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16. Abstract

Trucks constitute a large and growing segment of the traffic on Texas highways. In order to manage this growth, the Texas Department of Transportation needs to consider special or unique treatments for trucks such as truck lane restrictions, exclusive truck lanes, and exclusive truck facilities. This research addressed this topic for the state of Texas by developing tools for evaluating needs for special truck facilities, developing a truck route system, and developing recommendations for demonstration of a pilot system. Tasks required to accomplish these objectives began with a comprehensive literature review, to include the major corridor studies and an evaluation of special truck facilities implemented outside of Texas. The research then established criteria for each of the three levels of truck treatments, developed a plan to classify truck facilities, and developed an evaluation framework for these facilities. Based on these tasks, the research then investigated techniques for evaluating levels of service on truck facilities. The techniques were then applied to selected candidate corridors to demonstrate their utility. Finally, the research developed an action plan for implementation of the exclusive truck facilities.

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STRATEGIES FOR SEPARATING TRUCKS FROM PASSENGER VEHICLES: FINAL REPORT

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DISCLAIMER

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CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

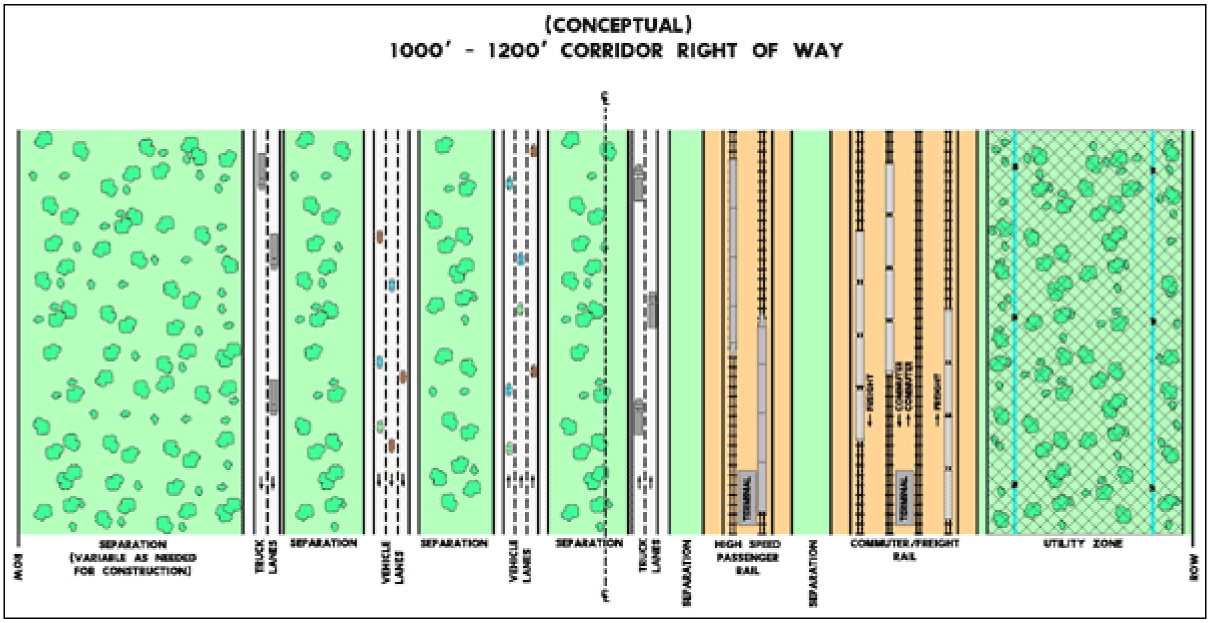
Truck traffic on Texas roadways has grown to the point that special treatments may be required to safely accommodate heavy vehicles. Trucks travel more than 196 million miles on U.S. highways each year, carrying more than 1 trillion tons of freight. Truck traffic is predicted to grow 2.6 percent annually, with no relief in sight for congested roads *(1)*. The crowded roadway conditions test drivers' patience and skills, and the results can be deadly. 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 *(1)*. The U.S. Department of Transportation (USDOT) has set an ambitious goal of a 50 percent reduction in truck-related crashes by the end of this decade. Meeting that goal will involve finding ways of improving the performance of all elements of the system – the driver, the roadway, and the vehicle. This research deals with the roadway aspect, by defining tools that will evaluate the need for special truck facilities and a truck network.

Deregulation of the trucking industry, the passage of the North American Free Trade Agreement (NAFTA), reductions in rail service, growth in time-sensitive freight and, until recently, a robust economy have greatly impacted the number of trucks on the nation's roadways. The increased trade between Mexico and the United States has already begun to impact the Texas roadway infrastructure. The number of trucks that crossed from Mexico into the United States grew from 2.7 million in 1994 to almost 4.5 million in 6 years, a 66 percent increase.

In Research Project 0-4364, TTI developed an evaluation process using average annual daily truck traffic (AADTT), which is a parameter defined by total annual truck traffic divided by 365 *(2)*. In that study, TTI defined a "truck" as anything that was Class 3 or higher simply because of how TxDOT data were compiled. However, the primary focus of Research Project 0-4663 is trucks Class 5 and above (single-unit and combination vehicles with three or more axles).

When considering the major truck corridors in Texas, one must include the very ambitious Trans Texas Corridor (TTC) project. This project is one of the most revolutionary ideas for transportation in Texas and one of the largest engineering projects ever proposed. It is a concept that will connect Texas and other states with a 4000-mile network of corridors up to 1200 ft wide with separate lanes for passenger vehicles (three in each direction) and trucks (two in each direction). The corridor as currently conceived will also include six rail lines and will also have a 200-ft wide dedicated utility zone. Figure 1 indicates the general layout of these facilities. The truck lanes and separate truck roadways would have the following geometric and structural features:

- 13 ft lane width (versus 12 ft for the passenger lanes),
- 12 ft outside shoulder width (versus 10 ft),
- 4 ft inside shoulder width (versus 10 ft),
- 80 mph operating speed on tollways, and
- significant load-carrying capacity on truck lane pavements only.



Source: Reference *(3)*.

Figure 1. Concept Plan View of the Trans Texas Corridor.

The two primary corridors under consideration in 2005 are the I-35 and the proposed I-69 corridors. The TTC-35 will generally parallel the existing I-35, while the proposed I-69 will parallel the existing U.S. 59. The TTC will connect major cities while not sending traffic directly through them, being developed in phases through several scenarios. For example, the truck lanes (two in each direction) might be built first and shared initially by both cars and trucks. As traffic volumes increase and additional capacity is warranted, separate passenger lanes would be constructed so that cars and trucks would then be separated on their own roadways *(3)*.

Even though much of the information in this report will apply to the TTC, one of the distinctions which should be made is that the TTC will probably be a toll road, and if separate truck facilities are built as part of the TTC they, too, will be toll facilities. The procedures in this report use some typical planning procedures which do not necessarily apply to toll roads. This project does not analyze the change in demand that may occur if truck facilities require a toll.

At the beginning of this research activity, researchers focused attention on three truck treatments: lane restrictions, dedicated or exclusive truck lanes, and truck roadways. As more information was gathered, the TxDOT advisors elected to minimize attention given to dedicated truck lanes. The initial portion of this report includes all three treatments; their descriptions follow.

- Lane restrictions: Trucks are restricted to and/or from specified lanes. Other vehicles may travel in any lane including lanes with trucks.

- Dedicated or exclusive truck 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 main lanes by barriers.

- Truck roadways, truckways, or exclusive truck facilities: Trucks use a facility that is designated for their use only. These lanes are generally separated from the non-truck lanes by barriers or medians.

1.2 OBJECTIVES

This research will address the topic of truck treatments for the state of Texas through the following specific objectives:

- develop tools for evaluating the need for special truck facilities,

- develop a truck roadway network, and

- develop recommendations for demonstration of a pilot system.

1.3 ORGANIZATION OF THE REPORT

Chapter 2 presents the literature findings pertaining to a variety of truck treatments. Chapter 2 uses these literature findings and researcher experience to determine a preliminary set of criteria to determine the conditions warranting truck treatments. Chapter 3 describes the use of simulation software to develop capacity and level of service criteria for truck-only freeway facilities. It also utilizes crash data from a facility in the United States to compare crash rates on mixed flow lanes with that of car-only lanes. Finally, it investigates some of the primary cost issues related to truck roadways. Chapter 4 establishes a plan based initially on truck and non-truck volume to classify truck roadways across the state of Texas. Chapter 5 is an evaluation framework to facilitate stepping through an analysis to evaluate the factors essential to determining the need for truck roadways. Chapter 6 further elaborates on some of the topics in Chapter 5 by providing truck facility analysis tools. Chapter 7 is an action plan for research implementation, concluding with a summary of corridor segments which appear to warrant truck roadways in the next 20 or 30 years. Appendix A is a cost estimate for two-lane truck roadways. Appendix B contains graphical results for the truck level of service analysis. Appendix C contains delay and fuel cost results. Appendix D has tables of crash details for the three case studies. Appendix E provides guidance on the use of CORSIM to evaluate truck roadways.

CHAPTER 2. LITERATURE REVIEW

2.1 INTRODUCTION

The issue of increasing truck traffic is a focal point for both traffic managers and the general public. The characteristics that matter most to the driver are safety, speed of travel, comfort, and convenience. The size and operating characteristics differential between trucks and passenger cars creates an intimidating psychological barrier, if not an actual barrier. Trucks have slower braking and acceleration rates than passenger cars, which increase frustration to drivers in congested situations. Additionally, the lack of maneuverability of trucks relative to passenger cars contributes to crashes *(4)*. Due to the large size and weight of trucks, truck crashes generally result in more severe injuries than crashes that do not involve trucks. Truck crashes also receive greater publicity.

Truck growth on Texas roadways is now at the point that special treatments may be required to safely accommodate heavy vehicles. Table 1 summarizes the characteristics of treatments that might be considered. Following the table, the organization of material covers background materials found in the literature. This first section is organized by truck treatment (listed in Table 1):

- lane restrictions,
- exclusive truck lanes,
- exclusive truck facilities,
- reserve capacity lanes,
- bypass facilities,
- dual facilities,
- multimodal capacity improvements,
- time of day restrictions,
- route restrictions, and
- speed restrictions.

The next section contains information about special corridor studies such as the I-35, I-69, and I-10 studies in Texas and some non-Texas corridor studies. The chapter culminates with information from the literature on criteria for decision-makers to determine when to consider special truck treatments.

Table 1. Summary of Special Truck Treatments.

Special Truck Treatment	Description	Examples
Lane Restriction	Trucks are restricted to specified lanes. Other vehicles may travel in any lane. Restricted lanes are not separated from mainlanes.	Capital Beltway, Virginia; Houston, Texas; California
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 mainlanes.	None implemented in U.S.
Exclusive Facilities	Trucks use a facility or lanes that are designated for their use only. These lanes are generally separated from the mainlanes by barriers or medians.	No freeway examples implemented in 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 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, Georgia
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

2.2 METHODOLOGY

The information gathered for this chapter came from a review of the literature and gathering of information pertaining to major corridor studies which have been conducted in the past five or so years. For the literature search, TTI used key words and phrases such as exclusive truck facilities, truck lane restrictions, truck lanes, truck roadways, motor carriers, capacity, and level of service. A researcher then reviewed the selected documents and used the ones that were most appropriate.

The major corridor studies also came partly from references in the literature or from researcher knowledge of these activities. The Texas corridor studies were especially useful, including the I-35, I-69, and I-10 studies. Of the studies conducted outside the state, the I-81 study in Virginia and California studies were especially helpful.

2.3 SPECIAL TRUCK TREATMENTS

2.3.1 Lane Restrictions

Lane restrictions are a management strategy that limits certain types of vehicles to specified lanes. These restrictions can take the form of time-of-day restrictions, peak period bans, or route restrictions. The most common type of lane restriction addresses truck traffic. A large presence of trucks, both in rural and urban areas, can degrade the speed, comfort, and convenience experienced by passenger car drivers. Some states, to minimize these safety and operational effects, have implemented truck lane restrictions or have designated exclusive truck lane facilities. In 1986, the Federal Highway Administration asked its division offices to conduct a survey and report on experiences encountered by states with lane restrictions. This survey indicated a total of 26 states used lane restrictions. The most common reasons for implementing lane restrictions were:

- improve highway operations (14 states),
- reduce crashes (8 states),
- pavement structural considerations (7 states), and
- restrictions in construction zones (7 states).

Some states provided more than one reason for the restriction *(5)*. Various jurisdictions have implemented lane restrictions in numerous situations; however, they have collected little data to document the actual effectiveness of the strategy.

In 1984, McCasland and Stokes examined truck traffic characteristics and problems on Texas urban freeways *(6)*. The study evaluated six different truck restrictions and regulatory practices using information obtained from a literature review and a survey of state policies. The strategies examined were lane restrictions, time-of-day restrictions, speed restrictions, route restrictions, driver licensing and certification programs, and increased enforcement of existing regulations. Results indicated that restricting truck traffic to one mixed-flow lane would probably not improve freeway safety or operations based on associated constraints and limitations. The authors also concluded that only reduced speed limits for all vehicles, improvement of driver licensing/training, and incident management techniques appear capable of producing substantial improvement in the safety and operational aspects of truck usage of urban freeways in Texas. However, all assessments and recommendations are based on findings of the literature review and state policy survey *(6)*.

