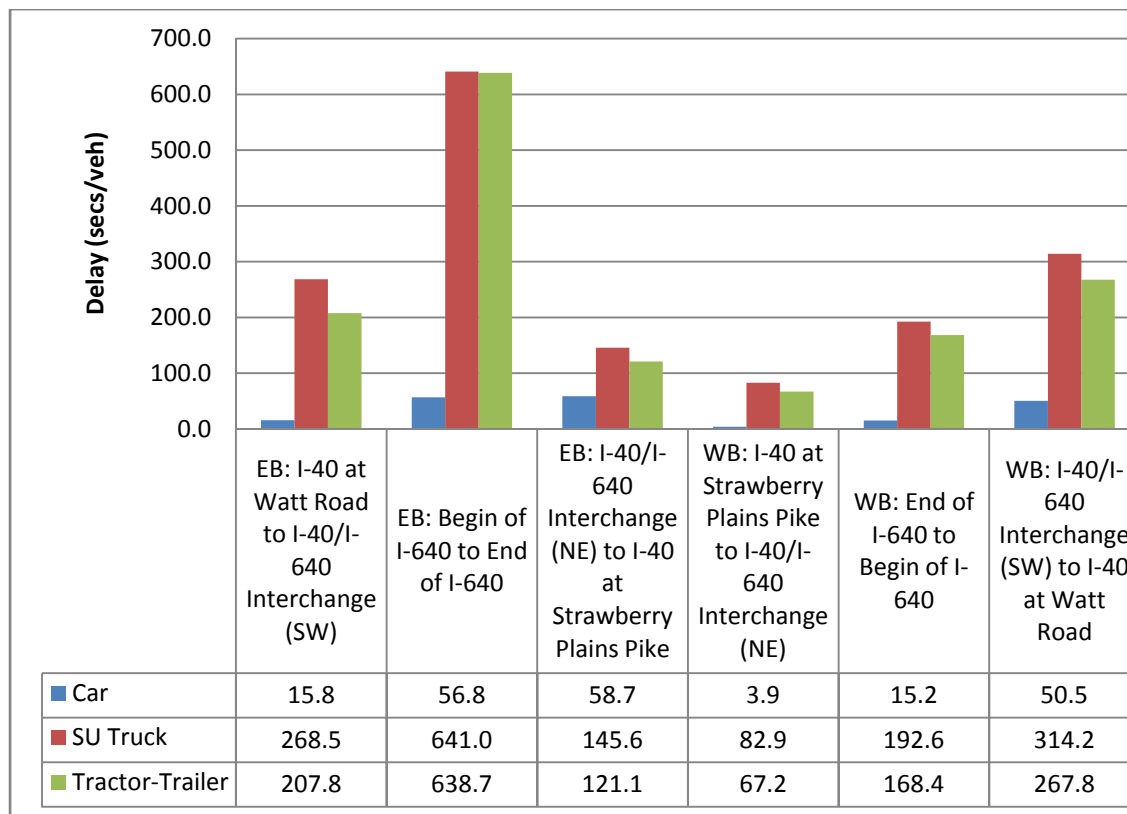


Figure 5-07. Average Delay by Vehicle Class for Configuration A – 2008 Analysis Year Scenario

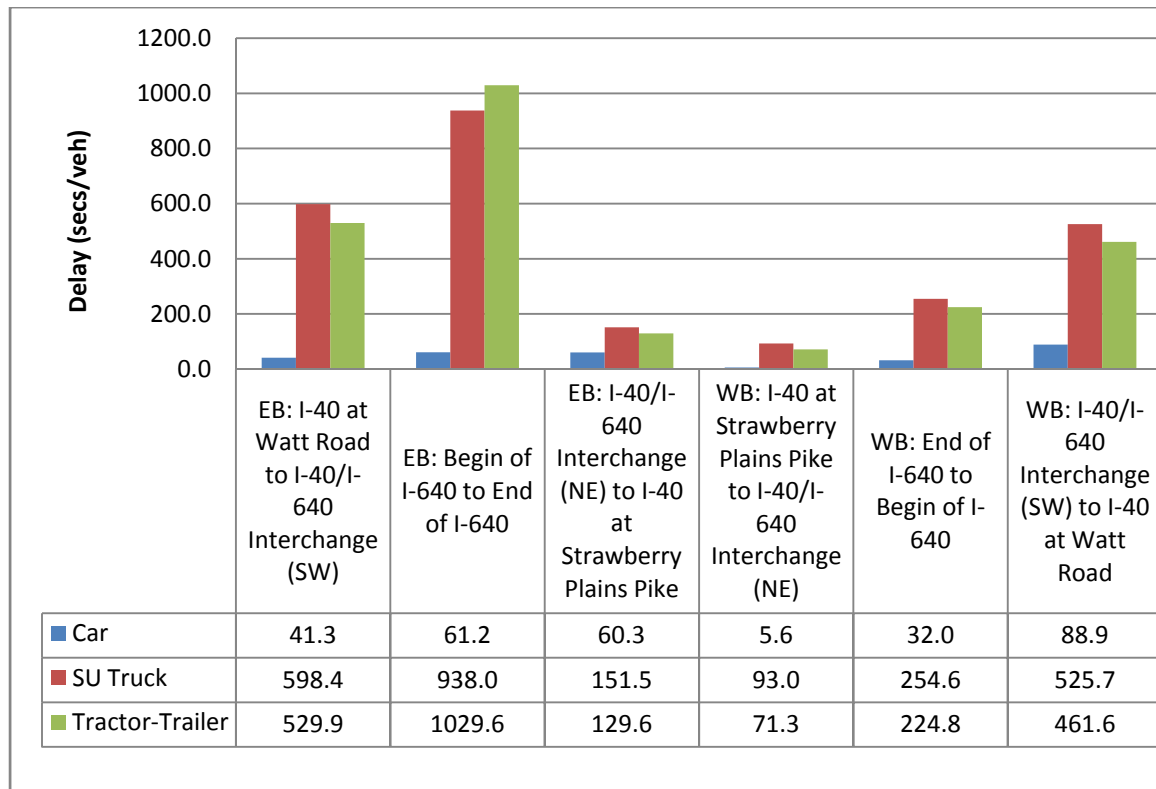


Figure 5-08. Average Delay by Vehicle Class for Configuration A – 2020 Analysis Year Scenario

Table 5-09. Average Lane Change Rate by Vehicle Class for Configuration A

Vehicle Class	2008 Analysis Year – Lane Changes Per Hour	2020 Analysis Year – Lane Changes Per Hour
Car	80353	112345
Single-Unit Truck	2371	2767
Tractor-Trailer	20333	25824

5.3 Configuration B – Two Left Lane Restriction

Speed Analysis

This configuration had all trucks restricted to the two left lanes. This includes both single-unit trucks and tractor-trailer units. From observing this model during simulation, about 60 percent of the trucks preferred to be in the leftmost lane. The other 40 percent were in the middle lane. Also, faster trucks passed on the right which means they used the middle lane for passing. The uneven distribution of trucks in these two left lanes based on lane preference resulted in a relatively low average speed for both the single-unit truck and tractor-trailer vehicle classes. The average speed for the car vehicle class turned out normal and expected. Table 5-10 contains the average speeds of vehicles for the “two left lane restriction” configuration for the 2008 and 2020 analysis year scenarios.

Travel Time Analysis

This configuration allows trucks to travel in the two left lanes. Travel times for all vehicle classes were expected to be moderate as a result of two shared lanes of capacity for trucks and two shared lanes of capacity plus one exclusive lane of capacity for cars.

For the 2008 analysis year scenario, the car vehicle class had a total travel time of 1716 seconds in the EB direction and 1688 seconds in the WB direction. The single-unit truck had a total travel time of 2458 seconds in the EB direction and 2490 seconds in the WB direction. The tractor-trailer vehicle class had a total travel time of 2494 seconds in the EB direction and 2484 seconds in the WB direction. The single-unit truck vehicle class and the tractor-trailer vehicle class had average travel times that were very close in value, with the largest travel time difference between these two vehicle classes being 10 seconds. Figure 5-09 shows average travel time by travel time section for the Configuration B network for the 2008 analysis year scenario.

For the 2020 analysis year scenario, the car vehicle class had a total travel time of 1797 seconds in the EB direction and 1677 seconds in the WB direction. The single-unit truck had a total travel time of 3025 seconds in the EB direction and 2584 seconds in the WB direction. The tractor-trailer vehicle class had a total travel time of 3064 seconds in the EB direction and 2560 seconds in the WB direction. Figure 5-10 shows average travel

time by travel time section for the Configuration B network for the 2020 analysis year scenario.

Delay Analysis

The truck vehicle classes have moderate average delay values while the car vehicle class has low average delay values. Table 5-11 shows total delay per vehicle and per mile for Configuration B for the 2008 analysis year scenario. Figure 5-11 shows delay values by vehicle class for each of the six travel time sections for the 2008 analysis year scenario. Table 5-12 shows total delay per vehicle and per mile for Configuration B for the 2020 analysis year scenario. Figure 5-12 shows delay values by vehicle class for each of the six travel time sections for the 2020 analysis year scenario.

Lane Change Analysis

Lane change analysis results for the configuration B network turned out as expected. Since this configuration restricted all trucks to the two left lanes, moderate to high lane change rates were expected for all vehicle classes. Table 5-13 contains the rate of lane changes by vehicle class for Configuration B for the 2008 and 2020 analysis year scenarios.

Table 5-10. Average Speed by Vehicle Class for Configuration B

Vehicle Class	2008 Analysis Year – Average Network Speed (mph)	2020 Analysis Year – Average Network Speed (mph)
Car	63.86	61.00
Single-Unit Truck	44.69	38.40
Tractor-Trailer	44.28	38.50

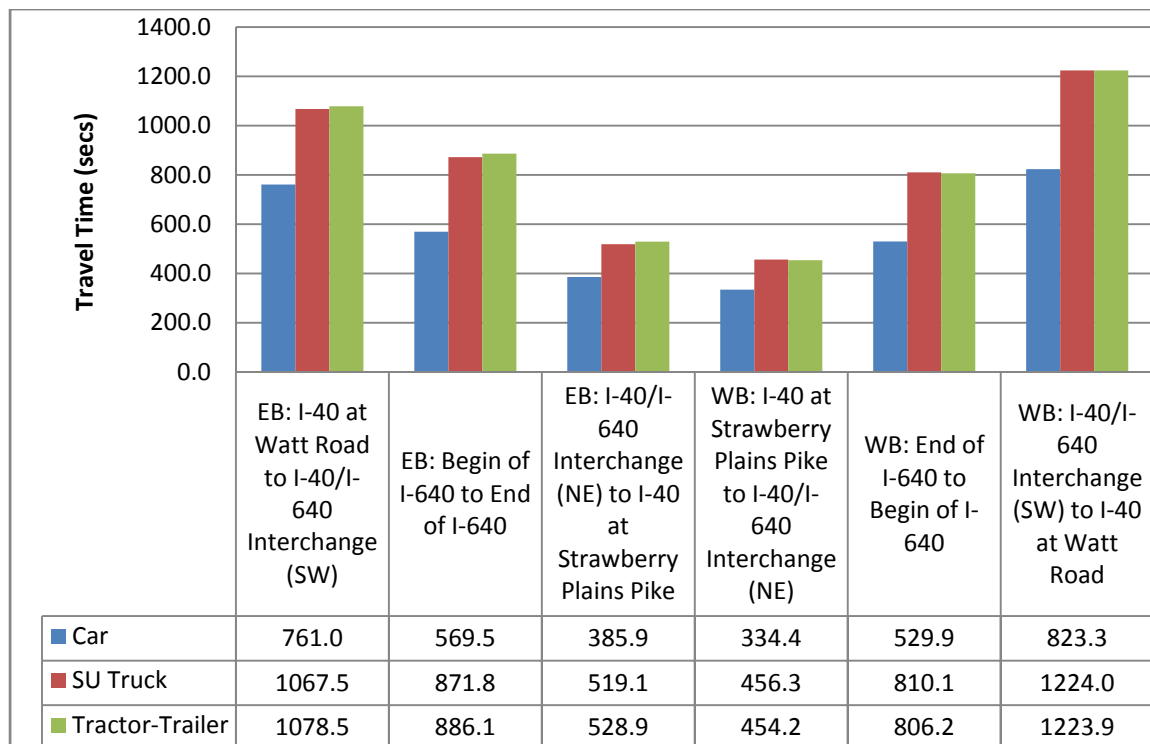


Figure 5-09. Average Travel Times by Vehicle Class for Configuration B – 2008 Analysis Year Scenario

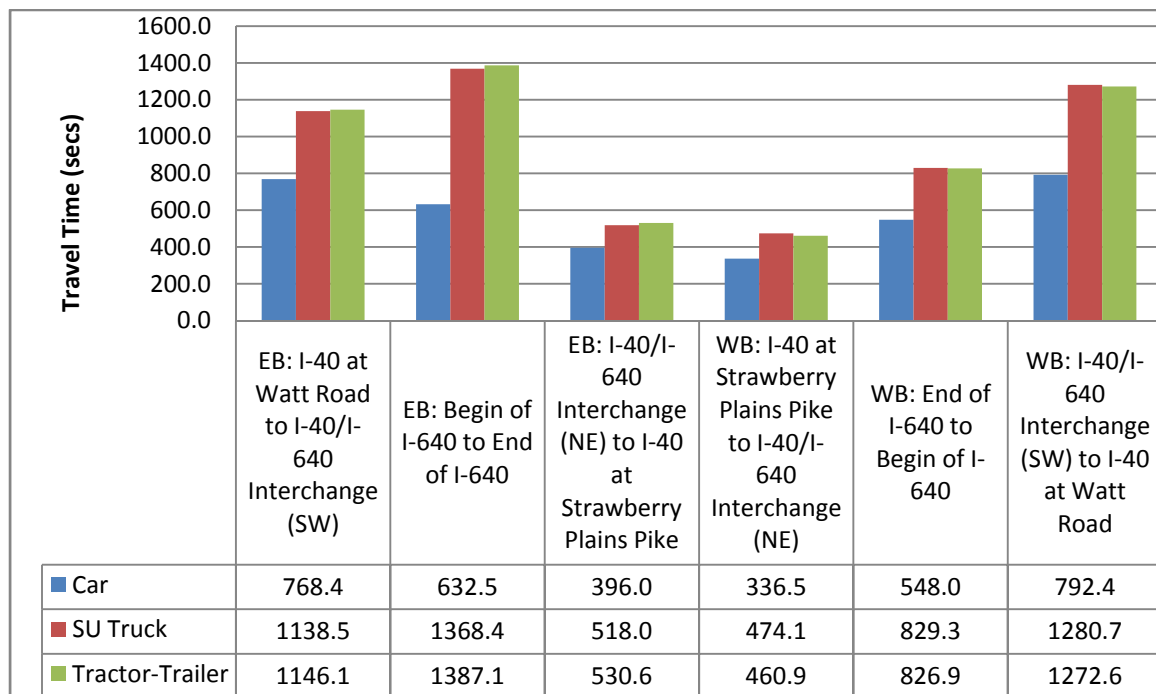


Figure 5-10. Average Travel Times by Vehicle Class for Configuration B – 2020 Analysis Year Scenario