One area of particular concern when implementing truck restrictions on urban freeways is the creation of a "barrier effect" in weaving areas. Weaving areas are segments of freeway formed by a diverge area that closely follows a merge area. Operationally, weaving areas are of concern because the "crossing" of vehicles creates turbulence in the traffic streams. When trucks are restricted to the rightmost lanes of a freeway and are of significant numbers, a barrier composed of trucks can form next to the weaving areas. Trucks limit the visibility and maneuverability of smaller vehicles attempting to enter and exit the freeway system. An indication of the barrier effect is an over-involvement of trucks in weaving area crashes, rear-end collisions, and side collisions. Some studies have shown that this problem may be magnified when a differential speed limit is present *(6, 7)*.

2.3.1.1 Capital Beltway Lane Restriction

The Highway and Traffic Safety Division of the Virginia Department of Transportation (VDOT) conducted a study of crashes, speeds, and volumes for one year prior to implementation of lane restrictions on I-95 (the Capital Beltway). The objective of the before/after study was to assess the impact of the truck restriction on this segment of I-95 by comparing traffic volume, speed, and crash data prior to the restriction with those during the restriction *(8)*. Findings indicate that the lane restriction caused a redistribution of trucks in the non-restricted lanes while passenger vehicles using the left lanes increased slightly. An opinion survey of drivers indicated that the majority of users of the Beltway support a truck-free lane.

The number of crashes along the restricted area of the Beltway remained constant. However, the crash rate declined slightly with the restriction, and there was a 20 percent reduction in injury crash severity. It should be noted that the 20 percent reduction in crash severity is actually only a reduction of injury crashes by eight (41 versus 33). Property-damage-only crashes increased during the time period by nine (60 versus 69). Therefore, the reduction is probably insignificant. The overwhelming public support for the restriction and the perception of the benefits, in conjunction with the slight reduction in crash rates, resulted in a recommendation that the truck lane restriction be maintained *(8)*.

Follow-on studies of the Virginia I-95 data continued to evaluate crashes, speeds, and volumes to determine the effects of the restriction *(9, 10)*. In 1987, the Traffic Engineering Division of VDOT updated the initial 1985 Capital Beltway study. This update determined that the crash rate increased 13.8 percent during the restriction; however, there was no change in fatal and injury crash severity. Traffic volume increased nearly 8 percent during the time the restriction was in place. The only significant change for the segment was the lane restriction. The crash rate for the section consisting of the I-95, I-495, and I-395 interchange was the primary contributor to the overall crash rate increase. Analysis of the crashes in that section indicated a change in distribution by lane of occurrence, type of maneuver, and collision type during the restriction. Although the data showed an increase in crash rates, there was no change in fatal or injury crash severity. This maintenance of crash severity level along with various intangible benefits such as favorable public perception and continuity of the lane restriction with Maryland resulted in a recommendation to retain the restriction *(9)*.

The Traffic Engineering Division of VDOT issued a final study update in June 1989. This study included the results of a field study of interchange ramps and loop geometry. The purpose of the field study was to determine if the posted maximum safe speed was appropriate for the existing superelevation. VDOT then analyzed the crash frequency and characteristics to determine the interface between drivers, vehicles, and roadway condition. Finally, the study team performed an exploratory evaluation of the Northern Virginia (NOVA) Freeway Management Team *(10)*.

An analysis of the data showed that the crash rate increased for trucks on southbound I-95 during the truck lane restriction. The four most prevalent factors in crashes involving trucks were: weather/visibility, vehicle defect, speeding, and road defect. Trucks were involved in 49 percent of the sideswipe collisions and 16 percent of the rear-end collisions *(10)*.

2.3.1.2 Demonstration of Truck Lane Restrictions in Houston

In an effort to improve truck safety on Houston freeways, the City of Houston decided to conduct a demonstration project restricting trucks from traveling in the left lane in 1999. TxDOT and TTI developed the demonstration project, which consisted of an 8-mile section of the I-10 East Freeway between Waco and Uvalde Streets. The criteria used for site selection included a requirement that the site be a radial freeway section within the city limits of Houston, that the minimum length of the section be 6 miles, and that the truck volume be at least 4 percent *(11)*.

TTI researchers monitored and evaluated the restriction for the duration of the demonstration project. In September 2001, the TTI research team published a report which described the monitoring, evaluation, and findings of the study. The research team monitored the following areas: compliance, enforcement, crash records, freeway operations, public perception, and status of the project. The team reported that compliance rates for the restriction were between 70 and 90 percent. The team also found that vehicle crash rates were reduced during the 36-week monitoring period, although several factors including increased enforcement may have contributed to that reduction. Traffic studies conducted during the evaluation revealed that there was no significant impact on freeway operations, travel time, frequency of lane changes, or traffic patterns. Public opinion was extremely positive, with 90 percent of automobile users in favor of the restriction *(11)*.

A TTI research team is currently conducting a project to further study lane restrictions and their effects on traffic operations and safety. The TxDOT research project titled *Evaluation of Vehicle Restrictions in Texas* is a two-year study that began in 2003 *(12)*. The project work plan includes a task to quantify the impact on safety of lane restrictions. The project will compare lane restrictions with increased enforcement with lane restrictions using “normal” enforcement.

2.3.2 Exclusive Truck Lanes

The operational strategy of exclusive truck lanes provides certain vehicles, usually designated by vehicle type, an exclusive operational lane. Typically, this strategy separates trucks in an attempt to decrease their effects on safety and to reduce conflicts between cars and trucks. The separation of trucks from passenger cars utilizes operational lanes rather than a physical barrier. These lanes may also use the name reserved capacity truck lanes. Exclusive truck lanes, possible lane configurations, and feasibility of implementation have been the subject of numerous past studies.

Janson and Rathi performed a study in 1990 examining the feasibility of designating exclusive lanes for vehicles by type *(13)*. This study ultimately resulted in a computer program known as exclusive vehicle facilities (EVFS). EVFS, also called the Oak Ridge model, evaluated exclusive lane use feasibility by utilizing the following lane use possibilities:

- mixed vehicle lanes – lanes utilized by all vehicles,
- light vehicle lanes – lanes utilized only by motorcycles, automobiles, pickup trucks, light vans, buses, and trucks weighing less than 10,000 pounds, and
- heavy vehicle lanes – lanes utilized only by single unit trucks weighing more than 10,000 pounds and all combination vehicles.

The authors designed an analysis format that could evaluate the economic feasibility of exclusive lanes for specific sites on high-volume, limited access highways in both urban and rural areas. In order for a highway to be considered, three or more lanes in one direction must be available. The format of the program considered potential benefits and costs, including travel time savings, vehicle operating cost savings, reduced crash costs, travel delay savings, initial construction costs, right-of-way costs, pavement resurfacing costs, and maintenance costs. The program then calculated net present worth, benefit-cost ratio, and other facility performance measures. The design resulted in five possible options with three options employing designated lane usage or vehicle facility alternatives.

- Option 1: Do nothing.
- Option 2: Designate existing lanes for mixed, light, and heavy vehicles.
- Option 3: Add mixed vehicle lanes.
- Option 4: Add nonbarrier separated lanes and designate the usage for both new and existing lanes.
- Option 5: Add barrier separated lanes and designate usage for both new and existing lanes.

Janson and Rathi also found that exclusive barrier-separated facilities were most plausible for congested highways when the following three factors exist: truck volumes exceed 30 percent of the vehicle mix, peak-hour volumes exceed 1800 vehicles per lane-hour, and off-peak volumes exceed 1200 vehicles per lane-hour *(13)*.

In 1996, a series of studies evaluated the strengths and weaknesses of the EVFS program as an analytic tool for transportation planners. Vidunas and Hoel conducted a study that applied the program to a 31.5-mile segment of I-81 in Virginia *(14)*. The authors concluded that there were four basic exclusive vehicle strategies provided by the EVFS program. Each of these strategies can be implemented using either a barrier or non-barrier separated design.

- inside lane: light vehicles only,
- inside lane: heavy vehicles only,
- outside lane: light vehicles only, and
- outside lane: heavy vehicles only.

Vidunas and Hoel found that the EVFS program was a valuable analytic tool that provides transportation planners with useful decision-making information. The authors also noted that the most difficult part of performing an economic evaluation of a strategy such as exclusive lanes is accounting for all of the costs and savings that accrue over the life span of the measure *(14)*.

In a concurrent study Wishart and Hoel examined problems with mixed vehicle traffic and the four truck traffic strategies described in the EVFS program *(15)*. The study considered a number of variables with safety, highway operations, and pavement deterioration being the dominant factors. The authors found that mixed vehicle travel is associated with higher risk, especially for the occupants of smaller or lighter vehicles, and that one contributing factor for crashes is the difference in operating characteristics of trucks and passenger cars. Wishart and Hoel concluded that when properly implemented, adequately publicized, and sufficiently enforced, truck traffic strategies could effectively increase safety, improve traffic operations, and decrease the pavement deterioration rate on interstate highways. The benefits considered in the study included savings in travel delay and reduced vehicle operations costs. The study also found decreased environmental impact from exhaust and fuel consumption, as well as injury and property damage savings from reduced crashes. Costs included engineering costs, construction costs, right-of-way acquisition costs, signage, enforcement costs, and increased maintenance *(15)*.

2.3.3 Exclusive Truck Facilities

Exclusive truck facilities offer lanes for trucks that are generally separated from mainlanes. These lanes are designated for use only by trucks and may not be utilized by other vehicles. In 1986, a research study by TTI examined the feasibility of an exclusive truck facility for a 75-mile segment of I-10 between Houston and Beaumont *(16, 17)*. The options considered in the study included: the construction of an exclusive truck facility within the existing I-10 right-of-way; construction of an exclusive truck facility immediately adjacent to I-10 outside of the existing right-of-way; or construction of an exclusive facility on, or immediately adjacent to, an existing roadway that parallels I-10 (U.S. 90). The studies concluded that existing and future trends in traffic volumes did not warrant an exclusive facility along the I-10 corridor.

Theoretically, truck facilities could have positive impacts on noise and air pollution, fuel consumption, and other environmental issues. Creating and maintaining an uninterrupted flow condition for diesel-powered trucks will result in a reduction of emissions and fuel consumption, when compared to congested, stop-and-go conditions. However, the creation of a truck facility may also shift truck traffic from more congested parallel roadways, thereby shifting the environmental impacts. There may also be increases in non-truck traffic on automobile lanes due to latent demand. The high initial capital cost of an exclusive facility also hinders implementation of exclusive facilities as a practical treatment. Feasibility studies for exclusive truck lanes have also occurred in Virginia, California, United Kingdom, and the Netherlands *(18)*.

One example of a proposed exclusive facility from the 1980s is the Bologna-Firenze Freeway. The proposed facility was the result of concerns about increasing traffic flow, congestion, and a 40-mph cap on truck speeds. Italian engineers designed exclusive truck facilities to bypass areas with the greatest congestion problems. The Bologna-Firenze Freeway was to be a direct link between Northern and Southern Italy *(18)*. However, to date, neither the Bologna-Firenze Freeway nor the other proposed exclusive facilities have been implemented.

2.3.4 Reserve Capacity Lanes

The reserve capacity lane treatment provides access for trucks to reserve capacity lanes such as high occupancy vehicle lanes in order to relieve mainlane congestion.

In 1996, Trowbridge et al. considered the impacts that would occur from providing trucks reserved capacity lanes that were in some cases separate from general traffic or allowing trucks access to HOV lanes *(19)*. The authors referenced a study by BST Associates in 1991 that found that trucks generally made up less than 5 percent of average daily traffic in urban areas and that an undue amount of effort was used devising strategies to restrict and manage this small portion of total traffic *(20)*. In lieu of strategies restricting truck traffic, the authors proposed allowing trucks access to reserve capacity lanes (high occupancy vehicle lanes) in order to relieve congestion.

The reserve capacity lanes consisted of two options for roadways in the Seattle area. The first option permitted heavy trucks to use existing HOV lanes, while the second option added a lane for the exclusive use of trucks on all facilities that had an existing or planned HOV lane. The authors attempted to determine the impacts of these options on vehicle travel time and vehicle miles traveled for single-occupant vehicles (SOVs), HOVs, and trucks. The authors collected traffic data and performed a traffic simulation and an estimate of the economic impacts of this type of strategy *(19)*.

When Trowbridge et al. investigated the possibility of using reserved capacity lanes as exclusive truck lanes in the Seattle area, they examined the benefit and cost of the strategy *(19)*. Based on current traffic data and simulation, the following economic impacts resulted:

- estimated $10 million in savings in truck travel time,
- estimated time savings of 2.5 minutes per average trip (this is less than an 8 percent savings of an average trip), and
- estimated $30 million in savings for SOVs.

The economic analysis reflected increased pavement deterioration in the reserved capacity lane and decreased pavement deterioration in other lanes. The net effect would be a modest overall increase in cost due to pavement deterioration and the consequent increased maintenance. To date, this type of treatment has not been implemented.

2.3.5 Bypass Facilities

A bypass facility is a treatment for a specific section or segment of roadway. This management strategy has been successfully used in several areas and often addresses a roadway segment that has the following characteristics: weaving area, a significant grade, high percentage of truck traffic, and/or congestion. Weaving areas are segments of freeway formed when a diverge area closely follows a merge area. Operationally, weaving areas are of concern because the "crossing" of vehicles creates turbulence in the traffic streams. Trucks limit the visibility and maneuverability of smaller vehicles attempting to enter and exit the freeway system. An indication of the barrier effect is an over-involvement of trucks in weaving area crashes, rear-end collisions, and side collisions. Some studies have shown that this problem may be magnified when a differential speed limit is present *(6, 7)*.

There are four truck-preferred interchange bypass facilities in the Los Angeles area:

- at I-5/I-405 in Orange County,
- at I-405/I-110,
- at I-5/I-405 north of Los Angeles in the San Fernando Valley, and
- a 2.4-mile bypass of I-5 in the vicinity of SR-14 and I-210.

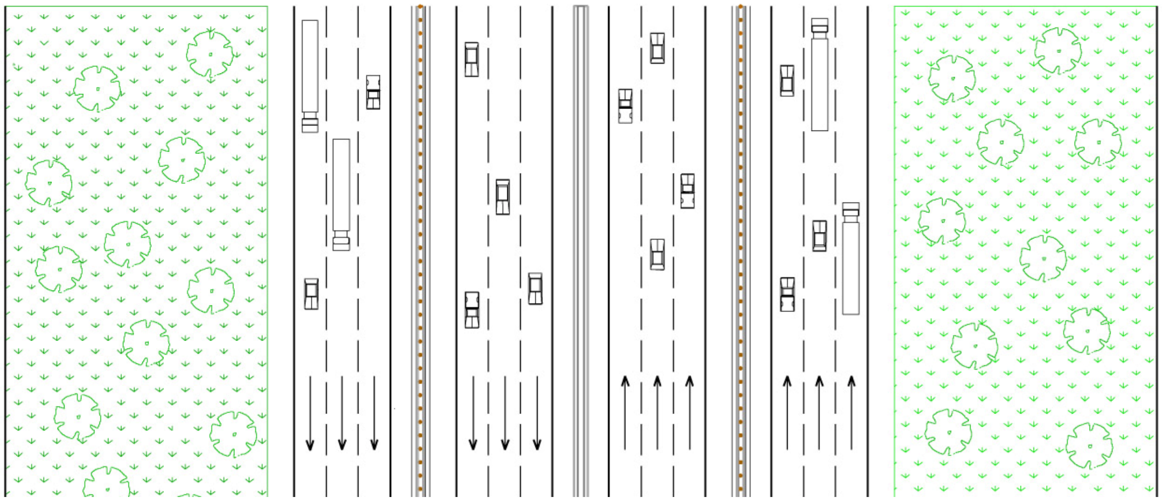
All of these bypass facilities separate heavy flows of trucks from other traffic to minimize the impact of grades or other features that would otherwise create operational and safety problems. Although these facilities were built for trucks to bypass interchanges, automobiles and other vehicles also use the lanes in order to avoid the weaving sections *(21)*.

Detailed information regarding the construction cost of the bypass lanes was unavailable. However, the reason cited by Caltrans engineers for building the truck bypasses was to reduce weaving problems. The truck bypass lanes have received mixed reviews; many passenger car drivers use them instead of going through the interchange in order to avoid weaving. Truck drivers would prefer to restrict the bypass lanes to trucks only due to differences in vehicle operating characteristics and because of an apparent lack of understanding by auto drivers of truck operating characteristics *(21)*.

A truck bypass facility exists on a section of northbound I-5 near Portland, Oregon, at the Tigard Street interchange; it is similar to some of the California facilities. The bypass lane requires trucks to stay in the right lane, exit onto a truck roadway, and re-enter the traffic downstream of the interchange. Passenger cars are also allowed to use the bypass facilities, so this facility fits the description of a truck-preferred facility. One reason this facility is needed is a significant grade on the main lanes of I-5. Without the truck roadway, larger vehicles would be forced to climb a grade and then weave across faster moving traffic that is entering the main lanes from their right. The resulting speed differentials caused by trucks performing these maneuvers created operational as well as safety problems prior to the implementation of the bypass facility. Truck speeds are now typically 50 mph in the merge area; whereas prior to implementation of the bypass lane, truck speeds were 20 to 25 mph. Observations of trucks traveling northbound indicated that nearly every truck uses the truck bypass with little or no need for enforcement *(21)*.

2.3.6 Dual Facilities

A dual facility is a special treatment strategy that consists of a facility that has both an inner and outer roadway in each direction. The inner and outer roadways are physically separated. The inner roadway is reserved for light vehicles or cars only, while the outer roadway is open to all vehicles. The New Jersey Turnpike has a 35-mile segment that consists of interior (passenger car) lanes and exterior (truck/bus/car) lanes within the same right-of-way. For 23 miles, the interior and exterior roadways have three lanes in each direction. Figure 2 shows a typical cross-section of the dual-dual portion of the turnpike. On the 10-mile section that opened in November 1990, the exterior roadway has two lanes, and the interior roadway has three lanes per direction. Each roadway has 12-ft lanes and shoulders, and the inner and outer roadways are barrier-separated. The mix of automobile traffic is approximately 60 percent on the inner roadways and 40 percent on the outer roadways *(21)*.



Source: Reference (2).

Figure 2. Typical Cross-Section of Dual-Dual Roadway.

The separated facilities, which are also referred to as dual-dual segments, were implemented to relieve congestion. Other truck measures that have been implemented on the turnpike are lane restrictions and ramp shoulder improvements. The New Jersey Turnpike Authority (NJTA) was one of the first jurisdictions to impose restrictions for trucks. The restriction implemented in the 1960s does not allow trucks in the left lane of roadways that have three or more lanes by direction. On the dual-dual portion of the turnpike from Interchange 9 to Interchange 14, buses are allowed to use the left lane. The resulting effect is that the left lane becomes a bus lane with the right lane(s) occupied by trucks. The NJTA rates compliance for truck lane restrictions as high *(21)*.

2.3.7 Multimodal Capacity Improvements

The multimodal capacity improvement treatment combines two or more transportation modes. The two modes most often combined are roadway and railway operations. Through trucks enter a rail terminal and are loaded on a rail car for transport by rail through an extremely difficult or congested segment of roadway. Environmental quality, safety, and capacity for the problem segment are improved by using the multimodal approach operations

One multimodal treatment currently being constructed is the Alp Transit St. Gotthard in Switzerland. This treatment addresses the segment of roadway that traverses the Swiss Alps. This segment of the European transportation system has seen dramatic growth in the past 20 years, with the amount of road traffic through the Alps doubling every eight years. A study by the European Union Commission on trade forecasts a 75 percent increase in goods traffic by 2010 *(22)*.

The Alp Transit Gotthard (ATG), a subsidiary of the Swiss Federal Railway, is carrying out the detailed planning, design, and construction of the new alpine traversal railway track, the Gotthard axis, which has new base tunnels at Gotthard, Zimmerberg, and Ceneri. The Gotthard base tunnels will be 35.4 miles long. When completed, the parallel tunnels will house high-speed rail for both passengers and goods. The high-performance goods trains, which will have a roll-on-roll-off capability, will travel at speeds of 99 mph *(22)*.

2.3.8 Time-of-Day Restrictions or Peak Period Bans

Time-of-day bans or restrictions prohibit or restrict trucks from a specific route during a specific time period. In the past, there have generally been two types of time-of-day restrictions for trucks: restrictions that prohibit travel during peak or daylight hours and restrictions that prohibit travel during the hours of darkness. Most time-of-day restrictions are safety oriented and are directed at oversize/overweight trucks. The implementation authority is usually the state transportation agency. California is the exception, as the California Highway Patrol also has the authority to implement time-of-day restrictions *(23)*.

A peak-period ban, on the other hand, bans trucks from travel on certain routes during peak periods. Cambridge Systematics found that peak-period truck bans on freeways would temporarily reduce congestion on core freeways; however, congestion would correspondingly increase on parallel arterial routes. Although the authors judged that peak-period truck bans would not be legal under the federal Surface Transportation Assistance Act of 1988, possible impacts of bans were examined due to the favorable perception of bans by the media and general public. The study found that the ban, which would cost the Los Angeles study site alone $22 million in direct costs, would improve speeds slightly on freeways, but adjacent surface street speeds would drop. The estimated reduction in total California business sales due to a peak-period ban was $27 million *(24)*.

2.3.9 Route Restrictions

Route restrictions implemented by state and local jurisdictions in an attempt to increase safety and operational effectiveness may take several forms. The most prevalent forms of route restrictions and their objectives are:

- Freeway section bans would ban truck traffic from designated sections of freeways. The objective of a freeway section ban is to eliminate or reduce truck traffic on specific freeway sections due to congestion, high numbers of accident severity, and incident reduction.

- Route diversions would divert trucks from specific freeway sections to other routes, which are reasonable alternatives. The objective of the route diversion is to divert the majority of trucks from specific freeway sections to suitable alternative routes, thereby decreasing congestion, accidents, and incidents.

- Access routing would selectively designate access routes from the Surface Transportation Assistance Act (STAA) network. The objective of access routing is to shift truck traffic to specified routes between STAA highways and terminals.

- Local ordinances would restrict truck movements on local streets based on size, weight, safety, and noise. The objective of local ordinances is to restrict truck access within a localized area or jurisdiction to minimize noise and safety impacts.

- Hazmat restrictions would place restrictions, based on safety, on trucks carrying hazardous materials. The objective of hazmat restrictions is to control the movement of hazardous materials to provide safety and reduce incidents *(24)*.

Most route restrictions currently in place apply to routing hazardous materials carriers or oversize/overweight trucks. The restrictions route the trucks around population centers or to avoid hilly terrain, toll roads, bridges, and tunnels. General route restrictions for hazardous materials, oversize/overweight, or for a specific segment of road due to a design or geometric feature such as a tunnel are not addressed in the following sections. State transportation agencies usually have the authority to implement these route restrictions by existing legislation. The State of California, however, allows both the California State Highway Patrol and the transportation agencies to implement restrictions. In all cases, suitable alternate routes must be available *(23)*.

2.3.10 Speed Restrictions

Speed restrictions require all trucks or specified trucks to travel at lower speeds than the rest of the traffic stream. Currently, a number of states have differential speed limits for trucks and other vehicles. The speed limit differentials vary from 5 mph to 10 mph, with truck speeds always being the lower speed *(23)*.

Garber and Gadiraju used simulation to study the effects of implementing different strategies on multilane highways. These strategies included differential speed limit (DSL) for trucks, truck lane-use restrictions, and a combination of DSL and lane-use restrictions. Trucks were defined as vehicles having six or more wheels in contact with the road and having a gross vehicle weight greater than 10,000 pounds. The research evaluated and compared the impacts of the strategies, and the final report presented the changes in flows, speeds, headways, and accidents that were significant *(25)*.

The authors concluded that no safety benefits resulted from the imposition of any of the strategies examined. The study results suggested the potential for increased crash rates, particularly when imposing the strategies on highways with high volumes and a high percentage of trucks. The results also indicated that the combination of lower speed limits for trucks and right lane restriction of trucks resulted in a slight, but statistically insignificant, increase of accidents in the right lane *(25)*.

The Department of Civil Engineering at the University of Maryland evaluated the effectiveness and desirability of differential speed limits on the Maryland interstate system. The department collected vehicular speed and crash data at 84 study sites, encompassing a variety of geometric designs and locations with and without truck DSL. The study concluded that no consistent and reliable relationship existed among speed parameters and crash rates, and that there is generally poor compliance by all vehicles with posted speed limits. Locations with higher operating speeds exhibited a decrease in the number of trucks involved in rear-end collisions. Increasing truck speeds (effectively removing the DSL) reduced the truck crash rate. Overall, the study found no consistent and reliable relationship among speed parameters and crash rates *(26)*.

2.4 MAJOR CORRIDOR STUDIES

In order for special treatments to have an effective impact on operations and safety, the responsible agency should implement treatments by corridor rather by site or location. This systems approach provides continuity and prevents the implementation of conflicting restrictions in adjacent jurisdictions and municipalities. The corridor approach to implementing special treatments for truck accommodations as well as other operational treatments has increased in recent years. Lane restrictions, exclusive lanes, exclusive truck facilities, reserved capacity lanes, and dual facilities are especially well suited for the corridor approach. California, Virginia, and Florida are considering the corridor approach in application of special treatments. Corridors that may be potential candidates for truck treatments in Texas are the I-35 corridor, the soon to be established I-69 corridor, and the I-10 corridor. The following sections examine various treatments considered for application on corridors with substantial truck traffic.

2.4.1 I-81 in Virginia

Interstate 81 (I-81) is the longest interstate in Virginia with a length of 325 miles and 90 interchanges. I-81 begins in Dandridge, Tennessee, at the intersection of I-40 and extends through New York state to the United States-Canada border. Construction on I-81 began in Virginia in 1957, with its full length opening to traffic in 1971. Table 2 indicates 2002 average annual daily traffic (AADT) on sections of I-81. The cited reference did not provide actual numbers of trucks, only percent ranges. The right-most column shows resulting numbers of trucks based on the percentages. The AADT more than doubled in some areas along I-81 from 25,000 vehicles in 1980 to more than 50,000 vehicles in 2000. It is expected to double again in the next 20 years. Though mostly a rural corridor, I-81 is one of the top eight truck routes in the United States. The highway was designed for 15 percent truck traffic, but trucks now account for 20 percent to 40 percent of the traffic *(27, 28)*.

A press release issued on November 20, 2003, indicated that a bill released the day before in the U.S. House of Representatives proposed $1.5 billion in federal funding over six years for projects that create dedicated truck lanes. HR 3550, the Transportation Equity Act – A Legacy for Users, will create a new program “to improve the safe and efficient movement of freight by separating truck traffic from traffic in regular lanes” *(29)*. Rep. Don Young, Alaska Republican and chairman of the House Transportation Committee, submitted the legislation after expressing interest in making I-81 a national pilot project. A competing team’s spokesman claimed that his team’s proposal was more equitable to all vehicle types, taking 70 percent of the traffic—cars—and giving them 100 percent of the highway (as opposed to giving half of the available lanes to 30 percent of the traffic—trucks). That proposal would have added lanes but would have allowed cars on all lanes while trucks were restricted to the right lanes. Another spokesman from the competing team cited installing a heavier grade of pavement, acquiring additional rights of way and running concrete barriers (all included in the STAR [Safer Transport and Roadways] proposal) as cost-prohibitive factors that discourage trucks-only lanes *(30)*.