Table 5-11. Total Delay by Vehicle Class for Configuration B – 2008 Analysis Year Scenario

	East Bound		West Bound	
	Delay/veh (s)	Delay/mile (s)	Delay/veh (s)	Delay/mile (s)
Car	147	4.80	106	3.41
SU Truck	605	19.77	534	17.21
Tractor-Trailer	465	15.19	425	13.70

Table 5-12. Total Delay by Vehicle Class for Configuration B – 2020 Analysis Year Scenario

	East Bound		West Bound	
	Delay/veh (s)	Delay/mile (s)	Delay/veh (s)	Delay/mile (s)
Car	259	8.47	106	3.42
SU Truck	1158	37.85	628	20.21
Tractor-Trailer	1044	34.11	508	16.37

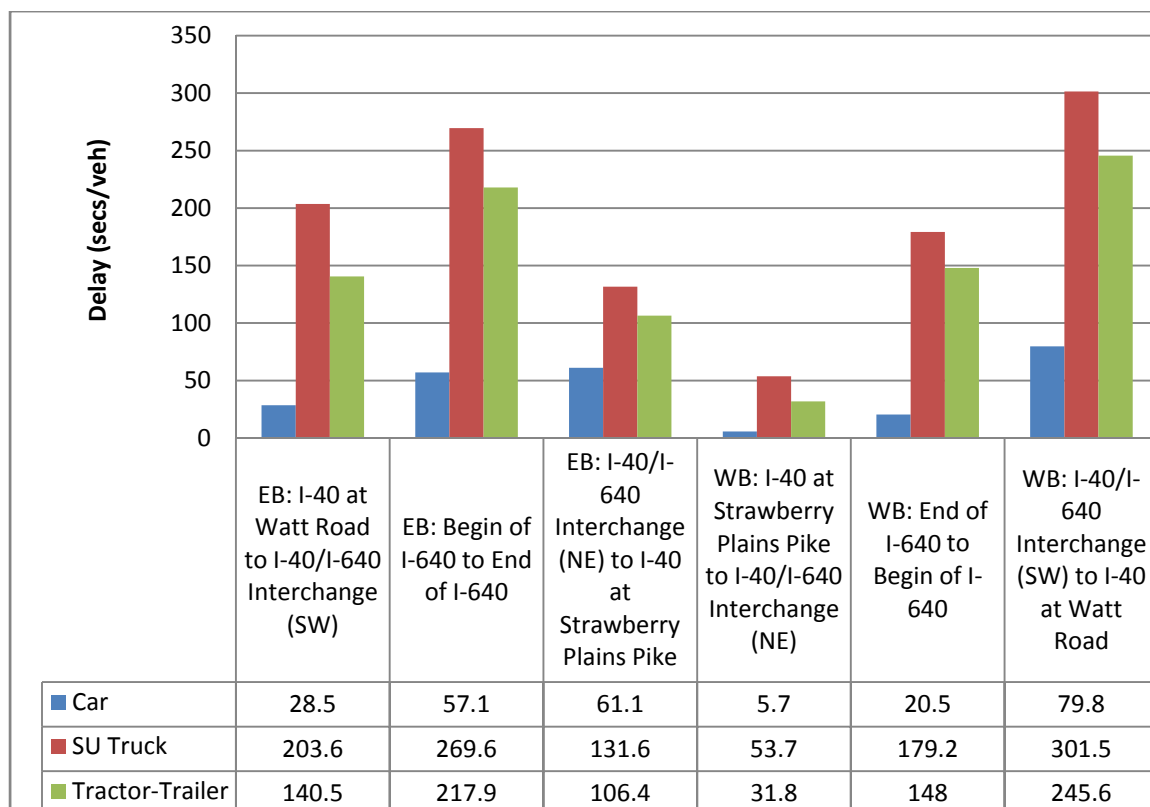


Figure 5-11. Average Delay by Vehicle Class for Configuration B – 2008 Analysis Year Scenario

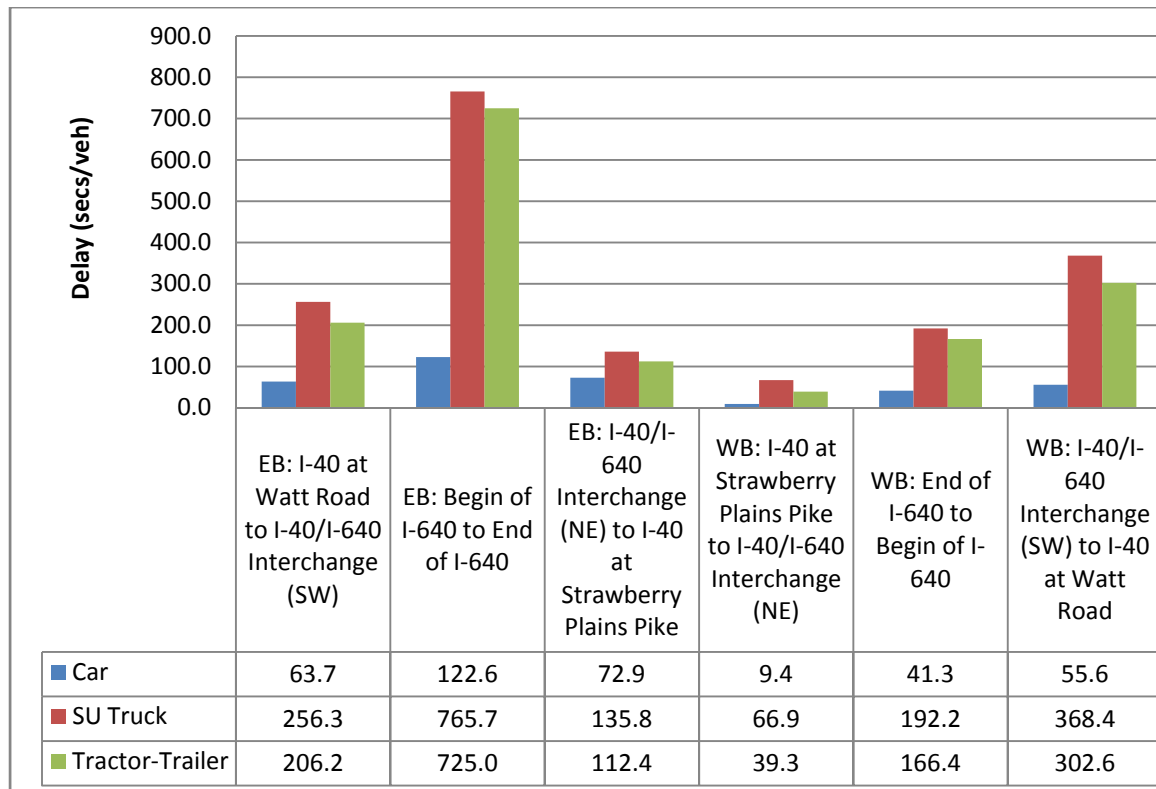


Figure 5-12. Average Delay by Vehicle Class for Configuration B – 2020 Analysis Year Scenario

Table 5-13. Average Lane Change Rate by Vehicle Class for Configuration B

Vehicle Class	2008 Analysis Year – Lane Changes Per Hour	2020 Analysis Year – Lane Changes Per Hour
Car	94343	113410
Single-Unit Truck	2590	3142
Tractor-Trailer	23133	29755

5.4 Configuration C – Optional Truck-Only Lane

Speed Analysis

The average speeds for this configuration were expected to be high. This configuration introduces an optional truck-only lane on the left that is barrier separated from the middle and right lane. Trucks that travel through Knoxville without stopping can use this optional truck-only lane without having to interact with cars. Trucks that have to stop in Knoxville either to drop off, pick up, rest, or refuel have the option of using the other two lanes open to general traffic. In observing this configuration during simulation, trucks used both the optional truck-only lane and the general traffic lanes. It appeared however that there were more trucks in the optional truck-only lane. The average speed results appeared to be high for the truck vehicle class and normal for the car vehicle class. Table 5-14 contains the results for average speed for Configuration C for the 2008 and 2020 analysis year scenarios.

Travel Time Analysis

Travel times for trucks were expected to be low while travel times for cars were expected to be moderate as a result of two shared lanes of capacity for cars and two shared lanes of capacity plus one exclusive lane of capacity for trucks.

For the 2008 analysis year scenario, the car vehicle class had a total travel time of 1664 seconds in both the EB and WB directions. The single-unit truck had a total travel time of 2067 seconds in the EB direction and 2159 seconds in the WB direction. The tractor-trailer vehicle class had a total travel time of 2143 seconds in the EB direction and 2231 seconds in the WB direction. Figure 5-13 shows average travel time by travel time section for the Configuration C network for the 2008 analysis year scenario.

For the 2020 analysis year scenario, the car vehicle class had a total travel time of 1709 seconds in the EB direction and 1765 seconds in the WB direction. The single-unit truck had a total travel time of 2113 seconds in the EB direction and 2234 seconds in the WB direction. The tractor-trailer vehicle class had a total travel time of 2168 seconds in the EB direction and 2259 seconds in the WB direction. Figure 5-14 shows average travel time by travel time section for the Configuration C network for the 2020 analysis year scenario.

Delay Analysis

Configuration C provides abundant lane capacity for trucks, therefore both the single-unit truck and tractor-trailer vehicle classes were expected to have low average delay results. Table 5-15 shows total delay per vehicle and per mile for Configuration C for the 2008 analysis year scenario. Figure 5-15 shows delay values by vehicle class for each of the six travel time sections for the 2008 analysis year scenario. Table 5-16 shows total delay per vehicle and per mile for Configuration C for the 2020 analysis year scenario. Figure 5-16 shows delay values by vehicle class for each of the six travel time sections for the 2020 analysis year scenario.

Lane Change Analysis

Configuration C was expected to generate low lane change rates because of the optional truck-only lane segregating traffic. The trucks that choose to get into this lane are not allowed to leave this lane as there is a physical barrier separating this lane from the other two lanes. This leaves the only measurable lane change events in the two right lanes. Table 5-17 presents average rate of lane changes for Configuration C for the 2008 and 2020 analysis year scenarios.

Table 5-14. Average Speed by Vehicle Class for Configuration C

Vehicle Class	2008 Analysis Year – Average Network Speed (mph)	2020 Analysis Year – Average Network Speed (mph)
Car	66.86	62.90
Single-Unit Truck	52.85	51.40
Tractor-Trailer	50.47	49.20

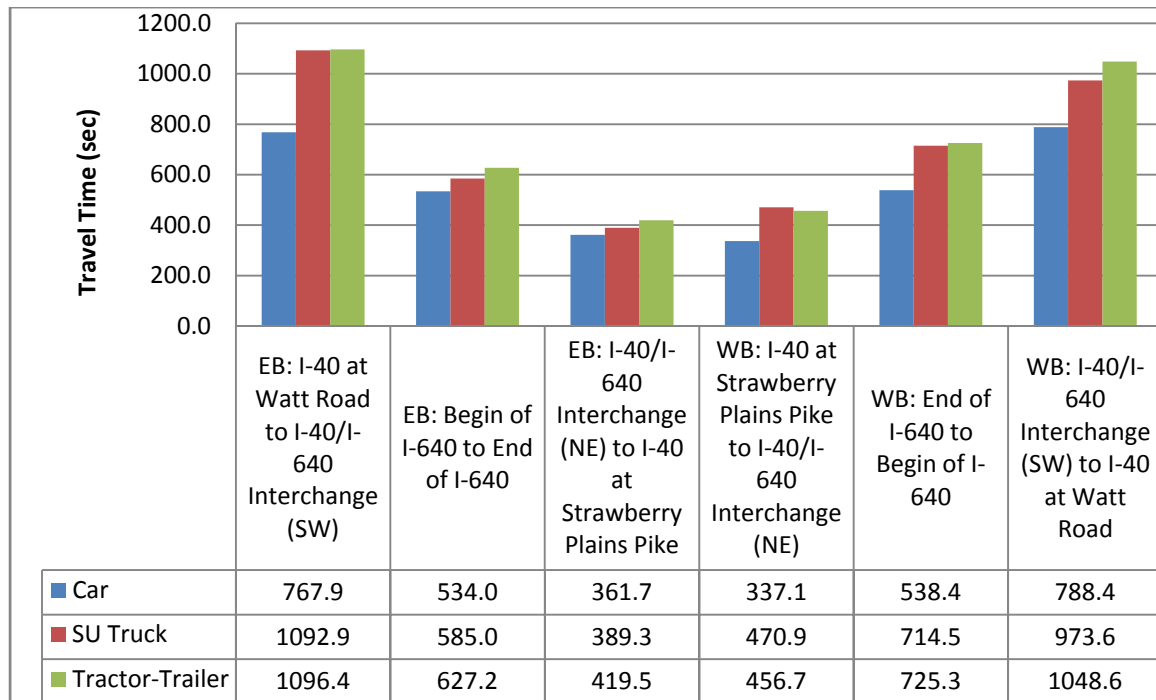


Figure 5-13. Average Travel Time by Vehicle Class for Configuration C – 2008 Analysis Year Scenario

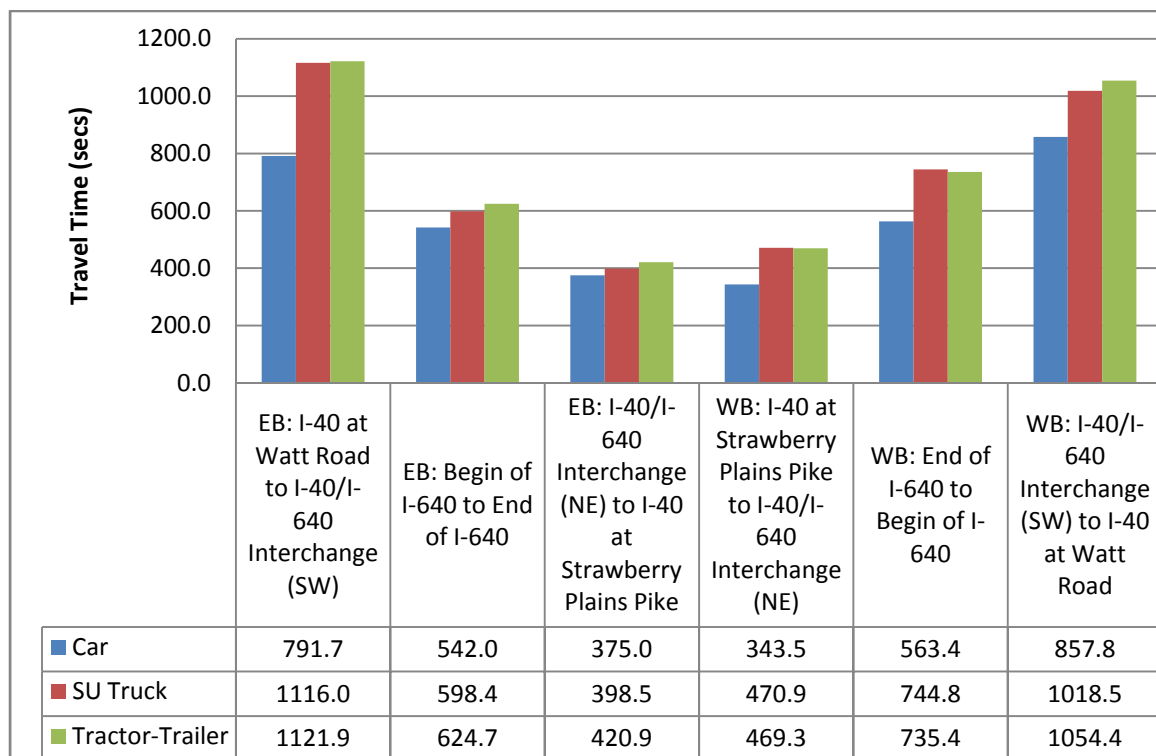


Figure 5-14. Average Travel Time by Vehicle Class for Configuration C – 2020 Analysis Year Scenario

Table 5-15. Total Delay by Vehicle Class for Configuration C – 2008 Analysis Year Scenario

	East Bound		West Bound	
	Delay/veh (s)	Delay/mile (s)	Delay/veh (s)	Delay/mile (s)
Car	73	2.38	73	2.35
SU Truck	289	9.45	251	8.07
Tractor-Trailer	207	6.77	168	5.40

Table 5-16. Total Delay by Vehicle Class for Configuration C – 2020 Analysis Year Scenario

	East Bound		West Bound	
	Delay/veh (s)	Delay/mile (s)	Delay/veh (s)	Delay/mile (s)
Car	111	3.63	172	5.52
SU Truck	307	10.03	327	10.52
Tractor-Trailer	232	7.59	211	6.80

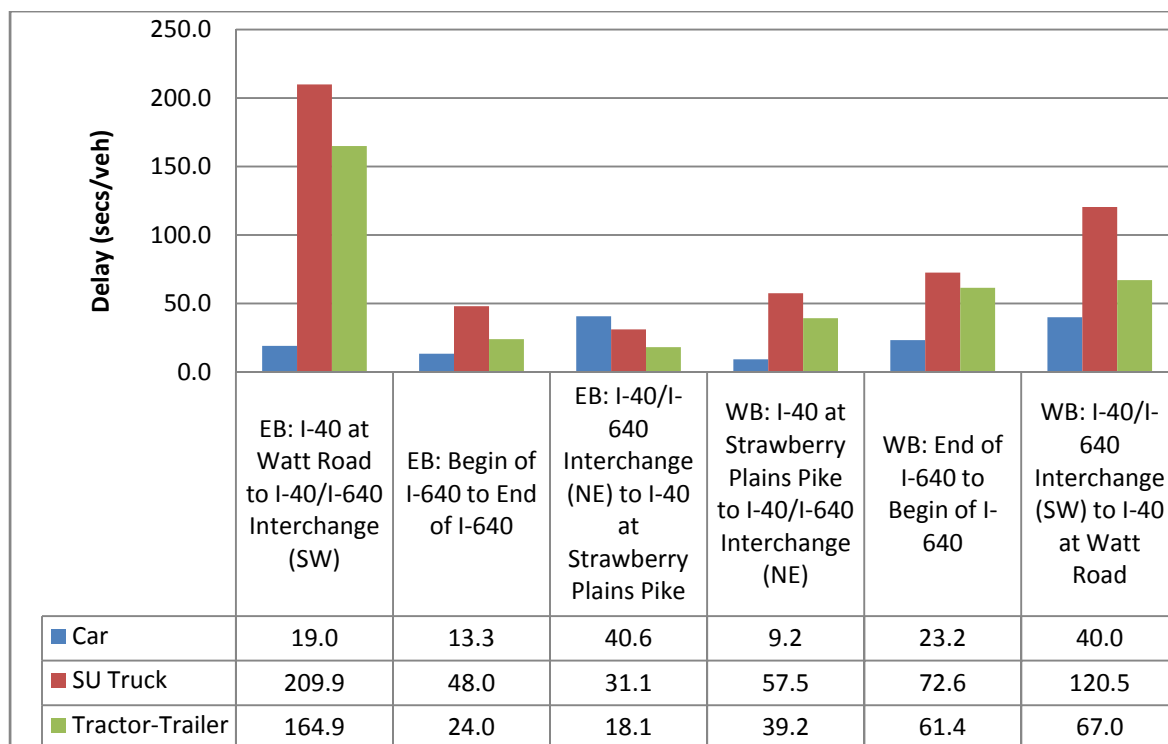


Figure 5-15. Average Delay by Vehicle Class for Configuration C – 2008 Analysis Year Scenario

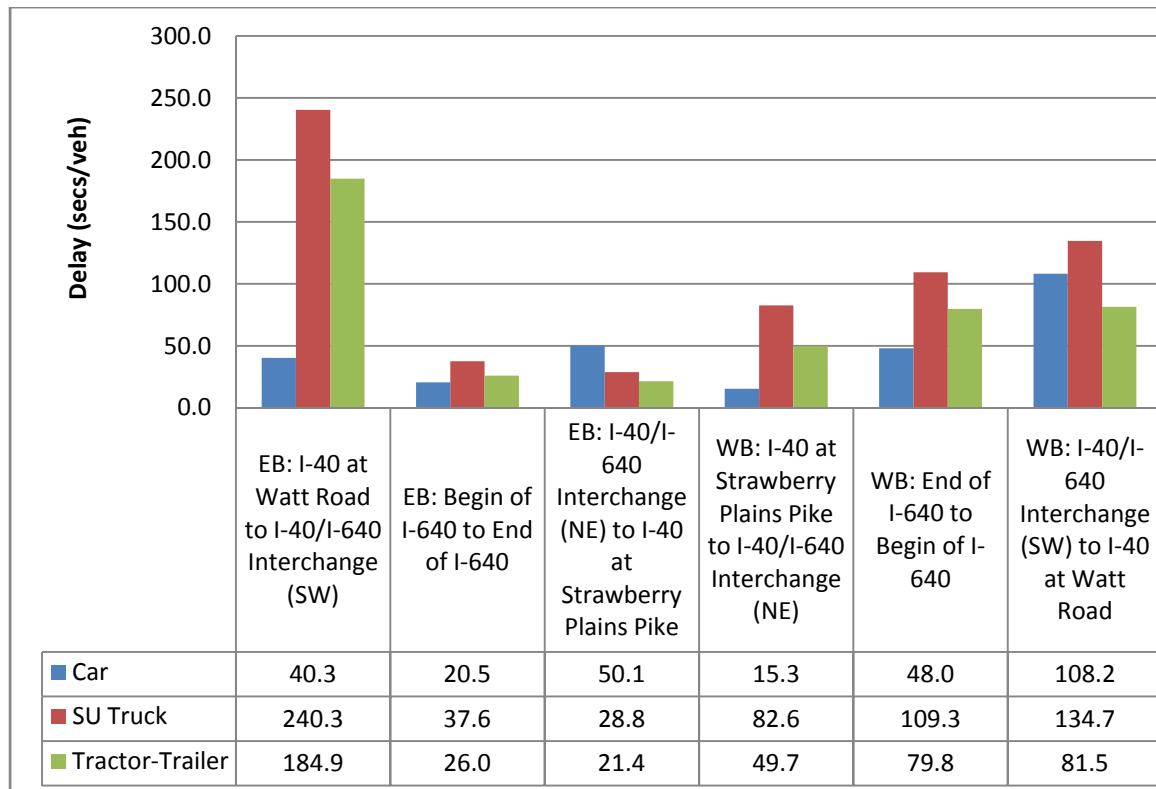


Figure 5-16. Average Delay by Vehicle Class for Configuration C – 2020 Analysis Year Scenario

Table 5-17. Average Lane Change Rates by Vehicle Class for Configuration C

Vehicle Class	2008 Analysis Year – Lane Changes Per Hour	2020 Analysis Year - Lane Changes Per Hour
Car	79648	119334
Single-Unit Truck	482	675
Tractor-Trailer	2825	4254

6.0 Comparison of Configurations

The purpose of this research is to evaluate several lane management options and come up with a lane management strategy that offers the best operational and safety improvements to highways in Knoxville. The configurations have been evaluated in Chapter 5 and they will now be compared side-by-side in this chapter.

The existing lane configuration of the Knoxville highways used in this research serves as the base configuration and is called “current situation”. This configuration restricts trucks to the two right lanes on the two sections of I-40 of the network, and there are no restrictions on the I-640 section of the network. The three configurations presented in Chapter 3 and 5 have various operational changes. As mentioned in Chapter 5, there are four basic parameters that were used to evaluate these configurations – Speed, Travel Time, Delay, and Lane Changes. In this chapter, the comparisons will be done for each of these four parameters. Two scenarios will be evaluated under each parameter - the 2008 analysis year and the 2020 analysis year. Furthermore, each parameter was evaluated by vehicle class in Chapter 5; therefore the comparisons for each parameter will also be done by vehicle class. The three vehicle classes that are included in the comparisons are car, single-unit truck, and tractor-trailer. The primary focus of this research is evaluating the effect of changing rules of the tractor-trailer vehicle class on all vehicle classes. Therefore configurations that favor the tractor-trailer vehicle class with minimal impact to other vehicle classes will be considered a great fit for operational improvement.

6.1 Speed Comparison

The average speed results for the three configurations were different from the current situation average speed result. Configurations A and B had significant speed differences while Configuration C had small speed differences.

The drastic decrease in speed for both truck vehicle classes could be attributed to the reduced capacity for trucks presented by Configuration A. Trucks would be going from two lanes of capacity in the current situation configuration to one lane of capacity in Configuration A.

Although Configuration B was expected to have higher average speeds for the truck vehicle classes, the fairly low measured truck average speeds could be attributed to

congestion in the left lane caused by the left lane preference by trucks in Configuration B. Unlike the current situation where trucks being restricted to the two right lanes have to interact with traffic entering on-ramps, trucks do not have to interact with such traffic when in the left lane. Trucks in the left lane also do not have to interact with many cases of cars changing lanes because cars do not like to be in a lane with many trucks. However, trucks in the middle lane do have to interact with cars changing lanes, hence the truck left lane preference. Compared to Configuration A (left lane only), Configuration B truck average speeds are higher as a result of the added capacity for trucks. The car average speed is lower for Configuration B, compared to Configuration A, because some capacity was taken away from cars since trucks are now allowed in the middle lane.

Configuration C and the current situation have very close average speeds for all three vehicle classes. Compared to Configurations A and B, Configuration C truck average speeds are much higher because it boasts the most capacity for trucks – 3 lanes. Also the average speed for the car vehicle class is higher because Configuration C keeps all cars in the free flowing 2 right lanes unlike Configurations A and B where some cars are stuck in the left lane dominated by trucks because they are allowed to use it.

2008 Analysis Year Scenario

The optional truck-only lane configuration offers slightly higher average speeds for the car and tractor-trailer vehicle classes. The current situation configuration offers a slightly higher average speed for the single-unit truck vehicle class. However, the percent changes show that the differences in average speeds between these two configurations are very small. Table 6-01 shows the speed comparisons between the alternative configurations and the current situation configuration. Figure 6-01 illustrates the differences in average speed.

2020 Analysis Year Scenario

The current situation configuration offers slightly higher average speeds for the three truck vehicle classes. However, like the 2008 analysis year scenario, the differences in average speeds between these two configurations are very small. Table 6-02 shows the speed comparisons while Figure 6-02 illustrates the differences in average speed.