Table 2. Interstate 81 Annual Average Daily Traffic through Virginia.

Location	**AADT Composite**	**Approximate No. of Trucks** (20% to 40% of AADT)
Bristol	50,000	10,000 to 20,000
Rural Retreat	24,000	4,800 to 9,600
Wytheville	53,000	10,600 to 21,200
Roanoke	72,000	14,400 to 28,800
Staunton	59,000	11,800 to 23,600
Harrisonburg	51,000	10,200 to 20,400
Winchester	55,000	11,000 to 22,000

Source: Adapted from Reference *(28)* http://www.interstate-guide.com/i-081.html.

A more recent press release issued on March 5, 2004, stated that VDOT had selected one of the two teams proposing I-81 improvements. The release stated that the advisory panel overseeing the project had defined the need to widen the highway to at least four lanes in each direction to accommodate expected traffic growth *(31)*.

The winning team for the project, STAR Solutions, proposed to widen I-81 from four to eight lanes throughout Virginia and separate commercial trucks from passenger vehicles in two-lane divisions for each direction of travel. The proposal anticipates that a substantial portion of the funding will come from tolls levied on commercial trucks, charged electronically to keep traffic flowing. The plan would widen I-81 over its entire 325-mile length through the state in 15 years instead of VDOT's proposed 30 to 40 years. Trucks would pay $65 to travel the full length, based on a fee of 20 cents per mile. Of course, the fee for commercial vehicles would be less if the Virginia law changes to allow tolls on cars or if other funding sources become available *(32)*. Advocates have stated that the time savings would offset the cost of the tolls. The STAR Solutions plan would redesign interchanges with other interstates and other major truck exits to allow for separation between cars and trucks at exits. Rest areas for commercial trucks would also be placed in the median to avoid cross-over traffic into the passenger vehicle lanes *(33)*.

The key elements of the STAR Solutions detailed proposal are *(32)*:

- implementation of a long-term solution for I-81 in 15 years;
- separation of cars and heavy commercial vehicles using Safe and Freight-Efficient (SAFE) lanes;
- a high-quality pavement to reduce the number of delays and lane closures for repairs;
- a 20-year pavement warranty for all new mainline/collector-distributor lanes and shoulders, which will lower VDOT's future maintenance costs and free up funds for other road projects;
- six dual interchanges and eight truck-only flyovers, as well as other interchange improvements;
- project cost of $6.3 billion, including a pavement warranty, with no finance gap;
- intermodal freight movement which included numerous elements, with a rail plan that would move 560,000 trucks per year to rail;
- true public-private partnership – shared responsibilities and assumption of risk by private sector;
- opportunities for VDOT to use the low-bid procurement process for elements of the project; and
- minimal environmental impact, based on reducing right-of-way needs (vs. previous proposals).

Figure 3 is a conceptual rendering of the proposal by STAR Solutions. Other information indicates that the car-only lanes might be closer at some locations but separated by rumble strips with barriers separating directions of flow.

2.4.2 I-10 Freight Corridor Study

A study of the I-10 freight corridor by a team led by Wilbur Smith Associates was a joint effort by the eight state departments of transportation (DOTs) traversed by I-10 *(34, 35)*. These states were: California, Arizona, New Mexico, Texas, Louisiana, Mississippi, Alabama, and Florida. The purpose of the study was to analyze current and future projected freight movements and assess their impact on the I-10 corridor. Freight transported along the corridor, which includes 15 major urban areas, has a total impact of $1.38 trillion dollars. This amount includes $339.4 billion in earnings paid to 10.4 million employees *(34)*. The study focused on a comprehensive evaluation of methods to enhance speed and reliability of freight movement, while reducing the effect of freight traffic on communities along the corridor.

Source: Reference (31) http://www.improve81.com/mediainformation.asp

Figure 3. Conceptual Rendering of the I-81 Improvement.

The study examined a series of strategies and approaches pertaining to feasibility and the effects of the approach on operations, safety, and congestion in the I-10 corridor. The strategies included:

- Widening I-10 to meet future demands – add enough lanes to each segment so that operation meets an acceptable level of service (LOS). This approach did not consider financial, environmental, or other constraints.
- Intelligent transportation systems (ITS) – use of ITS to manage flow and provide information to drivers pertaining to level of service. This approach included: traffic management, traveler information, incident management, commercial vehicle operations systems (CVOS), and system integration.
- Truck and auto separation – use of either separate facilities, separate lanes, or lane restrictions for truck and auto traffic as a means of improving operations and safety.
- Multimodal rail corridor – examined the amount of future traffic that could be transported by either truck or rail and the suitability of intermodal service.

- Maritime intermodal – evaluated the amount of traffic that could be transported by barge for at least a portion of the trip and the suitability of this form of intermodal combination.

- Urban truck bypass – uses a truck-only bypass route for major urban areas. This strategy examined the effects of such bypasses on congestion, emission reduction, and safety.

- Truck productivity – examines policies of size and weight increases as a means of improving freight productivity and safety while reducing facility costs.

- Other strategies – the study also examined a multitude of other strategies including freight villages and hours of truck operations *(34, 35)*.

The study team found that the most feasible strategy to enhance freight capacity was to focus on the highway facility itself. The most effective way of enhancing LOS was to increase the number of lanes on the facility; however, the study team also found that this alternative was not financially viable without significant funding increases.

Facilities and strategies that separate truck traffic from automobile traffic are feasible in concept for some parts of the corridor with heavy freight densities. Although feasible, truck separation has not been fully developed on any high-volume corridor. Therefore, it has not been fully developed as a viable strategy from the operations, design, or engineering standpoints *(34, 35)*.

The research team found that truck bypasses and truck productivity improvements do provide relief in operations. However, they cannot be considered as stand-alone strategies because they do not provide sufficient impact on capacity. Multimodal approaches using both rail and waterways would divert some freight traffic from the I-10 corridor. Nevertheless, the overall impact of these two approaches on congestion would be minimal *(33, 34)*.

The team also found that ITS and CVOS technologies were feasible and financially viable strategies for corridor-wide deployment. Results indicated that these strategies offered a return of $3 for every $1 invested and could be implemented in conjunction with traditional capacity improvements *(34, 35)*.

Finally, the implications of maintaining the status quo or doing nothing had considerable impacts. These impacts included significant degradations of I-10 and the I-10 region in the following ways:

- transportation system reliability;

- economics of just-in-time manufacturing or continuous flow supply practices;

- competitive position of the industrial and commercial base;

- employment and productivity;

- tourism attraction and retention;

- workforce attraction, retention, and quality of life; and
- national environmental, safety, and security goals *(35)*.

2.4.3 I-35 Trade Corridor Study

In 1999, the FHWA and the DOTs from the six most affected states sponsored a study of the I-35 corridor. The study, entitled *Recommended Corridor Investment Strategies (36)*, included participation from Texas, Oklahoma, Kansas, Missouri, Iowa, and Minnesota. The study assessed the needs for improved service at all levels on I-35 and formulated a plan to address those needs. The focus of the study was to improve the efficiency of I-35. It evaluated a number of emerging technologies that might warrant further investigation to improve transportation efficiency along the corridor *(36)*.

The study team proposed that several components be implemented for the corridor to accommodate anticipated growth of traffic and freight movement. The following components formulated the recommended strategy for the corridor to meet the needs of traffic in 2025:

- Widening I-35 in critical locations – only 35 percent of the existing roadway can accommodate traffic increases in the future. The study recommended that 1060 miles of I-35 be widened.
- Application of ITS and CVOS – ITS strategies recommended for the corridor included corridor traffic control, incident management, electronic toll collection, route guidance, traveler information systems, and commercial vehicle operations.
- Urban congestion relief – urban congestion relief is needed to meet both current and future traffic demands in several urban centers along the corridor. The study found that the implementation of widening, relief routes, ITS applications, and special provisions for freight movement could meet the needs of the congested urban centers.
- Special provisions for freight movement by truck – truckways in the form of separate facilities and special lanes within the I-35 corridor were recommended to meet the needs of freight movement along the corridor. Other provisions to meet the growing truck traffic needs include heavy duty pavement and bridges throughout the facility; the inclusion of complete ITS for commercial vehicle operations, and the development of pre-clearance centers for U.S., Canadian, and Mexican Customs operations.
- Development of relief routes for parts of the corridor – relief routes are recommended for a number of urban areas in the corridor because of the inability of the existing corridor right-of-way to meet demand *(36)*.

2.4.4 I-69 Route Feasibility Study

Recently, a team led by Turner, Collie, & Braden, Inc. conducted a route feasibility study for TxDOT regarding the then newly designated I-69 corridor thorough Texas. The study area included Harris and surrounding counties in southeast Texas, an area comprising the greater

Houston metropolitan area. Although the project identified routes, it did not specifically examine treatments and strategies for truck issues. It did address truck traffic and projected freight movements *(37)*.

2.4.5 Ports to Plains Feasibility Study

A 2001 study of a high-priority corridor between the Denver area and the Texas/Mexico border entitled the *Ports to Plains Study* focused on a number of strategies and issues regarding freight movement. This proposed corridor, which was designated as corridor 38 in the Transportation Equity Act for the 21st Century (TEA-21), utilized I-27 between Amarillo and Lubbock and other existing highway alignments. The proposal would improve these alignments to a four-lane divided principal arterial throughout the length of the corridor. Although the study found that a continuous four-lane highway was not feasible for the entire corridor, it identified a number of alternative strategies that would improve freight movement in the corridor area. These included additional truck climbing lanes, intersection improvements, and implementation of ITS measures *(38)*.

2.4.6 California State Route 60 Study

TTI was a member of a research team formed to evaluate the feasibility of implementing truck lanes on State Route (SR) 60 in the vicinity of Los Angeles, California. The project examined the segment of SR-60 between I-710 on the west and I-15 on the east, which is a heavily used truck route serving both the port of Los Angeles and domestic traffic. The feasibility study included an operational and safety analysis (by TTI), a financial feasibility analysis (using tolls for the exclusive truck facility), and a marketing analysis. The research team found that dedicated truck lanes were feasible under certain conditions. The team recommended that dedicated truck lanes be constructed in each direction either at freeway level or elevated above the freeway. The aerial or elevated level would be necessary where the at-grade widening of the corridor would be either impossible or impracticable *(39)*.

2.4.7 California I-710 Corridor Study

I-710 is the major north-south route providing access to the Ports of Long Beach and Los Angeles. In 1997 the Southern California Association of Governments (SCAG) began a program to address freight issues in southern California *(40)*. The consulting firm of Parsons-Brinckerhoff led a major corridor study on intermodal facilities and freight movement along the corridor in 2002. The study team analyzed the congestion and traffic problems on I-710, then developed multimodal, timely, and cost-effective solutions to address those problems. In the final part of the study, the team will analyze the feasibility of truck lanes as a measure for implementation on the corridor. The entire length of the corridor serves heavy truck volumes, with total truck traffic on the corridor south of I-405 comprising 20 percent of all traffic. Forecasts indicate that port-related truck traffic, currently 95 percent of all corridor truck traffic, will nearly triple by 2020. The I-710 study was slated for completion in 2004 *(40)*.

Fischer et al. considered both the SR-60 corridor plan and the initial results of the I-710 corridor study in an examination of truck lane strategies *(40)*. The research team found that successful truck lanes require more than high truck volumes; the location of the proposed facility is also very important. Urban truck trips are generally short distance trips, so an expanded multipurpose facility is best suited for this type of truck traffic. However, if the origin-destination locations are concentrated and there are extremely high volume facilities like ports or intermodal facilities, a separate truck lane or facility may be feasible *(40)*.

Fischer et al. also found that past research has not always properly accounted for safety benefits of separating truck and automobile traffic. Another factor that is sometimes overlooked as a potential benefit is allowing longer combination vehicles on heavy truck lanes *(40)*.

2.4.8 Florida Corridor Study

In 2002, the Center for Urban Transportation Research (CUTR) at the University of South Florida examined the potential use of special truck treatments in Florida *(41)*. The research team examined Florida roadways and the potential application of truckways and exclusive truck lanes. The researchers examined the following trip types: between cities trips, within cities trips, and regional trips. This report provides more information on this project below in the selection criteria section.

The research identified six candidate corridors for the between cities trip model. These corridors were:

- Miami to Titusville;
- Daytona to Jacksonville;
- Naples to Fort Myers;
- Tampa to Orlando to Daytona;
- Venice to Valdosta, Georgia; and
- Lake City to Jacksonville.

The within cities model focused on truck traffic related to intermodal facilities. Corridors identified through this process were: Port of Miami to the Miami Intermodal Center, Port of Tampa to I-4/275, and I-295 to I-95 in Jacksonville. Although researchers identified the corridors as potential candidates for exclusive truck facilities, they recommended further economic studies prior to implementation *(41)*.

2.5 TRUCK TREATMENT CRITERIA

2.5.1 Florida DOT Study

In the study sponsored by the Florida Department of Transportation (FDOT), the CUTR developed a site suitability model to identify optimum locations or segments of roadway to implement "reserved truck lanes and truckways" in the state of Florida *(41)*. The data used in this exercise came from the FDOT Statistics Office and the FDOT Safety Office. This study used the following variables:

- truck volume,
- truck percentages,
- truck crashes, and
- highway level-of-service.