**Table 6-01. Speed Comparison: Current Situation vs. Configuration A, B, and C
(2008 Analysis Year)**

Current Situation vs. Configuration A			
Vehicle Class	Current Situation Speed (mph)	Config A: Left Lane Only Speed (mph)	Percent Change
Car	66.8	64.3	-3.68
SU Truck	53.1	38.5	-27.57
Tractor-trailer	50.4	38.4	-23.70
Current Situation vs. Configuration B			
Vehicle Class	Current Situation Speed (mph)	Config B: 2 Left Lanes Speed (mph)	Percent Change
Car	66.8	63.9	-4.34
SU Truck	53.1	44.7	-15.87
Tractor-trailer	50.4	44.3	-12.13
Current Situation vs. Configuration C			
Vehicle Class	Current Situation Speed (mph)	Config C: Optnl Truck-Only Lane Speed (mph)	Percent Change
Car	66.8	66.9	+0.15
SU Truck	53.1	52.9	-0.49
Tractor-trailer	50.4	50.5	+0.17

**Table 6-02. Speed Comparison: Current Situation vs. Configuration A, B, and C
(2020 Analysis Year)**

Current Situation vs. Configuration A			
Vehicle Class	Current Situation Speed (mph)	Config A: Left Lane Only Speed (mph)	Percent Change
Car	63.0	61.0	-3.18
SU Truck	51.9	32.2	-37.96
Tractor-trailer	49.7	31.8	-36.02
Current Situation vs. Configuration B			
Vehicle Class	Current Situation Speed (mph)	Config B: 2 Left Lanes Speed (mph)	Percent Change
Car	63.0	61.0	-3.16
SU Truck	51.9	38.4	-26.03
Tractor-trailer	49.7	38.5	-22.55
Current Situation vs. Configuration C			
Vehicle Class	Current Situation Speed (mph)	Config C: Optnl Truck-Only Lane Speed (mph)	Percent Change
Car	63.0	62.9	-0.15
SU Truck	51.9	51.4	-0.93
Tractor-trailer	49.7	49.2	-1.03

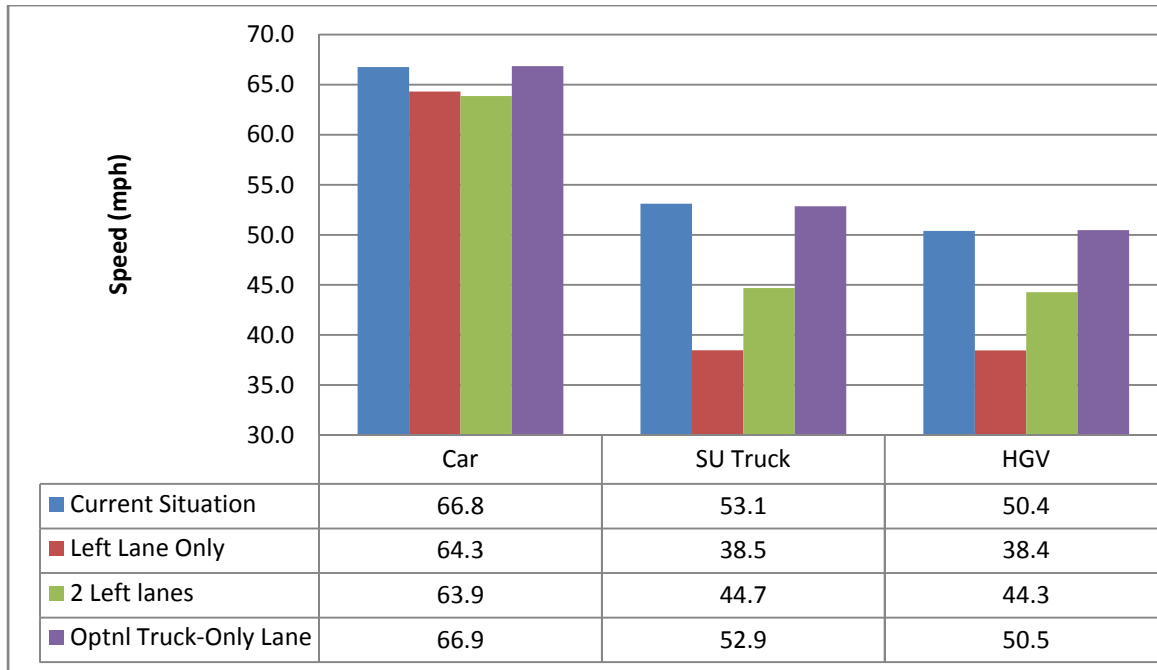


Figure 6-01. Average Speed Comparison – 2008 Analysis Year

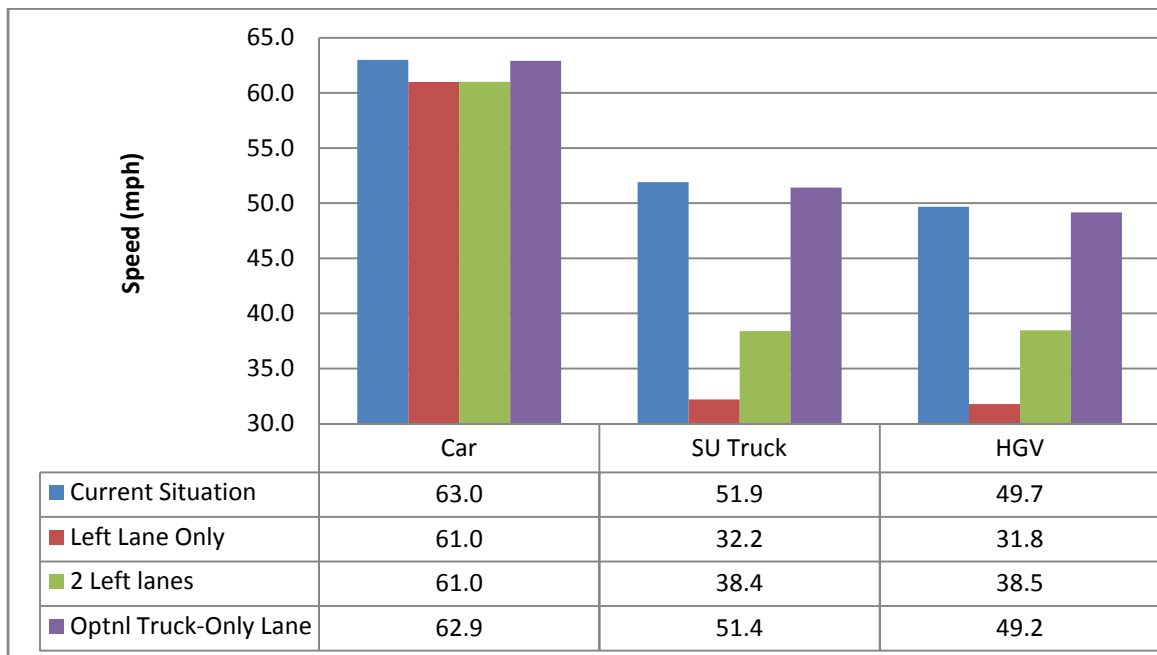


Figure 6-02. Average Speed Comparison – 2020 Analysis Year

6.2 Travel Time Comparison

Another way to express speed changes is in terms of travel time changes, which more clearly recognizes the increases or decreases in freeway efficiency for users. First, travel time comparisons for the 2008 analysis year scenario will be presented. Following this will be travel time comparisons for the 2020 analysis year scenario. The t-test was used to test the statistical significance of the differences in travel time presented by the alternative configurations. All three alternative configurations had travel times that were significantly different from the current situation configuration for all vehicle classes.

2008 Analysis Year Scenario

For the eastbound direction, the current situation configuration offers the shortest travel time for the single-unit truck and tractor-trailer vehicle classes while Configuration C (optional truck-only lane) offers the shortest travel time for the car vehicle class. Table 6-03 shows the eastbound travel time comparisons while Figure 6-03 illustrates the travel time differences by travel time section.

For the westbound direction, Configuration A (left lane only) presents the shortest total travel time for the car vehicle class. Configuration C presents the shortest total travel time for the single-unit truck and tractor-trailer vehicle classes. Table 6-04 shows the westbound travel time comparisons while Figure 6-04 illustrates the travel time differences by travel time section.

As seen in figures 6-03 and 6-04, the peak travel time values in the eastbound direction are higher than those in the westbound direction for the truck vehicle classes. This could be attributed to the fact that the eastbound direction had larger traffic volumes than the westbound direction as shown in the appendix.

2020 Analysis Year Scenario

For the eastbound direction, the current situation configuration offers the shortest travel time for the single-unit truck vehicle class while Configuration C (optional truck-only lane) offers the shortest travel time for the car vehicle class. Table 6-05 shows the eastbound travel time comparisons while Figure 6-05 illustrates the travel time differences by travel time section.

Table 6-03. Eastbound Travel Time Comparison: Current Situation vs. Configuration A, B, and C (2008 Analysis Year)

Current Situation vs. Configuration A				
Vehicle Class	Current Situation TT (s)	Config A: Left Lane Only TT (s)	Percent Change	Statistically Significant?
Car	1697	1713	+0.92	Yes
SU Truck	2000	2882	+44.11	Yes
Tractor-trailer	2119	2953	+39.35	Yes
Current Situation vs. Configuration B				
Vehicle Class	Current Situation TT (s)	Config B: 2 Left Lanes TT (s)	Percent Change	Statistically Significant?
Car	1697	1716	+1.13	Yes
SU Truck	2000	2458	+22.94	Yes
Tractor-trailer	2119	2494	+17.66	Yes
Current Situation vs. Configuration C				
Vehicle Class	Current Situation TT (s)	Config C: Optnl Truck-Only Lane TT (s)	Percent Change	Statistically Significant?
Car	1697	1664	-1.98	Yes
SU Truck	2000	2067	+3.38	Yes
Tractor-trailer	2119	2143	+1.12	Yes

Table 6-04. Westbound Travel Time Comparison: Current Situation vs. Configuration A, B, and C (2008 Analysis Year)

Current Situation vs. Configuration A				
Vehicle Class	Current Situation TT (s)	Config A: Left Lane Only TT (s)	Percent Change	Statistically Significant?
Car	1671	1651	-1.22	Yes
SU Truck	2210	2558	+15.78	Yes
Tractor-trailer	2285	2560	+12.05	Yes
Current Situation vs. Configuration B				
Vehicle Class	Current Situation TT (s)	Config B: 2 Left Lanes TT (s)	Percent Change	Statistically Significant?
Car	1671	1688	+0.97	Yes
SU Truck	2210	2490	+12.71	Yes
Tractor-trailer	2285	2484	+8.74	Yes
Current Situation vs. Configuration C				
Vehicle Class	Current Situation TT (s)	Config C: Optnl Truck-Only Lane TT (s)	Percent Change	Statistically Significant?
Car	1671	1664	-0.45	Yes
SU Truck	2210	2159	-2.29	Yes
Tractor-trailer	2285	2231	-2.36	Yes

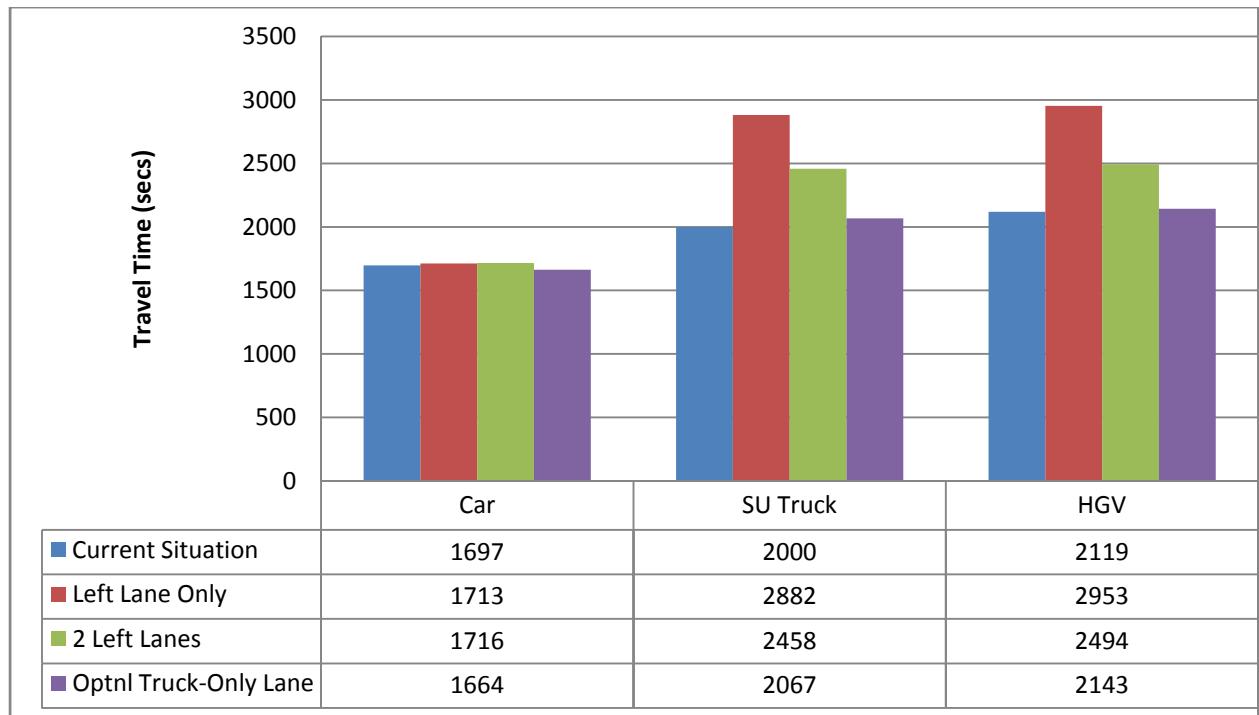


Figure 6-03. Eastbound Total Travel Time Comparison – 2008 Analysis Year

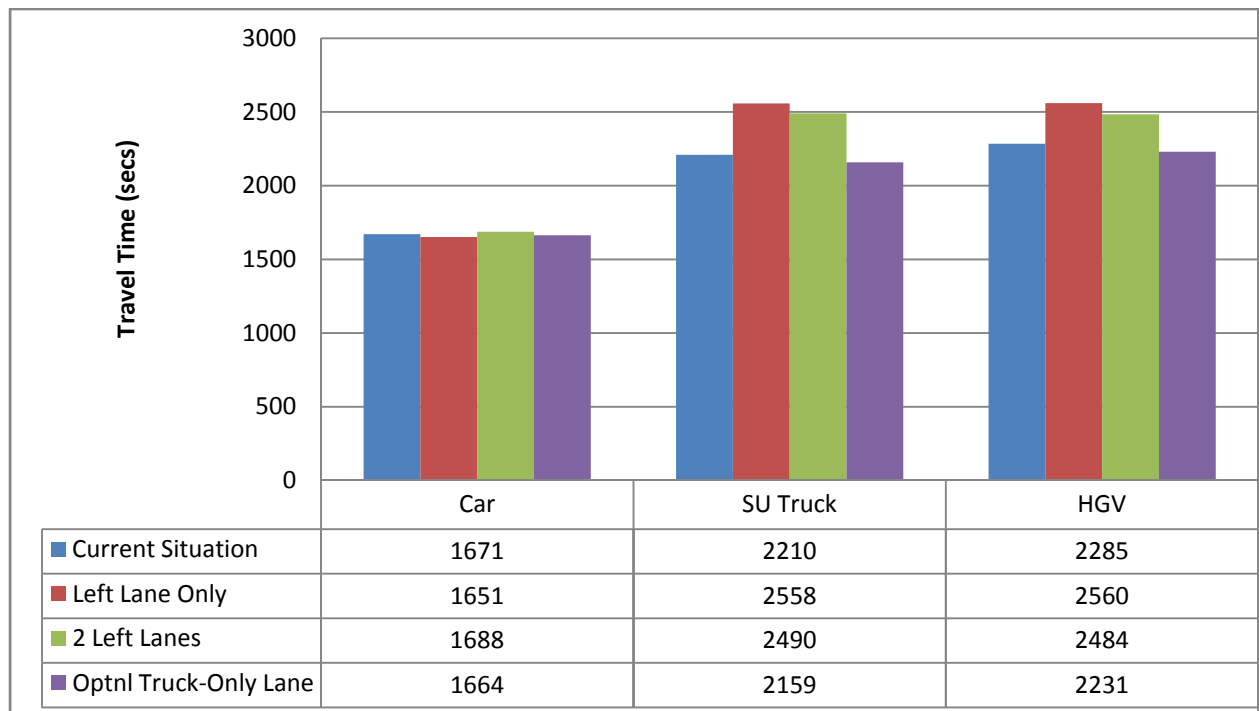


Figure 6-04. Westbound Total Travel Time Comparison – 2008 Analysis year

Table 6-05. Eastbound Travel Time Comparison: Current Situation vs. Configuration A, B, and C (2020 Analysis Year)