It also utilized FDOT data on truck terminals and Bureau of Transportation Statistics (BTS) data on seaports and international airports to develop a site suitability model. The research team used geographic information systems (GIS) technology to create a spatial model that reflected the locations of truck activity centers. This activity involved the use of ESRI's ARCView 3.2, Spatial Analyst 2, and ArcGIS 8.1. Spatial Analyst converts street (polyline) based files into grid (raster) based files and performs spatial analysis on the converted files. These tools allowed research staff to assign values to the roadways. The process resulted in a relative indication or comparison of sections of FDOT highways and how each ranks in comparison to the others. The model does not attempt to recommend truckway locations but rather which locations have the greatest potential for a truckway. CUTR used the model output to identify locations that merit site visits and case studies *(41)*.

To achieve the model's objective, there were questions to be addressed. Each variable in the model addressed a specific objective and answered a question. Once each variable was assigned rankings for the different data ranges, every variable was assigned a weighted value based on its contribution to the suitability model. The basis of the weighted value for each variable was how much that specific variable impacts the likelihood that the location is suitable for a special truck treatment. Highway segments with high scores were then more closely examined. The end result was a spatial model which evaluated the suitability of segments on the state highway system for special truck treatments.

Again, the variables used in this process were: AADTT, percent trucks, truck crashes, and LOS. Each variable required a suitability scale (from 1 through 9) to score the differing data characteristics and to determine their relative differences. The relative importance of the variables came from the CUTR literature review, case studies, deliberations with project staff, and consultation with FDOT. The following section describes the variables and the relative weights assigned to them *(41)*.

Truck classifications used were Classes 4 through 13 of the vehicle classification scheme F. Therefore, buses and any medium to large truck with two or more axles constituted this group of vehicles. This definition serves for both the "truck volume" and "percent trucks" variables. The ranking process gave a ranking of 9 to volumes in the 99th percentile, 8 to the 95th percentile, 5 to the 90th percentile, and 3 to the 75th percentile. Highways with truck volumes below the 50th percentile had a value of 1, and truck volumes below the 25th percentile had a value of 0 *(41)*. The percent of truck traffic identified the mix of truck and non-truck traffic. The percentiles were exactly the same as for truck volumes provided above.

Truck crashes utilized data from the FDOT Safety Office on all truck-related crashes that occurred on state highways in 1998 and 1999. Due to differences in coding, the vehicle classifications used for the crash analysis were not identical to the ones used earlier for truck volume. The analysis involved the following vehicle types: “05” (heavy truck – two or more rear axles) and “06” (truck tractor – cab). Researchers divided the truck crash rate into two suitability scales – above average and below average. All segments below average had a value of 1 and the ones that were above average had a value of 9.

The LOS variable classifies the operational performance of segments of roadway based on a lettering system. LOS “A” is the best, representing free-flow conditions with sufficient space around vehicles for much maneuverability. LOS “B,” “C,” and “D” represent successively increasing congestion and lower freedom of maneuverability. LOS “E” represents the capacity of the facility and LOS “F” is a forced flow, reduced speed scenario with lower capacity than LOS “E.” The suitability scales assigned to each LOS were as follows: LOS A-B was 1, LOS C was 2, LOS D was 3, LOS E was 5, and LOS F was 9 *(41)*.

The remaining variables were not attribute-based. In other words, they do not report on characteristics pertaining to the state highway system but rather on spatial relationships. These variables represent truck traffic generators, their distance to the highway system, and the type of activities that occur at these sites. The airport variable identifies roads impacted by truck traffic generated by airports. It assigned a value associated with a 10-mile buffer around each airport. The seaport variable identifies highway segments that are impacted by the truck traffic generated by seaports. The truck terminal variable identifies highway segments impacted by major truck terminals. Roads within 1 mile of a truck terminal had a value of 9, roads between 1 and 3 miles had a value of 7, roads between 3 and 5 miles had a value of 5, and roads farther away had a value of 0. The “trailer-on-flat-car” (TOFC) variable identified roads that were impacted by truck traffic from TOFC facilities. Roads within 5 miles of a TOFC facility had a score of 9, those within 5 to 7 miles had a score of 7, those within 7 to 9 miles had a score of 5, and those greater than 9 miles had a score of 0 *(41)*.

Creating suitability models required combining each of the suitability scores of their respective variables. Even though the original idea for this work focused on a long-haul facility serving intercity commercial traffic, current examples of truck facilities (other than the New Jersey Turnpike) only served local access needs. The three models that resulted from this effort combined the most appropriate variables and weighting of those variables to serve the following trip types: between cites, within cities, and regional facilities. Table 3 is an example showing the “between cities” model suitability scales; similar tables are also available for the other two models *(41)*.

2.5.2 Battelle Study

A study by Battelle sponsored by the USDOT *(42)* modified and updated the benefit-cost (B/C) model developed by Janson and Rathi *(13)* for evaluating the feasibility of exclusive truck facilities. Variables considered by the model include:

- traffic characteristics,
- construction costs,
- units of pavement damage by vehicle type, and
- costs associated with crashes.

Table 3. Between Cities Model Suitability Scale.

Factor	Weight	Input Variables	Scale Value
Truck Crash	5%	0 – 0.1996 >0.1996	1 9
Level-of-Service	15%	A+B C D E F	1 2 3 5 9
Percent Trucks	5%	0.006-0.11 0.11-0.17 0.17-0.21 0.21-0.33 0.33-0.754	1 5 7 8 9
Truck Volume	75%	0-1965 1965-4071 4071-6935 6935-14,475 14,475-23,002	1 3 5 8 9

Source: Reference (41).

The model considers many inputs and calculates the costs, benefits, net present value (NPV), and B/C ratios for different alternatives of potential exclusive truck facilities (ETF). Table 4 summarizes the criteria used by Battelle. The LOS of a highway segment, as discussed above in the FDOT study, is an indicator of freedom of maneuverability and is often associated with volume-to-capacity (*v/c*) ratios. Removal of significant numbers of trucks from a mixed traffic stream improves operating conditions and level-of-service by reducing the volume-to-capacity ratio.

Table 5 groups the alternatives used by Battelle into five scenarios plus the base case, or “do nothing,” alternative. Below the list is a more detailed description of each scenario. A second Battelle project began in 2003 to further refine and improve the results of the initial Battelle research.

2.5.3 TxDOT Research Project 3310

In earlier TTI research performed in 1985, Mason et al. *(43)* developed a moving analysis computer program using the *Highway Capacity Manual* (HCM) method to evaluate the LOS with trucks and without trucks (removing trucks from the mainlanes by adding an exclusive truck facility). Because the project emphasized the use of the median area for truck facilities, two inputs were the total median width and the effective median width (consideration of median obstructions).

Table 4. Suggested ETL Evaluation of Criteria.

Measure	Suggested Threshold	Remarks
AADT	≥100,000 vpd	Use in combination with AADTT percent
AADTT	≥ 25%	Use in combination with AADT
Level-of-service	E or lower – urban hwys F or lower – rural hwys (v/c ratio ≥ 1)	To rank potential locations that satisfy traffic criteria
Truck-involved fatal crash rate	≥ national average (2.3 per 100 MVMT, 1999)	To rank potential locations that satisfy traffic criteria
Proximity to intermodal facilities/ processing centers	≤2 miles from interstate or X tons of freight or Y TEUs of containers	To be considered with other criteria No data available to determine the values for X or Y

Source: Reference (42).

Table 5. Options Used by the Battelle Model.

Case	Description
Case 0	Do nothing. There is no change to the highway facilities.
Case 1	Add no new lanes but designate existing lanes for mixed, light, and heavy vehicles.
Case 2	Increase the number of mixed-vehicle lanes (no lane use restrictions).
Case 3	Add non-barrier separated lanes and designate at least one lane for the exclusive use of a certain vehicle class.
Case 4	Add non-barrier separated lanes and designate at least one lane for the exclusive use of a certain vehicle class. The difference between Case 4 and Case 3 is that in Case 4 trucks are allowed to use mixed lanes when the capacity of the designated lane is exceeded.
Case 5	Add barrier separated lanes and designate new and existing lanes for light and heavy vehicles. The additional exclusive lane is barrier-separated from the existing lanes and trucks are restricted to use this facility only. The use of barrier separation is the major difference between this alternative and Cases 3 and 4.

Source: Reference (42).

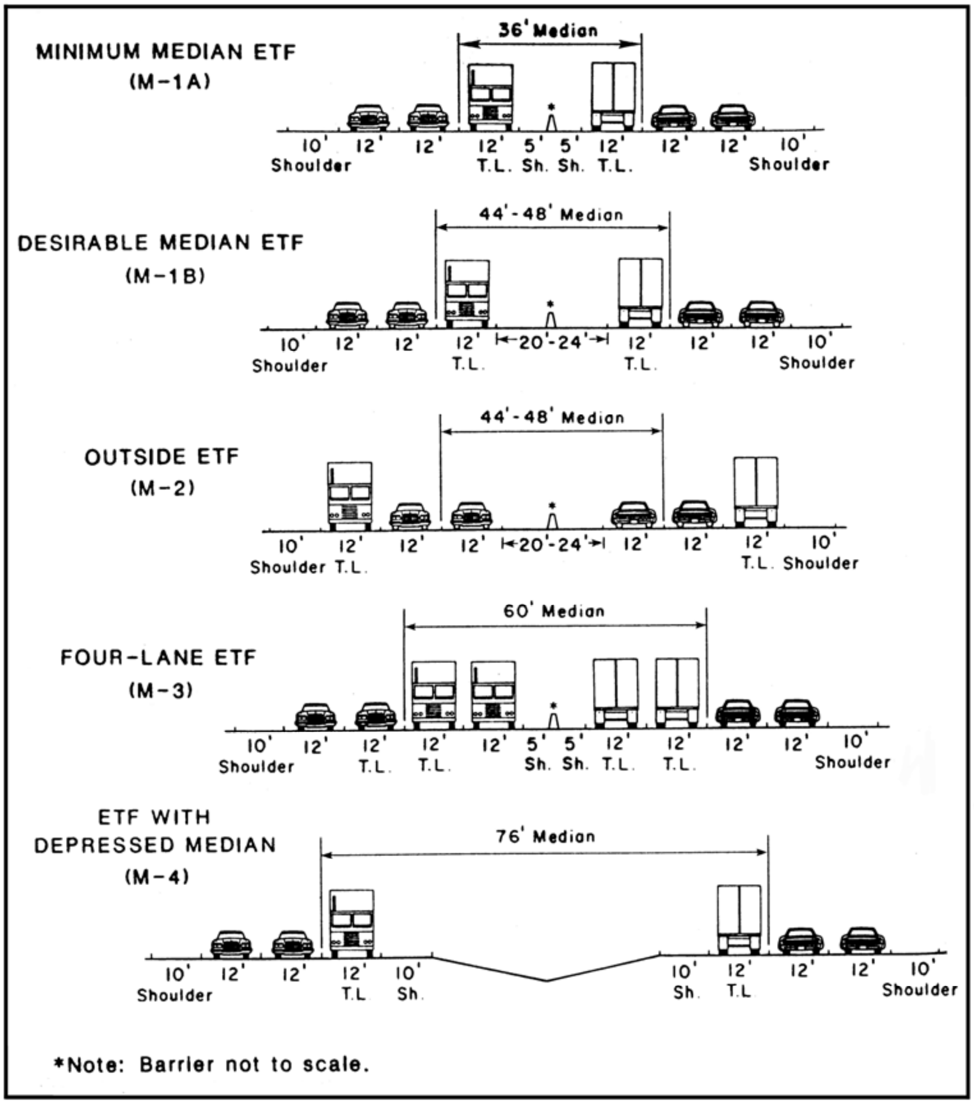
The program evaluated each half-mile segment and printed the results on that same length basis. Data input in half-mile segments were *(44)*:

- milepost,
- peak-hour volume,
- number or percent trucks,
- percent grade,
- length of grade,
- terrain factor,
- number of lanes,
- distance to lateral obstructions,
- total median width, and
- effective median width.

Unfortunately, the HCM and Highway Capacity Software (HCS) only consider truck percentages as high as 25 percent. On Texas roadways and across the United States, truck percentages higher than 25 percent are becoming more common, especially in non-urban areas and at night. In this study, Mason et al. described seven types of truck lane configurations *(43)*. Figure 4 shows the seven configurations. All of these lanes could fit within existing right-of-way. Descriptions of the configurations follow.

- The first truck lane, designated as M-1A, is a minimum median truck lane. Trucks use 12-ft inside lanes that have a 5-ft inside shoulder, while other vehicles utilize the outside lanes. Lanes for trucks and cars are not barrier separated.
- The second truck lane, designated M-1B, is a desirable median truck lane. The configuration is the same for the M-1A truck lane, with the exception of 10- to 12-ft inside shoulders.
- The third truck lane, known as M-2, is an outside truck lane. Trucks travel on 12-ft outside lanes that have 12-ft shoulders. These lanes are not barrier separated from the inside car lanes.
- The fourth type of configuration is the M-3 truck lane; it is a four-lane truck facility where trucks travel on two 12-ft inside lanes that have 5-ft inside shoulders. The trucks are not barrier separated from the outside car lanes.

- The fifth type of facility is the M-4, which is an inside 12-ft truck lane with a 10-ft inside shoulder and a depressed median. The truck lane is not barrier separated from the car lanes.