Current Situation vs. Configuration A				
Vehicle Class	Current Situation TT (s)	Config A: Left Lane Only TT (s)	Percent Change	Statistically Significant?
Car	1742	1721	-1.23	Yes
SU Truck	2082	3556	+70.77	Yes
Tractor-trailer	2171	3702	+70.56	Yes
Current Situation vs. Configuration B				
Vehicle Class	Current Situation TT (s)	Config B: 2 Left Lanes TT (s)	Percent Change	Statistically Significant?
Car	1742	1797	+3.15	Yes
SU Truck	2082	3025	+45.28	Yes
Tractor-trailer	2171	3064	+41.16	Yes
Current Situation vs. Configuration C				
Vehicle Class	Current Situation TT (s)	Config C: Optnl Truck-Only Lane TT (s)	Percent Change	Statistically Significant?
Car	1742	1709	-1.92	Yes
SU Truck	2082	2113	+1.48	Yes
Tractor-trailer	2171	2168	-0.14	No

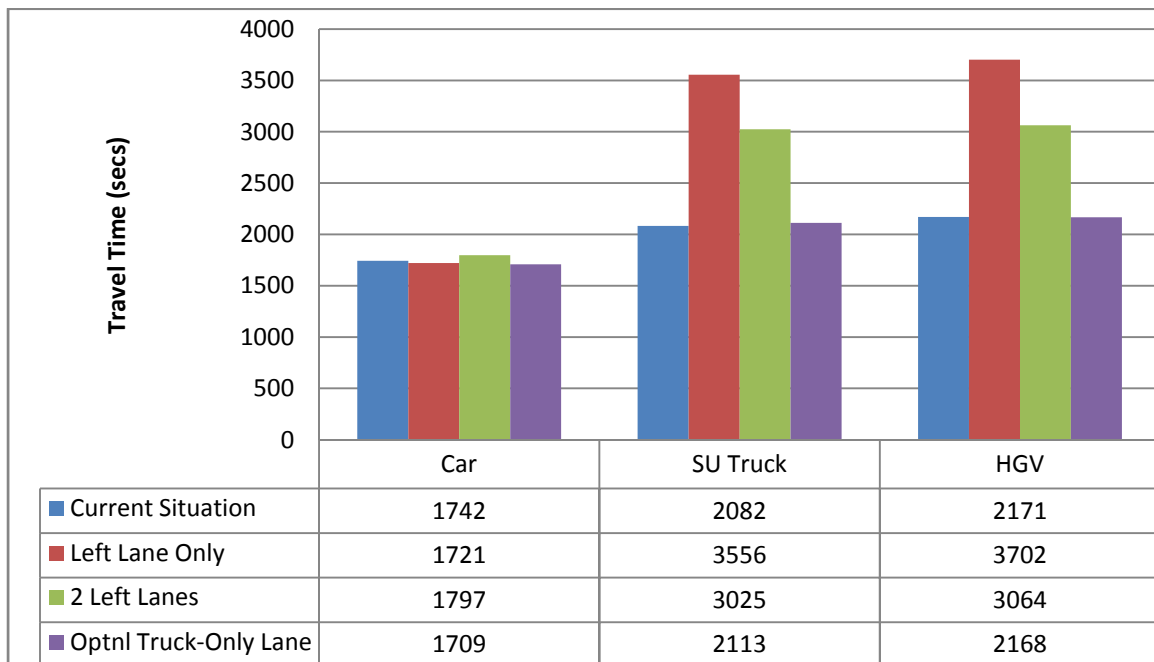


Figure 6-05. Eastbound Total Travel Time Comparison – 2020 Analysis Year

For the westbound direction, Configuration A (left lane only) presents the shortest total travel time for the car vehicle class. Configuration C presents the shortest total travel time for the tractor-trailer vehicle class. Table 6-06 shows the westbound travel time comparisons while Figure 6-06 illustrates the travel time differences by travel time section.

6.3 Delay Comparison

The average delay results for the three configurations varied from the current situation average delay result. Included in the delay comparison tables below are delay cost or savings in dollars. These values were calculated using the car and truck value of time used by the Federal Highway Administration. The car value of time is \$15.71 per hour and the truck value of time is \$25.24 per hour (Forkenbrock and March 2005). A positive delay cost/savings implies the amount of savings the alternative configuration will introduce to the particular vehicle class if implemented. A negative delay savings implies that there will be no delay savings if the alternative configuration is implemented. Instead, the alternative configuration will introduce some delay and the amount indicated will be the approximate additional delay cost.

2008 Analysis Year Scenario

For the eastbound direction, the current situation configuration offers the smallest delay for the single-unit truck and tractor-trailer vehicle classes of 174 seconds per vehicle and 124 seconds per vehicle respectively, for the entire corridor. The optional truck-only lane configuration offers the smallest delay of 73 seconds per vehicle for the car vehicle class. This configuration offers a delay savings of 20 cents per vehicle per hour or a system delay savings of about \$2,850.00 per hour. Table 6-07 shows the delay values for the current situation configuration and the three alternative configurations. Figure 6-07 illustrates the delay changes by vehicle class.

For the westbound direction, the optional truck-only lane configuration offers the smallest delay for the two truck vehicle classes with a combined delay savings of 57 cents per truck per hour or a system delay savings of about \$480.00 per hour.

Table 6-06. Westbound Travel Time Comparison: Current Situation vs. Configuration A, B, and C (2020 Analysis Year)

Current Situation vs. Configuration A				
Vehicle Class	Current Situation TT (s)	Config A: Left Lane Only TT (s)	Percent Change	Statistically Significant?
Car	1748	1709	-2.21	Yes
SU Truck	2240	2816	+25.73	Yes
Tractor-trailer	2286	2812	+22.99	Yes
Current Situation vs. Configuration B				
Vehicle Class	Current Situation TT (s)	Config B: 2 Left Lanes TT (s)	Percent Change	Statistically Significant?
Car	1748	1677	-4.04	Yes
SU Truck	2240	2584	+15.37	Yes
Tractor-trailer	2286	2560	+11.99	Yes
Current Situation vs. Configuration C				
Vehicle Class	Current Situation TT (s)	Config C: Optnl Truck-Only Lane TT (s)	Percent Change	Statistically Significant?
Car	1748	1765	+0.98	Yes
SU Truck	2240	2234	-0.25	No
Tractor-trailer	2286	2259	-1.19	Yes

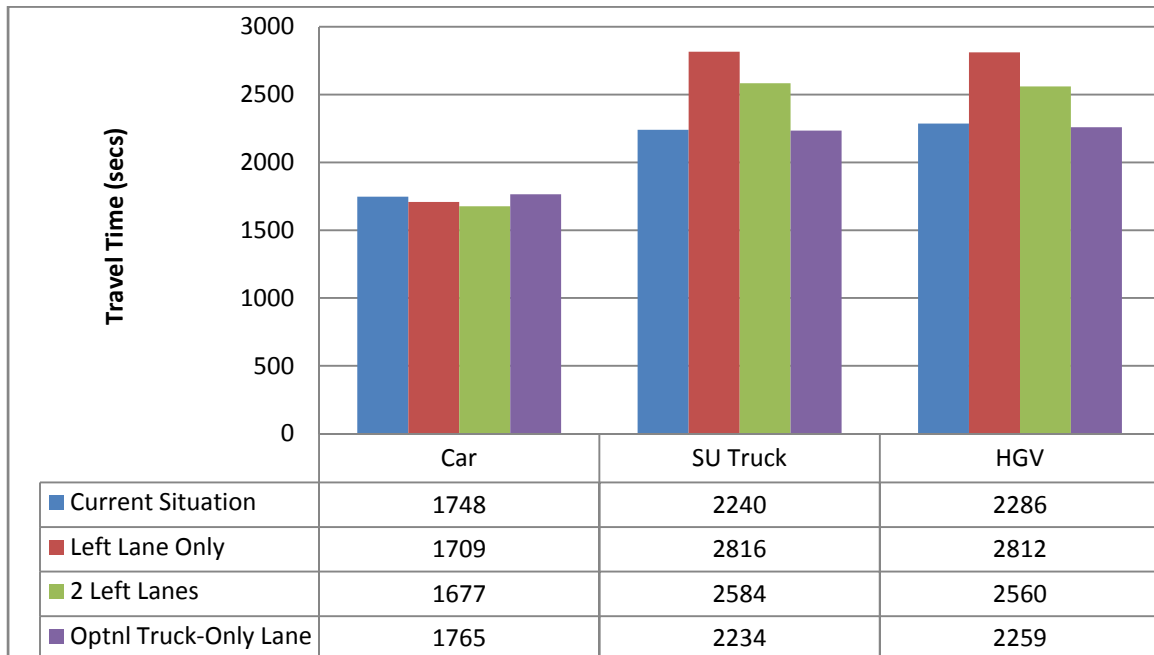


Figure 6-06. Westbound Total Travel Time Comparison – 2020 Analysis Year

Table 6-07. Eastbound Delay Comparison: Current Situation vs. Configuration A, B, and C (2008 Analysis Year)

Current Situation vs. Configuration A							
Vehicle Class	Current Situation Delay (s/veh)	Config A: Left Lane Only Delay (s/veh)	Percent Change	Delay Change (s/veh)	Delay Cost/Savings (\$/veh/hr)	Traffic Volumes (veh/hr)	System Delay Cost/Savings (\$/hr)
Car	119	131	+10.34	-12	-0.05	14197	-762.04
SU Truck	174	1055	> +95.00	-881	-6.18	330	-2038.57
Tractor-trailer	124	968	> +95.00	-844	-5.91	1981	-11716.77
Current Situation vs. Configuration B							
Vehicle Class	Current Situation Delay (s/veh)	Config B: 2 Left Lanes Delay (s/veh)	Percent Change	Delay Change (s/veh)	Delay Cost/Savings (\$/veh/hr)	Traffic Volumes (veh/hr)	System Delay Cost/Savings (\$/hr)
Car	119	147	+23.28	-28	-0.12	14197	-1716.13
SU Truck	174	605	> +95.00	-431	-3.02	330	-996.73
Tractor-trailer	124	465	> +95.00	-341	-2.39	1981	-4733.37
Current Situation vs. Configuration C							
Vehicle Class	Current Situation Delay (s/veh)	Config C: Optnl Truck-Only Lane Delay (s/veh)	Percent Change	Delay Change (s/veh)	Delay Cost/Savings (\$/veh/hr)	Traffic Volumes (veh/hr)	System Delay Cost/Savings (\$/hr)
Car	119	73	-38.66	46	0.20	14197	2849.89
SU Truck	174	289	+66.09	-115	-0.81	330	-266.07
Tractor-trailer	124	207	+66.94	-83	-0.58	1981	-1152.79

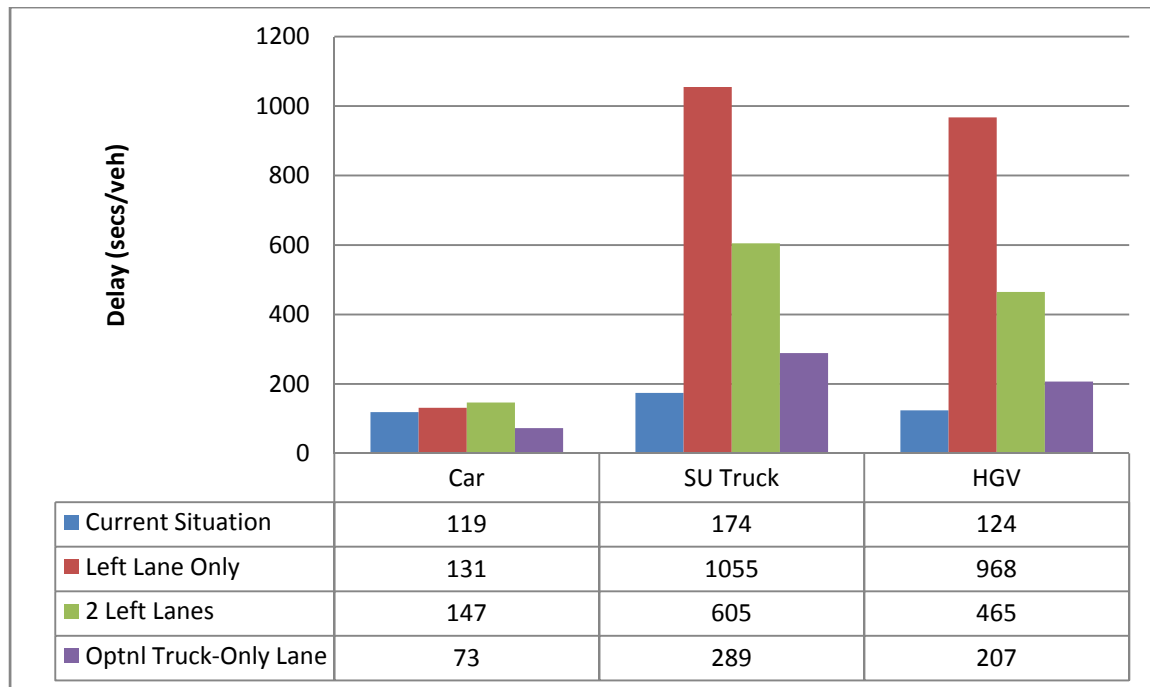


Figure 6-07. Eastbound Total Delay Comparison – 2008 Analysis Year

The left lane only configuration offers the smallest delay for the car vehicle class with a delay savings of about 5 cents per vehicle per hour or \$477.00 per hour in system delay savings. Table 6-08 shows the delay values for the current situation configuration and the three alternative configurations. Figure 6-08 illustrates the delay changes by vehicle class.