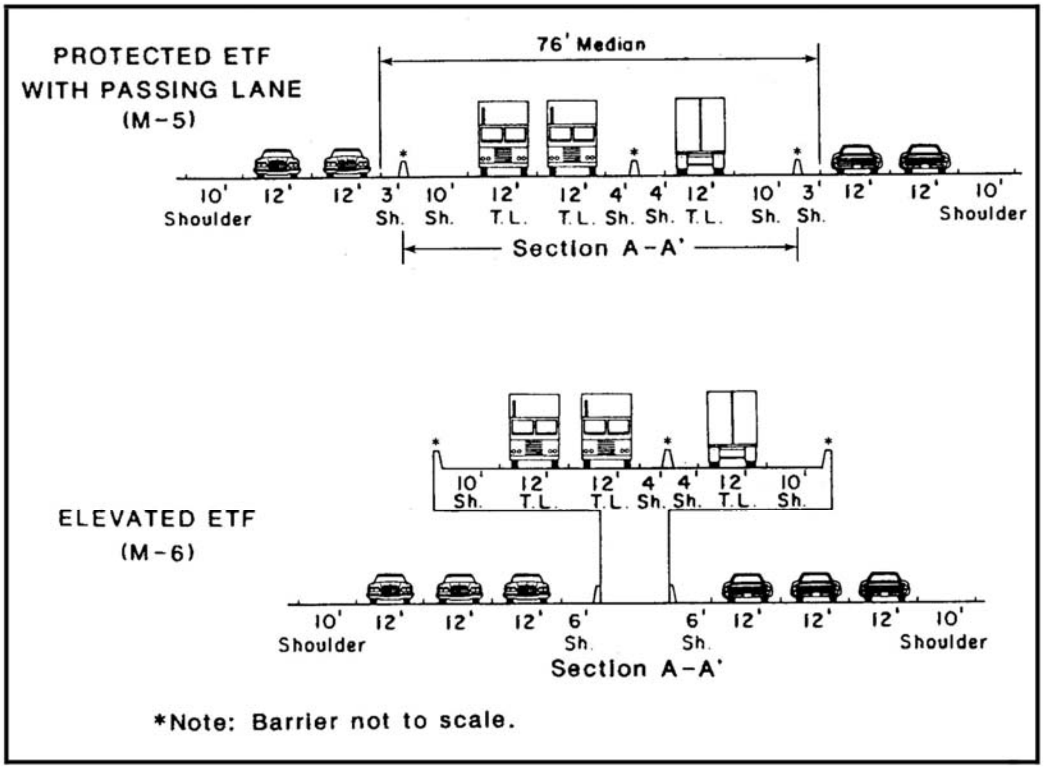


Source: Reference (43).

Figure 4. TTI Truck Facility Cross-Sections.

- The sixth type of configuration is the M-5 protected truck lane with a passing lane. Trucks travel on 12-ft lanes that have a 4-ft inside shoulder and a 10-ft outside shoulder. This facility is barrier separated from the outside car lanes.

- The final configuration is the M-6 elevated truck lanes. Trucks travel on two 12-ft lanes that have a 4-ft inside (left) shoulder and a 10-ft outside (right) shoulder. This facility is elevated above the passenger car lanes.



Source: Reference (43).

Figure 4. TTI Truck Facility Cross-Sections (Continued).

2.5.4 Reason Public Policy Institute Study

In a 2002 study, a Reason Foundation research team proposed a new approach to resolving the productivity dilemma for trucks – add truck lanes on interstate routes where longer combination vehicles (LCVs) might be appropriate *(45)*. These “toll truckways” would be designed to accommodate the heavier loads of longer doubles and triples (up to 150,000 lb gross vehicle weight rating [GVWR]). The concept would use staging areas adjacent to the truckways at major trans-shipment points to break down the multiple unit vehicles into smaller single-trailer units that could continue on the state highway system. The Reason team proposed that the facility consist of a single lane (plus breakdown lane) in each direction with passing opportunities every few miles. The cost analysis used a simulation model to determine operating and maintenance costs of the facilities using heavy-duty pavement design.

Simulation runs evaluated several scenarios that explored varying rates at which truck traffic might be attracted to the truckway and take advantage of the increased size and weight permitted. Results indicated that significant gains in productivity could be realized, using the assumption that motor carriers would be willing to pay tolls of up to half of the cost savings that would accrue from using the larger LCVs. A 1991 freeze prohibited further expansion of the LCV network and left the existing network fragmented. The Reason Public Policy Institute conducted a follow-up study to determine which routes should be considered as extensions to the existing, somewhat fragmented, network *(46)*. Unfortunately, the project did not have the resources to simulate the activity of motor carriers on a hypothetical toll truckway network. However, the study activities included contacts of motor carriers that already operated LCVs and asked them which new corridors would best serve their needs and the needs of shippers they served. It then took the recommendations and plotted the routes on a map that also showed the existing interstate and LCV networks. Of the routes recommended by the carriers interviewed, some Texas routes or segments were identified. These existing or proposed routes included:

- I-40 through the Texas panhandle,
- I-30 from Texarkana to Dallas,
- I-35 from Laredo to the Oklahoma border,
- the future I-69 from Brownsville to Texarkana, and
- I-10 from Houston to the Louisiana border.

The Reason analysts agreed that some of the corridors identified by the LCV carriers should be added to the existing LCV network, but that there were remaining gaps and logical extensions still needed. The analysts added more connectors, basically keeping the Texas segments noted above intact. With selection of a set of candidate routes, the Reason approach was to quantify each route's suitability for becoming a toll truckway. To accomplish this task, the team used two databases, a large goods movement database derived from the Federal Highway Administration's Freight Analysis Framework (FAF) and the longer established Highway Performance Monitoring System (HPMS) database. The criteria that evolved are not necessarily the same as for a non-toll facility since the financial feasibility is key to the success of a toll facility. Financial feasibility translates into either a high truck volume or relatively low construction cost, or both *(46)*.

The Reason process first reviewed factors that potentially affect demand, and hence revenue. Secondly, the process looked at the cost side. The revenue criteria investigated by Reason were:

- truck volume,
- congestion on the general purpose lanes,
- connectivity (especially for LCVs), and
- customer demand (based on industry input).

For truck volume, the Reason analysis selected routes with 2020 gross truck volume of at least 10,000 trucks per day over most of its length. (Based upon other information in the report, the definition of a "truck" appears to be the heavy-duty trucks, probably FHWA Class 7 and above.) For congestion in the mixed-flow or general purpose lanes, the Reason study used the predicted *v/c* ratio in 2020 for the unexpanded rural portion of the assumed network. For connectivity, the Reason analysis assumed that an important selling point of the truckways would be their ability to handle LCVs in states where these vehicles would not otherwise be allowed to operate. For customer demand, the Reason report used input from the motor carrier interviews and the willingness of carriers to pay a toll for the particular segments being investigated *(46)*.

On the cost side, the factors were right-of-way availability and terrain factor. In the 2002 Reason study, the truckways were part of wide, unused medians of existing interstate highways, so land costs were negligible. The Reason study eliminated 10 of the 20 initial candidate corridors and inquired about right-of-way availability from the appropriate states on the remaining 10 to evaluate cost aspects of each. The other factor that can significantly affect the cost of a toll facility for trucks is the type of terrain through which it will be built. Analysts asked each state DOT representative to categorize each corridor as flat, rolling, or mountainous *(46)*.

In the analysis of candidate corridors, Reason made several estimates and assumptions. First, the approximate capital cost of a rural two-lane toll truckway would be $2.5 million per route-mile, so Reason calculated that the facility must generate $1000 per day per mile in revenue. At a toll of 13 cents per mile (approximately what today's large truck pays in fuel taxes), that would require 8000 trucks per day for the facility to be self-supporting from toll revenues. Actual truckway tolls, especially for LCVs, would likely be much higher. The Reason report estimated that a basic toll truckway would probably need between 2000 and 4000 trucks per day to be self-supporting from toll revenues *(46)*.

The Reason report took its estimate one step further by formulating a point score for each corridor that attempts to quantify its relative ability to generate toll revenue. It then used a weighting factor to make the final determination of whether each route should be added to the existing LCV network. The following list shows the weighting factors resulting from the Reason procedure *(46)*:

- 35 percent for gross truck volume in rural sections in 2020,
- 15 percent for the additional factor of truck traffic being high all along the corridor,
- 15 percent for extent of congestion,
- 20 percent for connectivity to the LCV network, and
- 15 percent for LCV-using motor carrier interest.

Using a relative score approach and the weighting factors noted above, Reason developed a total score for each of the candidate corridors. The final step utilized the relative cost score and relative revenue potential to identify the 10 most promising corridors ranked from high to low.

In summary, the Reason study used the existing LCV network as a starting point and considered things like heavy truck volume, volume-to-capacity, connectivity, a goods movement database, potential for revenue generation, and likely right-of-way cost (based on availability and terrain factors). The study then developed a relative ranking scale and weighting factors to derive 10 likely extensions to the exiting LCV network. The five corridors noted earlier that are in Texas were not included in the ten highest priority corridors selected by this process. However, if LCVs are allowed on the future Trans Texas Corridor, the outcome might be different *(46)*.

2.5.5 Additional Information on Vehicle Volume

Truck and total vehicular volume are likely to be included among the criteria for establishing when to initiate truck treatments, even though other criteria should be considered as well. Measuring and predicting vehicular volume is reasonably accurate, so it appears to be a strongly viable candidate. The driving factor for designation of trucks to certain lanes is usually more than just vehicular volumes. Therefore, establishing a firm threshold pertaining to truck and total volume for this treatment might not be appropriate. Instead, where enough lanes exist, maintaining one or more lanes that are free of trucks seems to be the appropriate objective to optimize traffic operations.

One could utilize the implicit and explicit factors surrounding existing facilities in the United States that have incorporated special treatments for trucks to suggest evidence supporting the need for such facilities elsewhere. The New Jersey Turnpike, I-5 north of Los Angeles, and S.R. 60 near Los Angeles are examples that generate this type of information. The general useful information gleaned from these facilities, based on information from Douglas, pertains primarily to vehicular volumes as follows *(47)*.

The total two-way daily volume of heavy (Class 5+ in Texas 6 Scheme, 3+ axles) trucks should exceed 20,000. Experience has indicated that beyond 20,000 heavy trucks per day the volume of trucks alone can seriously reduce the operational characteristics of the roadway. S.R. 60 in California and the New Jersey Turnpike are examples where heavy truck demand already exists at this level and measures have either been taken or are being planned for preferential truck facilities. In the case of S.R. 60, one scenario under study was a two-lane exclusive truck facility. Douglas concluded that truck demand less than 20,000 heavy trucks per day would not fully utilize a (two-lane) facility *(47)*.

The total daily volume of heavy trucks should exceed 20,000 for a distance of 10 miles, or there should be major sources of truck traffic near the termini of the proposed truck facility. As an example, the initial segment of the New Jersey Turnpike using the dual-dual roadway concept was just over 15 miles in length. Distances shorter than 10 miles might still be justified in special cases near high truck traffic generators such as truck terminals, major warehousing districts, intermodal facilities, and ports *(47)*.

The existing or planned highway should have at least four travel lanes in each direction. Two of these lanes would be general purpose lanes to primarily serve light duty vehicles and two would serve trucks. It is conceivable that a few large trucks might still need to use the general purpose lanes if the ETF does not have as many access points as needed for local delivery or for access to certain services.

The total two-way daily volume of all vehicles on the highway should exceed 120,000. If the daily volume is less than 120,000 on an eight-lane highway (assumed freeway), the highway is not operating near its capacity, so even a truck volume exceeding 20,000 tpd would not impede the highway's operation enough to justify an ETF. If the truck demand does not meet its design horizon for several years, the operating agency might consider allowing smaller vehicles on the truck facility for a time in order to reduce congestion on general purpose lanes, and perhaps improve public opinion by higher utilization of the truck facility *(47)*.

Truck and total vehicular volumes are appropriate criteria for establishing thresholds that identify the need for truck roadways. Both Battelle and Douglas established traffic volume criteria, although the definition of a truck was different between the two studies. This difference could be quite significant. Douglas considered only "heavy trucks" with 3+ axles (Class 5 and above in the Texas 6 scheme), whereas the Battelle study considered trucks as vehicles heavier than 10,000 lb GVW (gross vehicle weight). To summarize, the two traffic volume criteria for exclusive truck facilities are as follows:

- The Battelle criterion for traffic volume is an AADT of at least 100,000 vpd and 25 percent trucks on a facility with four or more lanes in each direction *(42)*.

- The Douglas criterion for traffic volume is an AADT of at least 120,000 vpd and 20,000 (large) trucks per day where there are at least four lanes in each direction and the traffic demand occurs over at least a 10-mile length or has a large truck traffic generator at one terminus *(47)*.

Based on these two studies, the selected AADTT in Texas should be close to 20,000 large tpd (3+ axles) or 25,000 total tpd (over 10,000 lb GVW). The influence of the smaller two-axle trucks varies, with greater influence in and near urban areas. Other factors suggested in the two studies merit further consideration as well. As always, safety is an important consideration and can be factored into the decision process more effectively when safety aspects of truck roadways are better understood. Also, the LOS is a useful measure of quality of traffic flow where all the traffic and roadway characteristics are known or can be accurately predicted.

2.5.6 Criteria Summary/Recommendations

Some of the research cited in this section offered both criteria and weights or relative importance associated with each criterion, while some only offered criteria. The following summary includes the critical factors that decision-makers might consider along with some initial recommendations for applying these criteria to the state roadway network in Texas. A summary of the findings from the literature follows.

- The FDOT study used four factors or criteria in its "between cities" model and provided weights for each. Three of the criteria, representing 95 percent of the total by weight, pertain to truck or non-truck volumes. The fourth pertains to crash rates, but it only accounts for 5 percent of the total weight.

- The Battelle model proposes five criteria and the associated thresholds to establish minimum values, below which the criteria are not critical. Three of the criteria pertain to truck and non-truck volume, one is crash-related, and one pertains to distance from truck traffic generators.

- The TxDOT sponsored Research Project 3310 by Mason et al. only used calculations of level-of-service with and without trucks to determine the impact on the quality of traffic operations when trucks are removed so, again, truck volume is a key ingredient. Its focus was on use of the median area of freeways, so it also used median width as a criterion.