2020 Analysis Year Scenario

For the eastbound direction, the current situation configuration offers the smallest delay for the single-unit truck and tractor-trailer vehicle classes of 215 seconds per vehicle and 168 seconds per vehicle respectively, for the entire corridor. The optional truck-only lane configuration offers the smallest delay of 111 seconds per vehicle for the car vehicle class. This configuration offers a delay savings of 22 cents per vehicle per hour or a system delay savings of about \$4,073.00 per hour. Table 6-09 shows the delay values for the current situation configuration and the three alternative configurations. Figure 6-09 illustrates the delay changes by vehicle class.

For the westbound direction, the two left lanes configuration offers the smallest delay for the car vehicle class at 106 seconds per vehicle. The optional truck-only lane configuration offers the smallest delay for the tractor-trailer vehicle class of 211 seconds per vehicle respectively. The current situation configuration offers the smallest delay (302 seconds per vehicle) for the single-unit truck vehicle class. Table 6-10 shows the delay values for the current situation configuration and the three alternative configurations. Figure 6-10 illustrates the delay changes by vehicle class.

Table 6-08. Westbound Delay Comparison: Current Situation vs. Configuration A, B, and C (2008 Analysis Year)

Current Situation vs. Configuration A							
Vehicle Class	Current Situation Delay (s/veh)	Config A: Left Lane Only Delay (s/veh)	Percent Change	Delay Change (s/veh)	Delay Cost/Savings (\$/veh/hr)	Traffic Volumes (veh/hr)	System Delay Cost/Savings (\$/hr)
Car	82	70	-15.12	12	0.05	8823	477.43
SU Truck	282	590	> +95.00	-308	-2.16	205	-442.25
Tractor-trailer	218	503	> +95.00	-285	-2.00	1232	-2465.20
Current Situation vs. Configuration B							
Vehicle Class	Current Situation Delay (s/veh)	Config B: 2 Left Lanes Delay (s/veh)	Percent Change	Delay Change (s/veh)	Delay Cost/Savings (\$/veh/hr)	Traffic Volumes (veh/hr)	System Delay Cost/Savings (\$/hr)
Car	82	106	+29.27	-24	-0.10	8823	-924.06
SU Truck	282	534	+89.50	-252	-1.77	205	-362.77
Tractor-trailer	218	425	> +95.00	-207	-1.45	1232	-1791.46
Current Situation vs. Configuration C							
Vehicle Class	Current Situation Delay (s/veh)	Config C: Optnl Truck-Only Lane Delay (s/veh)	Percent Change	Delay Change (s/veh)	Delay Cost/Savings (\$/veh/hr)	Traffic Volumes (veh/hr)	System Delay Cost/Savings (\$/hr)
Car	82	73	-10.98	9	0.04	8823	346.52
SU Truck	282	251	-11.17	32	0.22	205	45.27
Tractor-trailer	218	168	-23.12	50	0.35	1232	435.34

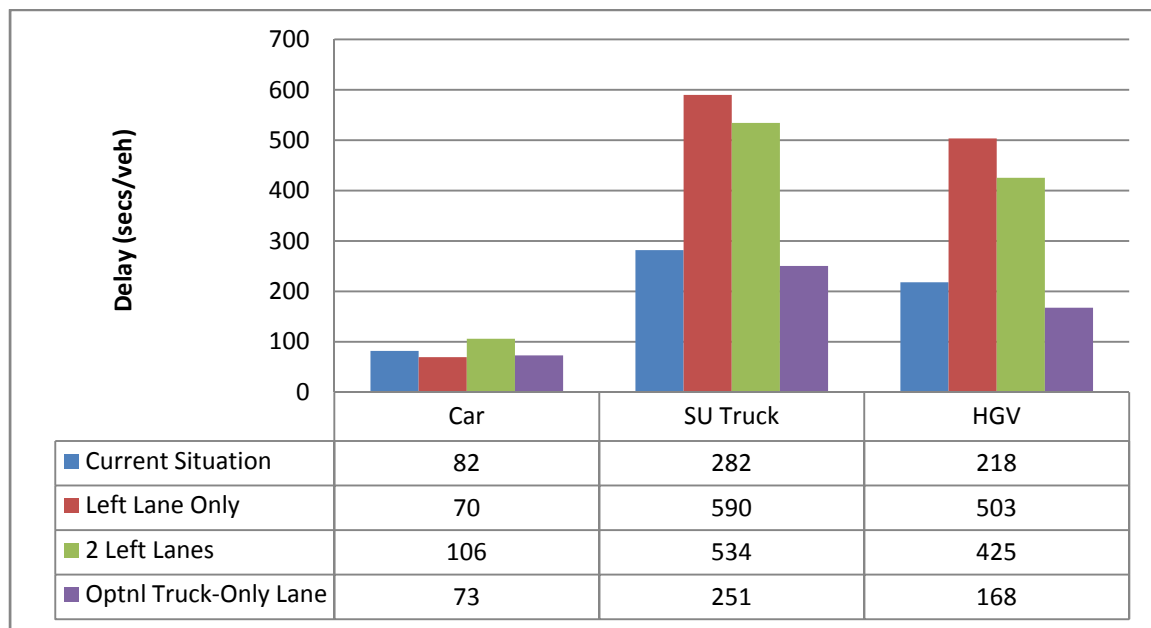


Figure 6-08. Westbound Total Delay Comparison – 2008 Analysis Year

Table 6-09. Eastbound Delay Comparison: Current Situation vs. Configuration A, B, and C (2020 Analysis Year)

Current Situation vs. Configuration A							
Vehicle Class	Current Situation Delay (s/veh)	Config A: Left Lane Only Delay (s/veh)	Percent Change	Delay Change (s/veh)	Delay Cost/Savings (\$/veh/hr)	Traffic Volumes (veh/hr)	System Delay Cost/Savings (\$/hr)
Car	161	163	+1.37	-2	-0.01	18783	-180.33
SU Truck	215	1688	> +95.00	-1473	-10.33	437	-4514.28
Tractor-trailer	168	1689	> +95.00	-1521	-10.66	2823	-30100.23
Current Situation vs. Configuration B							
Vehicle Class	Current Situation Delay (s/veh)	Config B: 2 Left Lanes Delay (s/veh)	Percent Change	Delay Change (s/veh)	Delay Cost/Savings (\$/veh/hr)	Traffic Volumes (veh/hr)	System Delay Cost/Savings (\$/hr)
Car	161	259	+61.39	-99	-0.43	18783	-8081.94
SU Truck	215	1158	> +95.00	-943	-6.61	437	-2890.13
Tractor-trailer	168	1044	> +95.00	-875	-6.14	2823	-17324.26
Current Situation vs. Configuration C							
Vehicle Class	Current Situation Delay (s/veh)	Config C: Optnl Truck-Only Lane Delay (s/veh)	Percent Change	Delay Change (s/veh)	Delay Cost/Savings (\$/veh/hr)	Traffic Volumes (veh/hr)	System Delay Cost/Savings (\$/hr)
Car	161	111	-30.95	50	0.22	18783	4073.76
SU Truck	215	307	+42.98	-92	-0.65	437	-282.49
Tractor-trailer	168	232	+38.03	-64	-0.45	2823	-1266.71

Table 6-10. Westbound Delay Comparison: Current Situation vs. Configuration A, B, and C (2020 Analysis Year)

Current Situation vs. Configuration A							
Vehicle Class	Current Situation Delay (s/veh)	Config A: Left Lane Only Delay (s/veh)	Percent Change	Delay Change (s/veh)	Delay Cost/Savings (\$/veh/hr)	Traffic Volumes (veh/hr)	System Delay Cost/Savings (\$/hr)
Car	157	127	-19.63	31	0.13	11673	1574.04
SU Truck	302	873	> +95.00	-572	-4.01	271	-1086.24
Tractor-trailer	231	758	> +95.00	-527	-3.69	1754	-6477.09
Current Situation vs. Configuration B							
Vehicle Class	Current Situation Delay (s/veh)	Config B: 2 Left Lanes Delay (s/veh)	Percent Change	Delay Change (s/veh)	Delay Cost/Savings (\$/veh/hr)	Traffic Volumes (veh/hr)	System Delay Cost/Savings (\$/hr)
Car	157	106	-32.47	51	0.22	11673	2603.02
SU Truck	302	628	> +95.00	-326	-2.28	271	-619.21
Tractor-trailer	231	508	> +95.00	-277	-1.94	1754	-3410.09
Current Situation vs. Configuration C							
Vehicle Class	Current Situation Delay (s/veh)	Config C: Optnl Truck-Only Lane Delay (s/veh)	Percent Change	Delay Change (s/veh)	Delay Cost/Savings (\$/veh/hr)	Traffic Volumes (veh/hr)	System Delay Cost/Savings (\$/hr)
Car	157	172	+8.96	-14	-0.06	11673	-718.25
SU Truck	302	327	+8.29	-25	-0.18	271	-47.50
Tractor-trailer	231	211	-8.66	20	0.14	1754	245.95

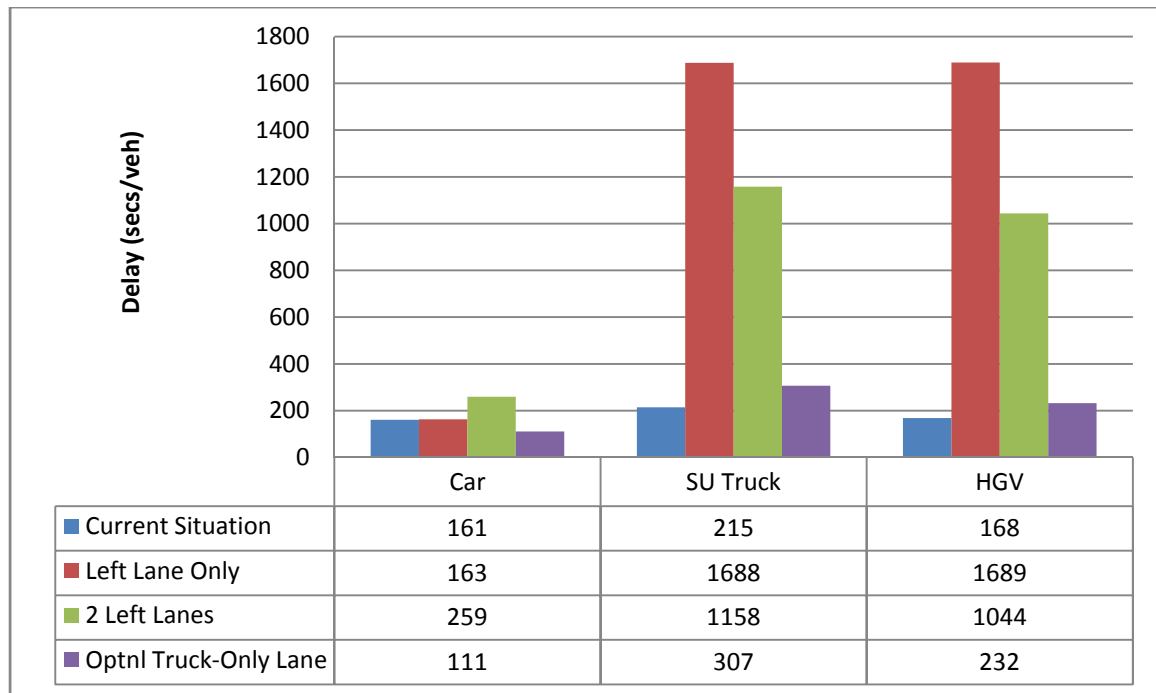


Figure 6-09. Eastbound Total Delay Comparison – 2020 Analysis Year

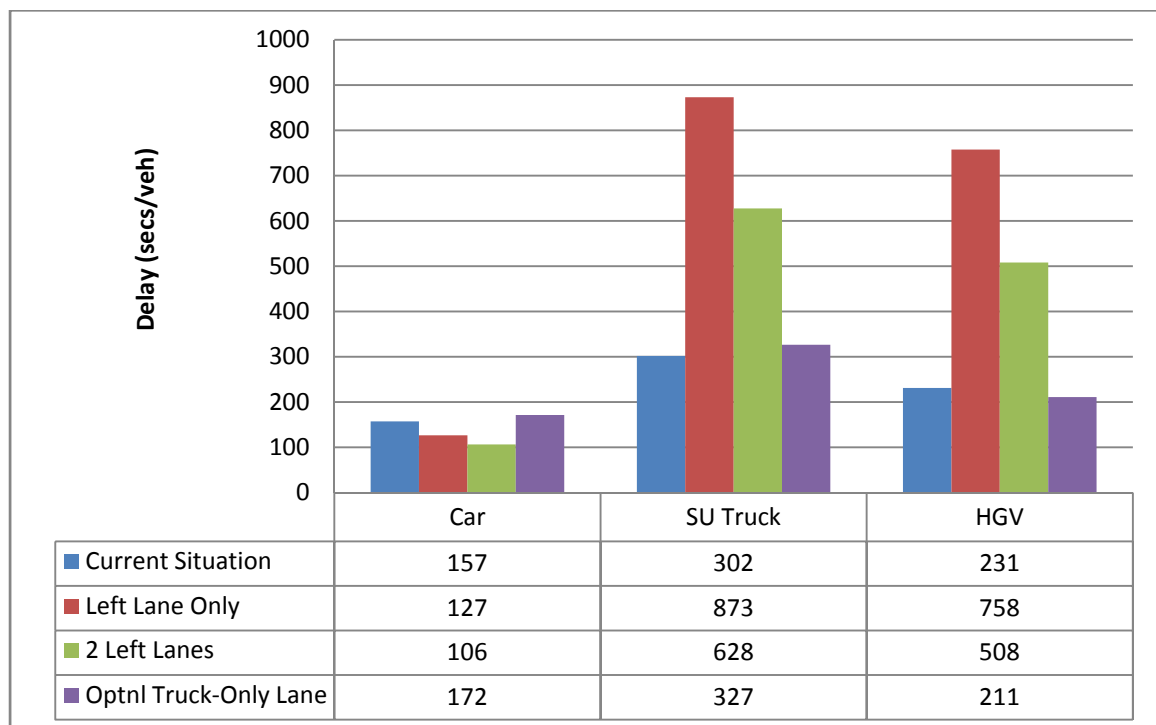


Figure 6-10. Westbound Total Delay Comparison – 2020 Analysis Year

6.4 Lane Change Comparison

The average lane change rate results for the three configurations were significantly different from the current situation average lane change rate result. The drastic decrease in lane changes demonstrated by Configuration A for all three vehicle classes could be attributed to the restriction of trucks to the left lane only. The car vehicle class experienced a huge decrease in lane changes as a result of huge volumes of trucks in the left lane thereby forcing cars to utilize the middle and right lane most of the time.

Although Configuration B was expected to have lane change rates close to those of the current situation configuration, the decrease in lane change rates for the truck vehicle classes could be attributed to the left lane preference by trucks in the Configuration B. As mentioned in the speed comparison section of this report, unlike the current situation where trucks being restricted to the two right lanes have to deal with traffic entering on-ramps, trucks do not have to deal with such traffic when in the left lane. Trucks in the left lane also do not have to deal with many cases of cars changing lanes because cars do not generally enter a lane with large truck volumes. However, trucks in the middle lane do have to deal with these two issues, hence the truck left lane preference. Compared to Configuration A (left lane only), Configuration B average lane change rates for all three vehicle classes are higher due to Configuration B allowing trucks in the middle lane. This allows more cars to get into the left lane since there are now fewer trucks in that lane.

Considering the three alternative configurations, Configuration C has the lowest rate of lane changes because of the presence of the barrier separated optional truck-only lane. The model did not have a barrier separating the left lane from the other two lanes because this option was not available in VISSIM. However, the lane settings were adjusted so that lane changing was prohibited for vehicles in the left lane and the left lane was closed to vehicles that were not already in the left lane for specific sections of the network.

A significant percentage of trucks used the optional truck-only lane resulting in a significant reduction in lane changes as a result of all trucks that chose to use this lane. Furthermore, all cars and the remainder of trucks that were in the general traffic lanes

were strictly restricted to two lanes of travel and this would also lead to a significant reduction in lane changes.

2008 Analysis Year Scenario

As shown in Figure 6-11, the current situation configuration has the highest lane change rates for all three vehicle classes. Table 6-11 shows the percent change in lane change rates by vehicle class for Configurations A, B, and C from the current situation configuration. Configuration C (optional truck –only lane) has the lowest average lane change rates for all three vehicle classes.

2020 Analysis Year Scenario

As shown in Figure 6-12, in this scenario Configuration A had the lowest lane change rate for the car vehicle class. Configuration C had the lowest lane change rates for the single-unit truck and tractor-trailer vehicle classes. Table 6-12 shows the percent change in lane change rates for Configurations A, B, and C from the current situation configuration. Figure 6-12 illustrates these changes.

Table 6-11. Lane Change Rate Comparison: Current Situation vs. Configuration A, B, and C (2008 Analysis Year)

Current Situation vs. Configuration A			
Vehicle Class	Current Situation Lane Change Rate (lcph)	Config A: Left Lane Only - Lane Change Rate (lcph)	Percent Change
Car	137975	80353	-41.76
SU Truck	3259	2371	-27.23
Tractor-trailer	28533	20333	-28.74
Current Situation vs. Configuration B			
Vehicle Class	Current Situation Lane Change Rate (lcph)	Config B: 2 Left Lanes - Lane Change Rate (lcph)	Percent Change
Car	137975	94343	-31.62
SU Truck	3259	2590	-20.53
Tractor-trailer	28533	23133	-18.93
Current Situation vs. Configuration C			
Vehicle Class	Current Situation Lane Change Rate (lcph)	Config C: Optnl Truck-Only Lane - Lane Change Rate (lcph)	Percent Change
Car	137975	79648	-42.27
SU Truck	3259	482	-85.21
Tractor-trailer	28533	2825	-90.10

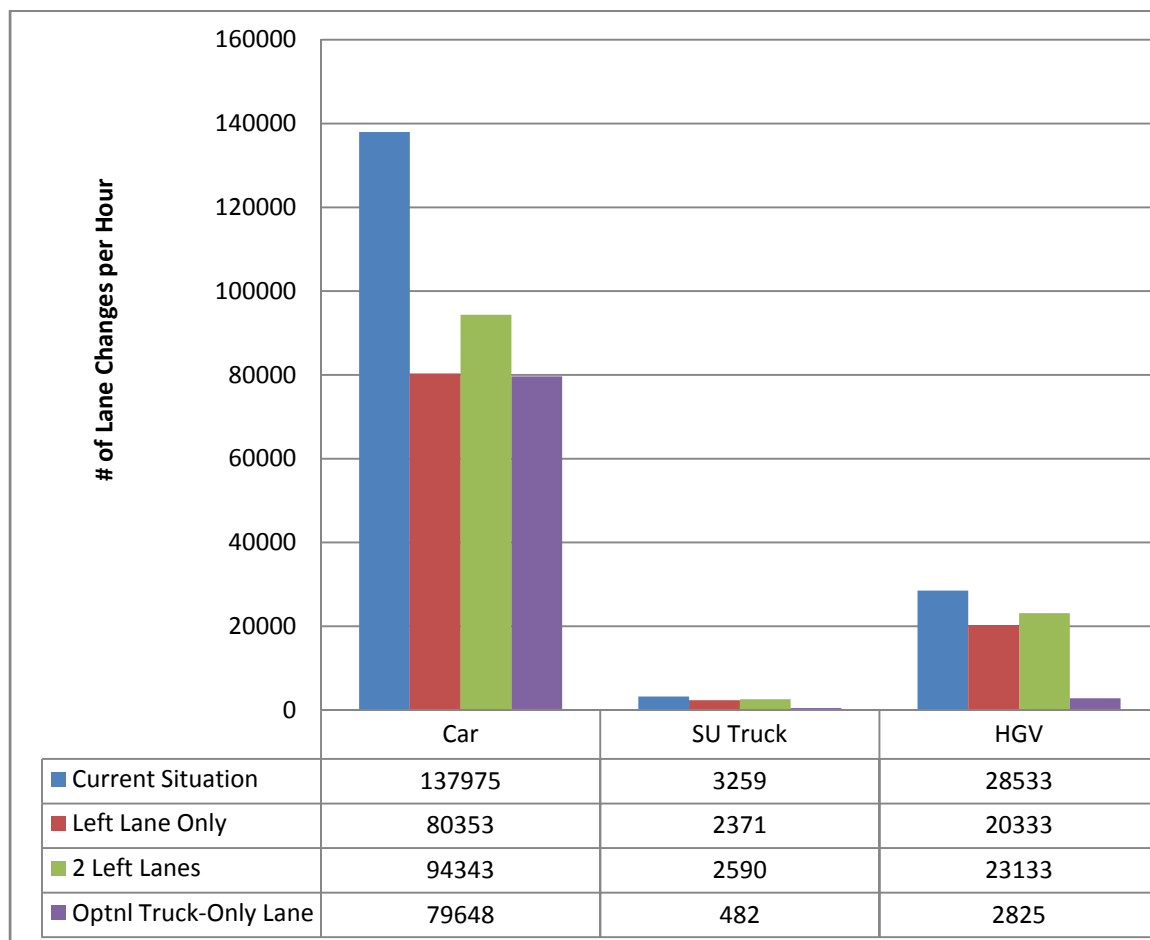


Figure 6-11. Average Lane Change Rate Comparison – 2008 Analysis Year

Table 6-12. Lane Change Rate Comparison: Current Situation vs. Configuration A, B, and C (2020 Analysis Year)

Current Situation vs. Configuration A			
Vehicle Class	Current Situation Lane Change Rate (lcph)	Config A: Left Lane Only - Lane Change Rate (lcph)	Percent Change
Car	198969	112345	-43.54
SU Truck	3500	2767	-20.93
Tractor-trailer	33283	25824	-22.41
Current Situation vs. Configuration B			
Vehicle Class	Current Situation Lane Change Rate (lcph)	Config B: 2 Left Lanes - Lane Change Rate (lcph)	Percent Change
Car	198969	113410	-43.00
SU Truck	3500	3142	-10.22
Tractor-trailer	33283	29755	-10.60
Current Situation vs. Configuration C			
Vehicle Class	Current Situation Lane Change Rate (lcph)	Config C: Optnl Truck-Only Lane - Lane Change Rate (lcph)	Percent Change
Car	198969	119334	-40.02
SU Truck	3500	675	-80.71
Tractor-trailer	33283	4254	-87.22

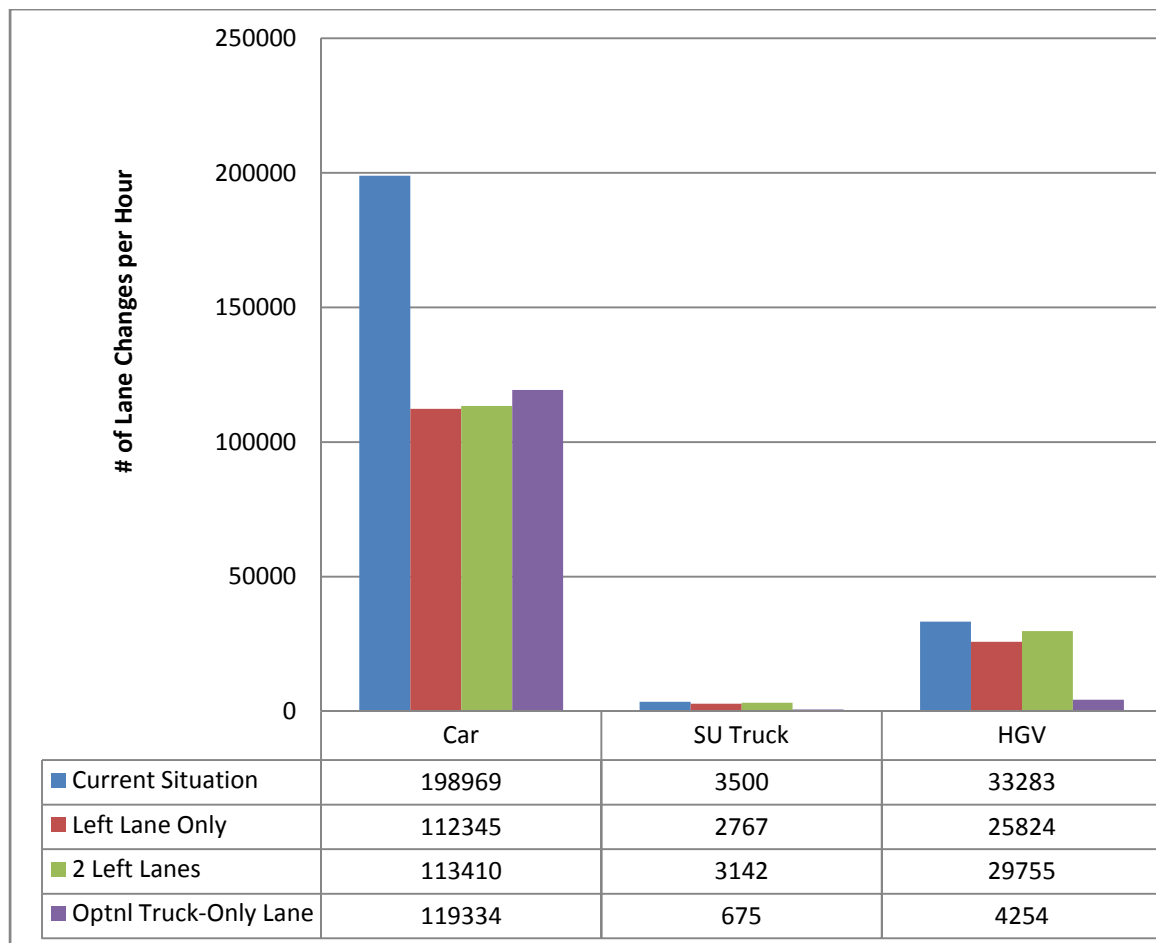


Figure 6-12. Average Lane Change Rate Comparison – 2020 Analysis Year

7.0 Conclusions and Recommendations

This research was conducted to aid in the development of truck management solutions in response to the challenge of increased freight movement on the US highway systems. The impacts of this truck traffic are particularly felt in urban areas coping with increased local traffic in addition to increased freight movement. Knoxville's urban area is currently experiencing this trend as the city is at the crossroads of two major freeways, resulting in high proportions of through truck traffic. One of the potential solutions that have been debated in the Knoxville's urban area and many other urban areas throughout the US is the development of truck by-pass routes. These new highways are politically difficult to build and finance, leading to discussions of management of truck traffic through urban areas. This chapter will conclude three items - the truck survey that was conducted as a part of this research, the microsimulation analysis that was done, and a brief infrastructure needs assessment. Recommendations for implementation will be drawn from these conclusions.

Truck Survey

A truck survey was developed to understand some of the difficulties experienced by truck drivers through urban areas, identify driver preferences on future truck lane management, and finally identify if truck drivers were willing to pay for infrastructure improvements that could reduce their delay.

Perhaps the most interesting response from the survey is the widespread support of left side truck lanes (Configuration B and C). Simply reversing the current rule so that truckers are required to use the left two lanes, rather than the right two lanes would reduce much of the conflict associated with merging vehicles as well as reducing the lane changing problems of cars interacting with trucks. It could potentially improve the efficiency of the freeway allowing higher utilization of lane capacity. This option had the lowest number of strong dissidents. There was also widespread support of a managed lane that is optional for trucks to use. Many of the respondents seemed to support the idea of a "truck only" lane for the sake of dedicated infrastructure. The status quo, restricting trucks to the right, seemed to be popular among some, but unpopular among others, with fewer neutral respondents. Those who supported this option often cited that this

configuration was the something they were used to and did not see a reason to change. However, this indicates that a large proportion of the existing drivers are dissatisfied with the current system and are looking for an operational change.

Interestingly, willingness to pay did not statistically vary by most of the respondents in the survey. For instance, respondents who supported truck only lanes were not willing to pay more to avoid congestion than those who were supportive of other operational changes. Independent operators are also not willing to pay more (or less) than company drivers. Willingness to pay to avoid congestion was also lower than expected, with 70% of the respondents not willing to pay anything more to avoid ten minutes of congestion. Of those willing to pay, the average “toll” they would pay to save ten minutes of travel time is over \$5, while the average willingness-to-pay of the entire population is about \$2. This implies an average value of time (from the drivers’ perspective) of only \$10 per hour, much lower than the \$25 per hour value of truck time used by the FHWA (Forkenbrock and March 2005). The true value of time for the commodity being moved could be much higher, but is not represented by the drivers’ value of time.

Microsimulation Analysis

The purpose of the microsimulation analysis in this research was to obtain a microscopic view on the behavioral output of a highway under different lane configurations as it relates to operational improvements.