- Douglas postulated that the total daily volume of heavy trucks (three-plus axles) should exceed 20,000 for a distance of at least 10 miles, or there should be major sources of truck traffic near the termini of the proposed truck facility.

- The Reasons investigation addressed the need for truck facilities or treatments from the standpoint of increased sizes and/or weights (specifically longer combination vehicles) and by using tolls to pay for the facilities. There were four criteria used by Reasons, two of which related directly to truck and non-truck volumes, one relating to connectivity to existing LCV routes, and one relating to customer demand based on industry input (i.e., truck volume). For truck volume, the Reason analysis selected routes with 2020 gross truck volume of at least 10,000 tpd over most of its length.

Table 6 summarizes the findings from the literature sources. For determining thresholds of the criteria for the three levels of treatments, the most difficult may be lane restrictions because conclusive evidence of its benefits has been elusive at best. There are cases in which improvements in operations occurred perhaps due to grades, but there may be other cases in which operations degrade due to lane restrictions. Even though lane restrictions are included in this project, the project statement emphasized “truck-only roadways” over lane restrictions, and other research is simultaneously addressing lane restrictions and should improve the current body of knowledge. One approach that might serve as a starting point is to use the same criteria for all three but with different thresholds.

Researchers recommend the criteria in Table 7 as the initial evaluation framework. In selecting the criteria, TTI used the literature findings, researcher knowledge, variables that are measurable and easily obtained, and variables that are specific to the state of Texas (i.e., they might not always be transferable). At this point, truck lane restrictions are omitted because of their inclusion in other research; a later section will describe criteria for this treatment.

Table 6. Summary of Truck Treatment Criteria.

Criteria	FDOT	Battelle	TxDOT 331	Douglas	Reasons	S.R. 60	I-81
Truck crashes	(5%)[a]	[≥ national average][b]	--	--	--	--	--
LOS_{car}	--	--	Included	--	--	Included	--
LOS_{mixed}	(15%)	[E-urban] [F-rural]	Included	--	--	Included	--
% Trucks	(5%)	[≥ 25%][c]	--	--	--	--	Included
Truck volume	(75%)	See %T	Included	[≥20k trucks Per day]	[≥10k trucks Per day] (35%) (+15%)[e]	Included	--
AADT or congestion	--	[≥100k][c]	--	--	(15%)	Included	--
Proximity to activity centers	Included (0%)	[≤2 mi from Interstate][d]	--	--	--	Included	--
Available median Width	--	--	Included	--	--	--	--
Minimum length	--	--	--	[10 mi]	--	--	--
Connectivity	--	--	--	--	(20%)[f]	--	--
Motor carrier interest	--	--	--	--	(15%)[f]	--	--
Cost elements	--	B/C Analysis	--	--	Included	Included	Included

[a] ( ) designates weight or priority; [ ] designates thresholds.
[b] Truck-involved fatal crash rate ≥ national average.
[c] Battelle: use 25% trucks in combination with average daily traffic (ADT) of 100,000 vpd.
[d] Battelle: Specifies activity center as intermodal facilities/processing centers.
[e] Reasons: If truck volume is high along the full length of the corridor.
[f] Reasons: Pertains to the LCV network.

Table 7. Proposed Selection Criteria for Truck Treatments.

Criterion	Exclusive Truck Lanes	Exclusive Truck Roadway
Level-of-Service mixed traffic	X	X
Level-of-Service on truck facility	X	X
Truck-involved crash rates	X	X
Financial feasibility [a]	X	X
Location of major truck generators	X	X
Primary TTC corridor	X	X
NAFTA corridor designation	X	X
Hazardous route designation	X	X

[a] Relates to demand, toll v. non-toll, topography, urban v. rural.

CHAPTER 3. FINAL CRITERIA FOR TRUCK TREATMENTS

3.1 INTRODUCTION

This section summarizes previous efforts found mostly in the literature to identify the key criteria for selecting truck treatments. The Florida Department of Transportation, the Federal Highway Administration, and the Texas Department of Transportation sponsored research that addressed this topic. All but one of the information sources assumed that truck size and weight elements would remain constant. Some scenarios have investigated increased sizes and/or weights of trucks as incentives to attract greater participation by motor carriers. The other sources of information for this section came from analyses done by the research team related to safety and the capacity of truck-only roadways. The safety analysis used crash data from four sections of the New Jersey Turnpike, and the capacity analysis used the VISSIM program to simulate truck-only flows on roadways with two lanes. Results from this chapter will provide input for finalized analysis tools covered in Chapter 6.

3.2 METHODOLOGY

The initial information pertaining to selection criteria came from researcher experience and from previous studies on the subject (see Chapter 2). Of the criteria considered by others and presented in Chapter 2, researchers anticipated that the following primary criteria might influence the need for truck facilities: mixed traffic LOS, truck LOS, crashes, and costs.

Early on, researchers believed that either traffic volume or level-of-service would be a good indicator of the need for special truck treatments. The Transportation Planning and Programming (TPP) Division of TxDOT regularly measures truck volume throughout the state, and it should be readily available. Additionally, if sufficient up-to-date geometric information was available, one could carry the evaluation one step further and develop truck facility improvement needs based on the concept of level of service as defined in the *Highway Capacity Manual (48)*.

One of the key deficiencies related to capacity and level of service analyses prior to this study was establishing the appropriate criteria for roadways with 100 percent trucks. The HCM method corrected for the number of trucks using a passenger car equivalent concept, but it only goes as high as 25 percent trucks. Therefore, this project had to develop relationships pertaining to capacity and level of service for exclusive truck facilities.

Safety is always an important consideration, but historical data for truck-only freeway facilities do not exist. Therefore, researchers conducted a study of the next best available scenario: a mixed-flow freeway beside a car-only freeway. TTI requested crash data from the New Jersey Turnpike Authority to conduct this comparison. This comparison established a preliminary result which indicated the need for additional analysis. It was anticipated that costs might be the final comparison criterion, utilizing crash costs on existing roadways compared with a mathematical representation of crashes and their estimated costs on truck roadways.

3.3 LEVEL OF SERVICE AS A CRITERION

3.3.1 Introduction

Level of service is a widely used concept to quantify traffic flow on a highway facility. From the driver's perspective, it can be thought of as freedom to maneuver within a particular traffic stream. In the typical scenario of mixed vehicular traffic, the *Highway Capacity Manual* converts large vehicles like trucks to passenger car equivalents *(48)*. However, a roadway with trucks only requires a new methodology. The first step in developing the methodology is to determine the capacity of the roadway with 100 percent truck traffic.

3.3.2 Truck Capacity Facility Modeling

The concept of truck-only roadways has received limited attention in the research, primarily because of the expense of creating multiple transportation facilities within the limited right-of-way along existing roadways, or the even greater expense of creating wholly separate roadway facilities for one class of roadway user. However, truck traffic is reaching levels in some locations along highways in Texas that a re-investigation of the practicality of creating roadways solely for truck use is required *(49)*.

A fundamental question that arises when considering roadways exclusively utilized by heavy vehicles is the inherent capacity of the roadway. For freeways with passenger car traffic, capacity ranges from 2200 to 2400 passengers cars per hour per lane (pc/h/l) depending on speed *(48)*. In terms of how a given facility actually operates under prevailing conditions, traffic engineers often assign a level of service designator ranging from A (free flow) to F (congested) based on the density of vehicles in passenger cars per mile per lane (pc/mi/l). However, basic sources for traffic analysis methodologies, such as the *Highway Capacity Manual (48)*, indicate that they are not applicable where special roadway lanes are set aside for a single vehicle type, and include factors for truck percentages in the traffic stream of up to only 25 percent.

Recent research in Florida attempted to assess the potential for reserved truck lanes within existing facilities or entirely new roadways devoted exclusively to truck use, but the research focused on issues that would affect the viability and cost effectiveness of such facilities rather than the fundamental traffic flow issues of their operation *(50)*. Research in truck operations also occurred in Florida, but it focused on quantifying truck performance – in terms of level of service – within mixed flow facilities rather than on an examination of truck-only roadways *(41)*.

Since the HCM and other basic analytical tools for roadway operations and assessment cannot address truck-only lanes or exclusive truck facilities, some researchers have employed simulation as a means of determining the operational impacts of truck-only lanes *(51)*. However, this study was primarily concerned with examining the issues surrounding the implementation of lanes reserved for truck use within an otherwise mixed-flow facility, so it did not include truck-only lane capacity within its scope.

3.3.2.1 Purpose

The current research is being conducted to answer fundamental questions about the capacity of potential truck-only roadways in Texas. Facilities being considered have general design details that have been developed based on findings from decades of past research into truck behavior and the impacts of roadway design features on truck performance. Specifically, the minimum design would include:

- uninterrupted flow (i.e., access controlled) operations,
- at least two lanes in each direction (for improved performance on grade and to allow ease of passing), and
- minimization of grades where possible.

A primary consideration in the assessment of capacity for truck-only roadways is the type of vehicle associated with the term "truck." For design and operational purposes in Texas, this definition most consistently indicates a vehicle with three or more axles that does not provide human transport as its primary function (i.e., not a bus). Unlike assessments of capacity based on passenger car traffic which includes a range of vehicles with relatively similar performance and operating characteristics, the current research will include vehicles ranging from gross vehicle weights of approximately 15,000 pounds to approximately 120,000 pounds.

The practical intent to this research is to define how many trucks could theoretically use a truck-only facility. The course of investigation is constrained to conditions that are expected to be found in Texas in a generic rural setting. Whereas information about roadway capacities employing varying mixes of different truck types is of research interest, this research will employ only a vehicle mix that is generally representative of the truck type distribution found in rural Texas areas (i.e., where truck-only roadways would most likely be constructed).

3.3.2.2 Methodology

Since the mathematical models employed by standard traffic engineering analysis procedures cannot account for a vehicle stream composed only of trucks, this research relied upon a simulation tool. From the different types of simulation tools, researchers selected a microscopic tool with the flexibility to incorporate a variety of different vehicle types and constantly regulate their performance with respect to the roadway and surrounding vehicles.

Several different microscopic traffic simulation models exist for purposes of traffic flow modeling, including CORSIM *(52)*, Paramics *(53)*, VISSIM *(54)*, Integration *(55)*, and SimTraffic *(56)*. When model cost, flexibility in defining different truck types and operating characteristics, and available user support are factored into a comparison of these tools for truck facility modeling, the VISSIM tool is the most efficacious choice.

Researchers developed VISSIM simulation models of generic rural freeway sections as a starting point for determining the capacity of a truck-only facility. Analysts then developed variations on this basic model to explore the capacity impacts of grades and entrance and exit ramps. To ensure adequate measurement of capacity effects and to thoroughly examine truck acceleration and deceleration, analysts modeled a 20-mile segment of truck-only freeway. They determined capacity under prevailing operating conditions by increasing the input flows in each model until output flow reached it maximum value.

3.3.2.3 Truck Types and Characteristics

The modeling process considered both the "Texas 6" and Federal Highway Administration classification schemes for roadway vehicles to determine the types of trucks modeled in this investigation. Analysts defined "trucks" as vehicles with three or more axles. Therefore, trucks in the Texas 6 scheme include a total of nine classes – vehicle Class 5 through Class 13. In the FHWA scheme, trucks with three or more axles constitute Class 6 through Class 13. Table 8 shows vehicle classifications according to both the Texas 6 and FHWA schemes.

Table 9 contains supplementary details about each type of truck, including the minimum and maximum truck weights assumed for the study and the power for each truck type. Trends developed in past research indicate that the maximum weight-to-horsepower values should not exceed 210 lb/hp, which is the basis of the tabulated maximum values of weights *(57, 58)*. The next step was to enter this information into the VISSIM model.

For the purposes of the simulation, it was necessary to know not only the weight and power distributions for each truck type, but also the overall percentage of each type of truck in the vehicle stream. As the proposed locations of truckways in Texas are mostly in rural locations, researchers assembled truck data for rural sites from Automatic Traffic Recorder (ATR) stations operated by the Texas Department of Transportation. These stations record vehicle classification and volumes on a 24-hour basis throughout the year for use in a variety of planning and design purposes. In this case, researchers used data from two rural stations (13D near Sulphur Springs, Texas, and 198 near Shamrock, Texas) to develop an average truck type distribution for use in the simulation model. Table 10 shows both the station data and the final distribution. Based on site characteristics, analysts gave greater weight to Station 198 in the final truck distribution than Station 13D.

3.3.2.4 Truck Performance

In addition to truck weight and power values, the VISSIM model requires performance information in terms of average and maximum acceleration and deceleration. Researchers collected information from a number of sources to check values from the literature against default values used in the model *(59, 60, 61, 62, 63)*. Figures 5 through 8 present the VISSIM default maximum acceleration, desired acceleration, maximum deceleration, and desired deceleration.

Added to each figure are values found in the literature relating to each performance characteristic. As the values from the literature suggested less aggressive deceleration and acceleration profiles than the default values in VISSIM, researchers created new profiles and input them into the model. However, experimentation with the new profiles indicated some

Table 8. Truck Classification Schemes.