There were four lane configurations evaluated – the current situation configuration, the left lane only configuration (Configuration A), the two left lanes configuration (Configuration B), and the optional truck-only lane configuration (Configuration C). Each of these four configurations was evaluated based on four parameters; speed, travel time, delay, and lane change. Each of these four parameters were also evaluated by vehicle class; car, single-unit truck, and tractor-trailer. The four lane configurations were evaluated under two scenarios – the 2008 analysis year scenario and the 2020 analysis year scenario. Comparisons were made on the results obtained from the evaluation of the four lane configurations in order to find the best operational and safety improvements now and in the future.

2008 Analysis Year Scenario

For the speed parameter, Configuration C (optional truck –only lane) and the current situation configuration have very similar average speeds. Configurations A and B offer lower speeds for all vehicle classes compared to the current situation configuration and Configuration C. These low speeds will especially affect the truck vehicle classes adversely in terms of efficiency. Therefore in regards to speed, Configuration C – the optional truck-only lane configuration and the current situation configuration are both the great fits for highway operational improvement.

For the travel time parameter, the current situation configuration has the shortest travel times for the two truck vehicle classes in the eastbound direction. Configuration A has the shortest travel time for the car vehicle class in the westbound direction. Configuration B travel times are high in both directions for all vehicle classes. However, Configuration C has the shortest travel times for the car vehicle class in the eastbound direction and for the two truck vehicle classes in the westbound direction. This makes Configuration C the only configuration that offers the shortest travel time for all three vehicle classes. It is also important to know that the differences in travel time between the three alternative configurations and the current situation configuration are statistically significant. Therefore in regards to travel time, Configuration C is the better fit for highway operational improvement.

For the delay parameter, the current situation configuration has the smallest delay for the two truck vehicle classes in the eastbound direction. Configuration A has the smallest delay for the car vehicle class in the westbound direction. Configuration B delay times are high in both directions for all vehicle classes. However, Configuration C has the smallest delay for the two truck vehicle classes in the westbound direction and the smallest delay for the car vehicle class in the eastbound direction. Configuration C is also the only alternative configuration that offers delay savings for the car and two truck vehicle classes. Therefore in regards to delay, Configuration C is the better fit for highway operational improvement.

For the lane change parameter, all three configurations significantly reduce the rate of lane changes compared to the existing system. Configuration C has the lowest average lane change rates for all three vehicle classes. Lane change can be used as a

proxy measure of highway safety. If vehicles interact with each other at a minimal rate on the highway, the safer it is for drivers. Therefore in regards to highway safety, Configuration C, again, is the better fit for highway operational improvements.

2020 Analysis Year Scenario

For the speed parameter, Configuration C (optional truck –only lane) and the current situation have very similar average speeds. The differences are also very small (0.1 to 0.5 mph). Just like the 2008 analysis year scenario, Configurations A and B offer lower speeds for all vehicle classes compared to the current situation configuration and Configuration C. This does not help when it comes to improving efficiency. Therefore in regards to speed, Configuration C – the optional truck-only lane configuration and the current situation configuration are both great fits for highway operational improvement.

For the travel time parameter, the current situation configuration has the shortest travel time for the single-unit truck vehicle class in the eastbound direction. Configuration B has the shortest travel time for the car vehicle class in the westbound direction. Configuration A travel times are high in both directions for all vehicle classes. Configuration C has the shortest travel times for the car and tractor-trailer vehicle classes in the eastbound direction and for both truck vehicle classes in the westbound direction. However, the Configuration C travel time for tractor-trailers in the eastbound direction is not statistically different from that of the current situation configuration. Also the Configuration C travel time for single-unit trucks in the westbound direction is not statistically different from that of the current situation. Nevertheless, Configuration C is still the only configuration that offers the shortest travel time for the car and truck vehicle classes.

For the delay parameter, the current situation configuration has the smallest delay for the two truck vehicle classes in the eastbound direction and the single-unit truck vehicle class in the westbound direction. However, this configuration does not favor cars in terms of delay. Configurations A and B experience fairly large amounts of delays with the exception of Configuration B having the smallest delay for the car vehicle class in the westbound direction. Configuration C has the smallest delay for the car vehicle class in the eastbound direction and the tractor-trailer vehicle class in the westbound direction.

This makes Configuration C the only configuration that offers the smallest delay for the car and truck vehicle classes. Configuration C is the only alternative configuration that offers delay savings for both car and truck vehicle classes. Therefore in regards to delay, Configuration C is the better fit for highway operational improvement.

For the lane change parameter, the current situation configuration has the highest lane change rates for all three vehicle classes. Configuration B also has fairly low lane change rates for all vehicle classes. Configuration A has the lowest average lane change rates for the car vehicle class. Configuration C has the lowest average lane change rates for the single-unit truck and tractor-trailer vehicle classes. Nevertheless Configuration C offers a lane change rate that is very close to that of Configuration A for the car vehicle class.

Recommendation

The results of the survey concerning which configuration the truck drivers favored the most indicates that they would rather have the lane configurations proposed by Configurations B and C – two left lanes and optional truck-only lane respectively. This result put together with the microsimulation analysis result would make Configuration C – the optional truck-only lane configuration, the most highly recommended configuration for future implementation. As stated in Chapter 1, over 67% of all truck traffic on Knoxville highways is passing through, with neither an origin nor a destination in the region (Knoxville Regional Transportation Planning Organization 2007). This configuration separates the thru' truck traffic from all other traffic. Therefore there is much less trucks in the general traffic lanes which in turn increases travel time, reduces delay, and increases safety. This configuration also seems to handle a greater volume of trucks better than the current situation. However it is important to note that the state of Tennessee is considered to have a rolling terrain. The study corridor is in East Tennessee so the conclusions from this research would only apply to areas with similar terrain conditions. This configuration is potentially the most controversial, so it warrants further study and Configuration B still provides lane change advantages, but at the cost of higher delay.

Infrastructure Needs

This analysis is intended to be a brief overview of the infrastructure needed to implement the lane configurations presented in this research. These configurations are meant to be low cost approaches to big problems.

The first lane configuration presented was the current situation configuration. This will cost little as it is also referred to as the “do nothing scenario”. To manage this system, one would require signage and enforcement, which is already taking place. This is the current lane configuration of the existing Knoxville highways I-40 and I-640 and they will remain the way they are which is trucks remain restricted to the two right lanes on sections of I-40 and no restriction on I-640.

The second lane configuration presented was the left lane only configuration tagged as Configuration A. This configuration requires trucks to be restricted to the left lane only on both I-40 and I-640. The requirements for the implementation of such configuration would be to put up signs that display the message “all trucks must use left lane only” or similar. For maximum conveyance of this information to the truck drivers these signs must be placed as often as design standards permit along the shoulders of the highway or even over the left lane on sign bridges. Furthermore, significant enforcement may be required, especially since the microsimulation shows that this configuration will cause slower speeds in the left lane.

The third lane configuration presented was the two left lanes configuration tagged as Configuration B. This configuration is the opposite of the current configuration. It requires that trucks be restricted to the two left lanes of the highway on both I-40 and I-640. The requirements for implementation will be the same as that of the left lane only (Configuration A) configuration with a simple exception – the message on the signs will read “all trucks must use left two lanes” or similar. This configuration will also require more enforcement and education as it is different from the normal operations encountered in most cities.

The final lane configuration presented was the optional truck-only lane configuration tagged as Configuration C. This configuration requires a barrier separated truck-only lane on the left side of the highway. This is the most expensive configuration to implement, however it is expected that this has much lower costs compared to adding

new lanes or building new highways. To implement this configuration, concrete barriers will be needed to separate the left lane from the middle lane. Restriping will be required on sections of the highway where some extra pavement exists in order to create some allowance between the concrete barriers and the lanes the barrier separates. There will also need to be periodic pullouts or adequate shoulder to accommodate emergency stops. Signs will also be a requirement to display the message “optional truck-only lane. No other vehicles allowed” or similar. The cost of implementing this configuration will depend on the number of miles of highway for which this needs to be done, however the operational improvements could be worth the investment. It is also very affordable compared to the large-scale capital projects that are being proposed for solutions to the same problems.

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APPENDIX

Appendix A:

Traffic Flow Volumes

Table A-01. Traffic Flow Volumes at Data Collection Points

Data Collection Points (DCPs)	Westbound (veh/hr/ln)				Eastbound (veh/hr/ln)			
	Car	Single-Unit Truck	Tractor-Trailer	Bus	Car	Single-Unit Truck	Tractor-Trailer	Bus
I-40 at Parkside Drive	1045	10	125	0	852	17	156	0
I-40 at Papermill Road	811	5	44	0	913	14	110	1
I-640 at Western Avenue	556	14	99	0	977	17	58	3
I-640 at Wilson Road	789	31	97	6	1161	31	114	6
I-640 at Dutch Valley Road	844	13	81	3	1142	21	50	0
I-640 at Millertown Pike	477	20	69	0	387	9	60	0
I-40 at Asheville Hwy	475	11	137	0	708	23	103	0
I-40 East of Holston River Bridge	329	4	114	2	556	15	105	2

Appendix B:

SURVEY QUESTIONNAIRE ON TRUCK DRIVER BEHAVIOR ALONG I-40/I-640/I-75 IN THE KNOXVILLE URBAN AREA

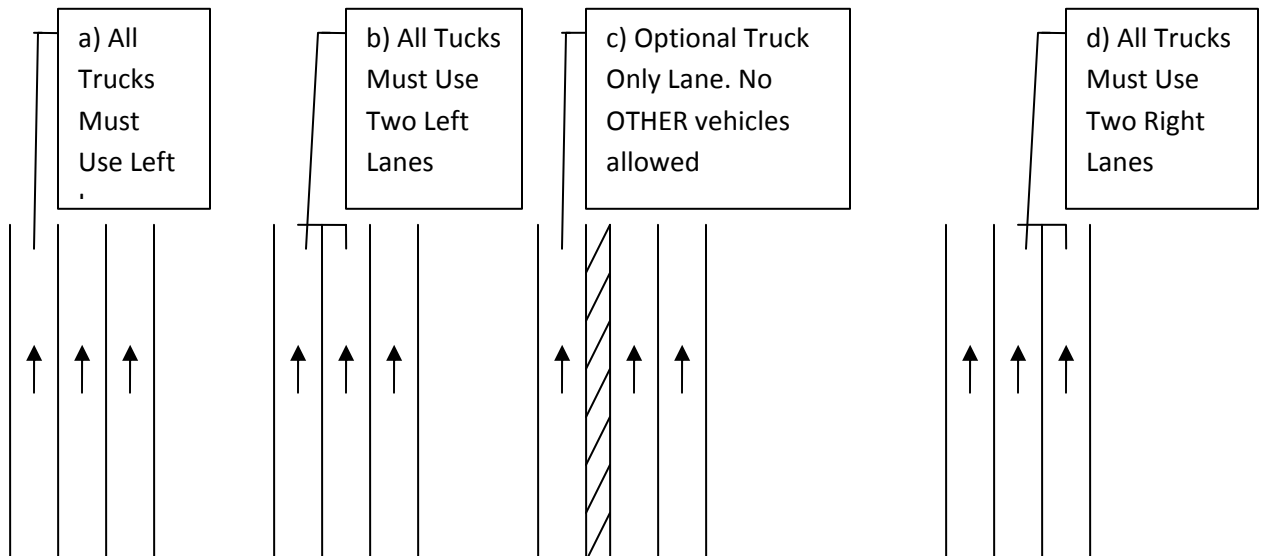
Researchers at the University of Tennessee are investigating operational improvements to the freeway system that might affect truck traffic. We would like to understand the perspective of users of the system before making any recommendations. We would like to ask a few questions and you are free to answer as many or as few as you would like. No personal identifying information is being collected. If you have questions call Dr. Chris Cherry 865.974.7710

1. Check the following that applies to your status
☐₁ Independent operator
☐₂ Driver for corporate motor carrier
2. How long have you driven trucks?
3. What is your origin and destination for this segment/load?
4. Did you/Will you stop in Knoxville? Where?

5. How often do you travel this I-40/I-640 or I-75 routes through Knoxville?

6. Do you ever encounter severe congestion in Knoxville? If so, what times?

7. Please rate the following lane configurations on a scale of **1 to 4** with 1 being unacceptable and 4 being acceptable.



8. From the previous question, why do you favor the highest scoring alternative?
-
-
9. Do you adjust your schedule or route to avoid congestion in Knoxville? If so, check the following boxes that apply?
- ☐₁ I travel earlier to avoid the peak
 - ☐₂ I travel later to avoid the peak
 - ☐₃ I take a bypass route (what route)
 - ☐₄ I don't make the trip on certain days
 - ☐₅ No I don't adjust my schedule or route to avoid congestion
10. When driving in a city, check the top two factors that reduce your **efficiency** and **safety** most significantly?
- ☐₁ Aggressive Car drivers
 - ☐₂ Car Lane Changing
 - ☐₃ Vehicles entering on-ramps
 - ☐₄ Vehicles exiting off-ramps
 - ☐₅ Slow trucks
 - ☐₆ Fast Trucks
 - ☐₇ Congestion
11. How do smaller vehicles moving at faster speeds affect your driving task? Check the box that applies
- ☐₁ Does not affect in anyway
 - ☐₂ Does not affect much
 - ☐₃ Affects minimally
 - ☐₄ Makes my driving task uncomfortable
 - ☐₅ Makes my driving task very difficult
12. How much would you be willing to pay to save **ten** minutes by avoiding congestion through Knoxville? _____

Date:

Time:

Location:

Vita

Adebola Adelokun was born in Lagos, Nigeria. He received a Bachelor's degree in Civil Engineering Technology from Southern Polytechnic State University in Marietta, Georgia in July, 2007. During his undergraduate career, he participated in a cooperative education program (Co-Op) with the Georgia Department of Transportation where he worked for three semesters. He also worked with Wolverton and Associates, Duluth, Georgia as a transportation engineering intern. His work at these two firms range from a research project on nuclear gauge calibration to highway design. In August 2007, he started his Masters program in Civil Engineering with a focus in transportation at the University of Tennessee, Knoxville, Tennessee. He worked as a graduate research assistant for the Southeastern Transportation Center under the supervision of Dr. Christopher Cherry. In the summer of 2008, he worked at Moreland and Altobelli, Inc., Norcross, Georgia in highway design. He is a member of the Institute of Transportation Engineers.

This thesis completes his requirements to receive a Master of Science degree in Civil Engineering, with a concentration in Transportation Engineering awarded in December 2008.