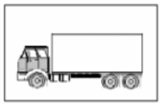
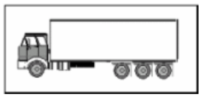
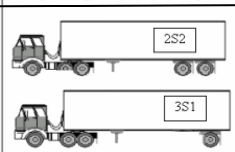
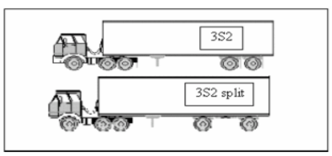
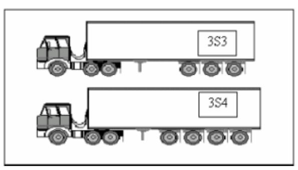
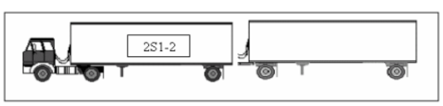
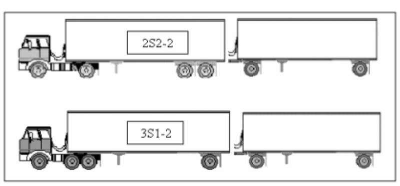
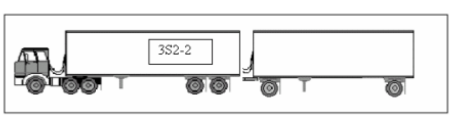
Typical Vehicle Type	Texas 6 Classification	FHWA Classification
	**Class 5**: 3 axles, single unit	**Class 6**: 3 axles, single unit
	**Class 6**: 4 or more axles, single unit	**Class 7**: 4 or more axles, single unit
	**Class 7**: 3 axles, single trailer	**Class 8**: 3 to 4 axles, single trailer
	**Class 8**: 4 axles, single trailer	
	**Class 9**: 5 axles, single trailer	**Class 9**: 5 axles, single trailer
	**Class 10**: 6 or more axles, single trailer	**Class 10**: 6 or more axles, single trailer
	**Class 11**: 5 or less axles multi-trailers	**Class 11**: 5 or less axles, multi-trailers
	**Class 12**: 7 or more axles multi-trailers	**Class 12**: 6 axles, multi-trailers
	**Class 13**: 6 axles, multi-trailers	**Class 13**: 7 or more axles, multi-trailers

Table 9. Physical and Performance Characteristics of Trucks.

Class		Weight (pounds)		Power (hp)
Texas 6	**FHWA**	**Minimum**	**Maximum**	
5	6	15,000	46,000	220
6	7	20,000	53,000	250
7	8	25,000	52,000	250
8	8	28,000	66,000	310
9	9	30,000	80,000	380
10	10	32,000	87,000	410
11	11	35,000	92,000	440
12	12	35,000	106,000	500
13	13	35,000	120,000	570

Table 10. Truck Type Distribution for Rural Texas Conditions.

Truck Class	ATR Station 13D (40% Weight) (Daily Volume)	ATR Station 198 (60% Weight) (Daily Volume)	Final Distribution (Percent)
5	345	546	8.2
6	48	53	0.9
7	6	6	0.1
8	180	62	1.9
9	3169	5817	83.5
10	49	20	0.6
11	135	285	3.9
12	36	60	0.9
13	0	1	0.0

undesirable results in VISSIM, wherein following vehicles would overtake leading vehicles in the same lane when the leading vehicles decelerated (say, due to downstream congestion or slowing on grade). Researchers contacted VISSIM developers about the issue and learned that the new profiles had unrealistic values for deceleration. VISSIM personnel stated that the engine alone would cause a deceleration of -3 ft/s^2 even without using the brakes.

While reviewing the literature sources for acceleration and deceleration values, analysts discovered that the values provided in those sources were primarily geared toward design rather than based on measured vehicle performance and that the primary sources were, in some cases, 10 or more years old. Because vehicle performance has improved over time and because model values need to be vehicle-performance based rather than design values, analysts determined that the VISSIM default values were the most reliable current source of this information and restored them in the model *(57)*.

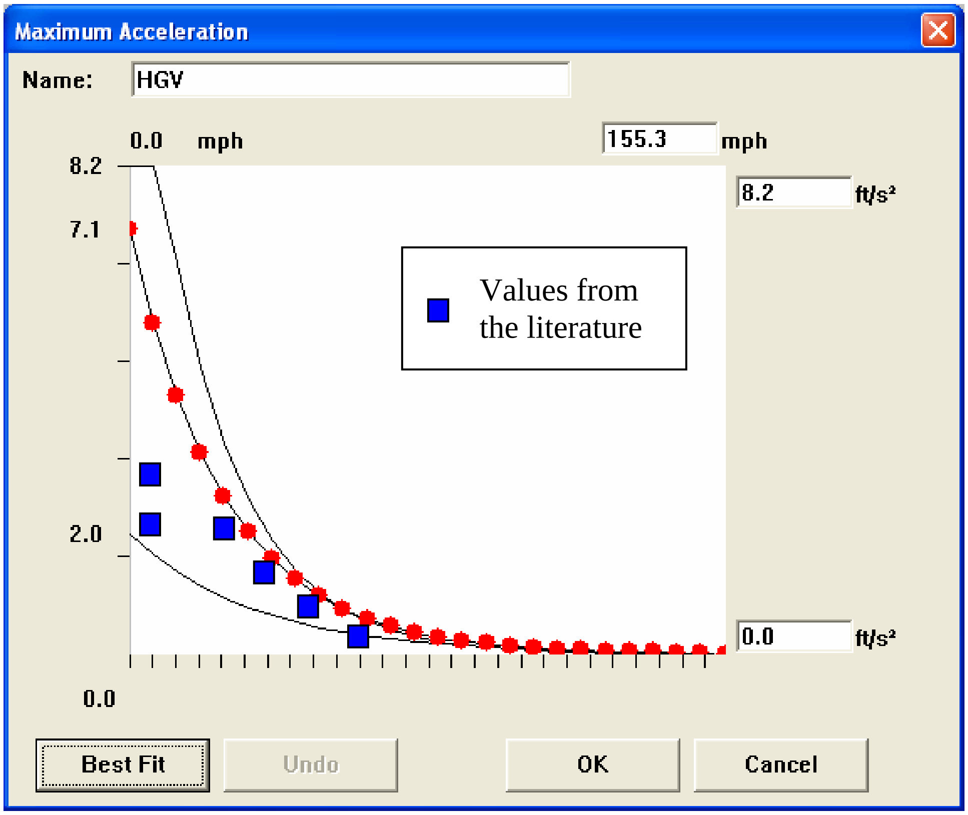


Figure 5. VISSIM Maximum Acceleration for Trucks.

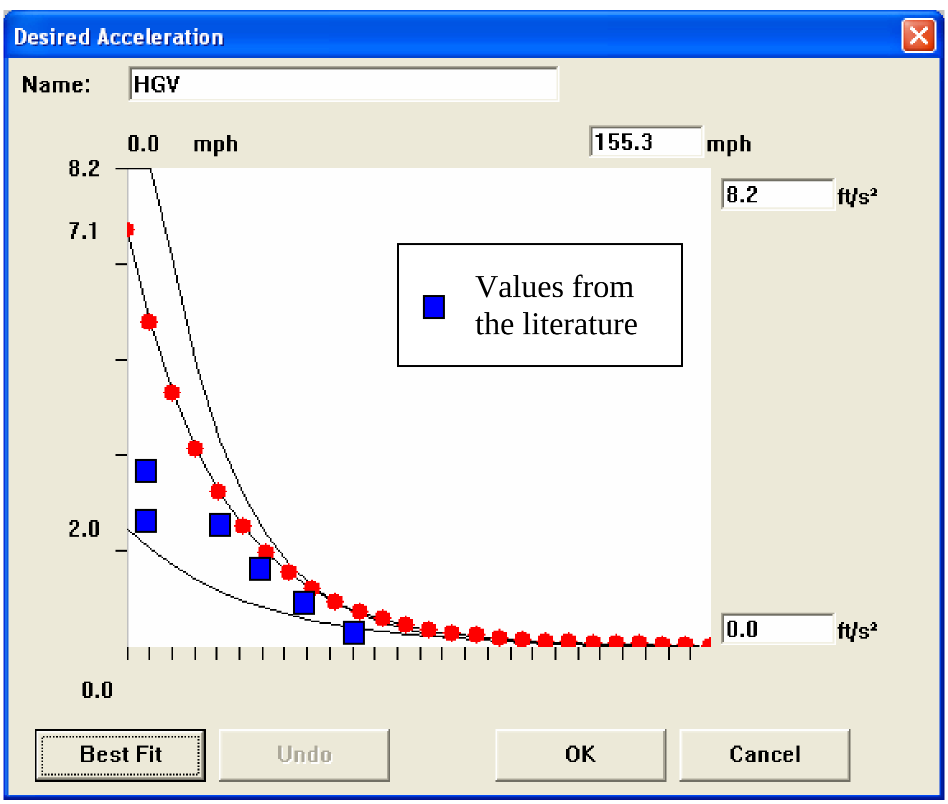


Figure 6. VISSIM Desired Acceleration for Trucks.

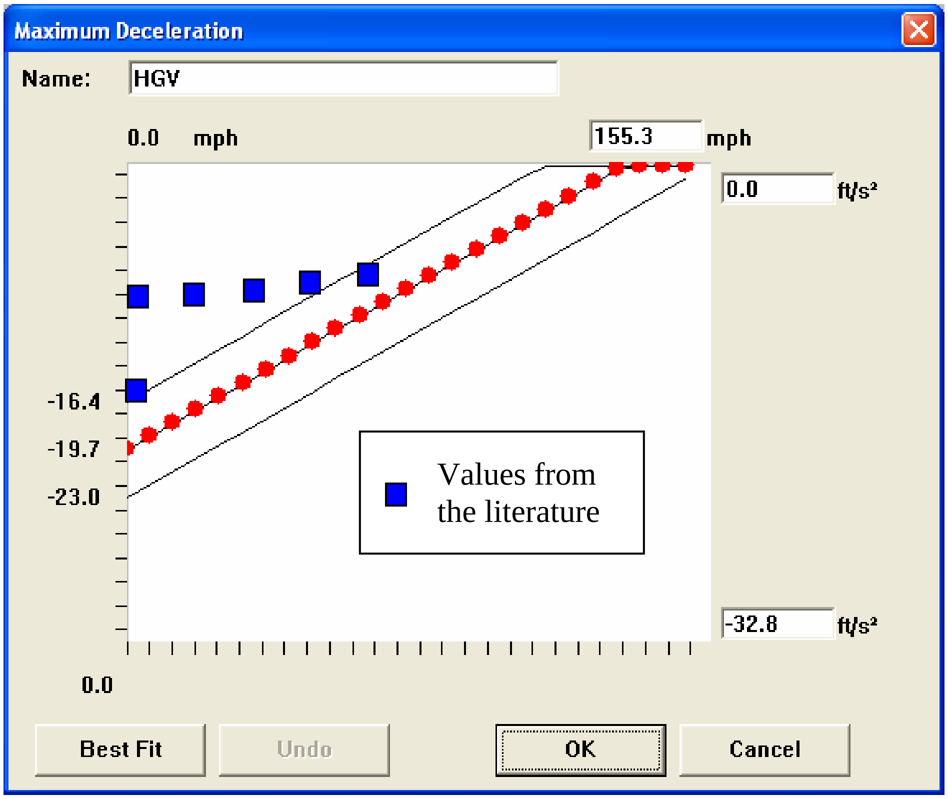


Figure 7. VISSIM Maximum Deceleration for Trucks.

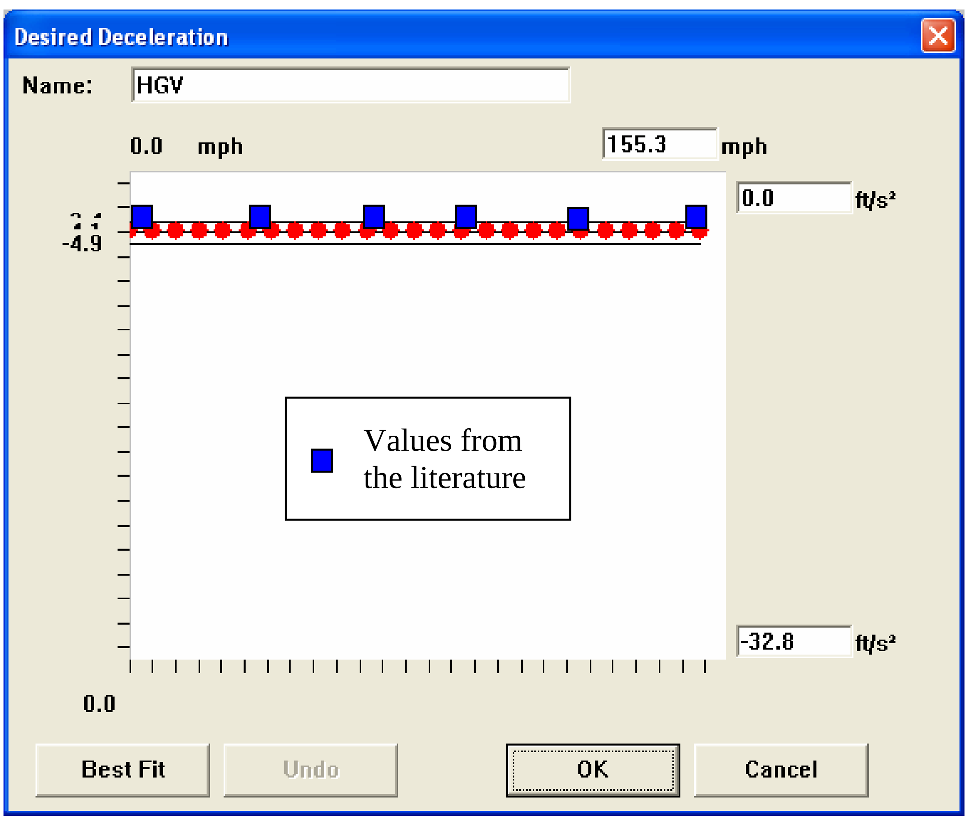
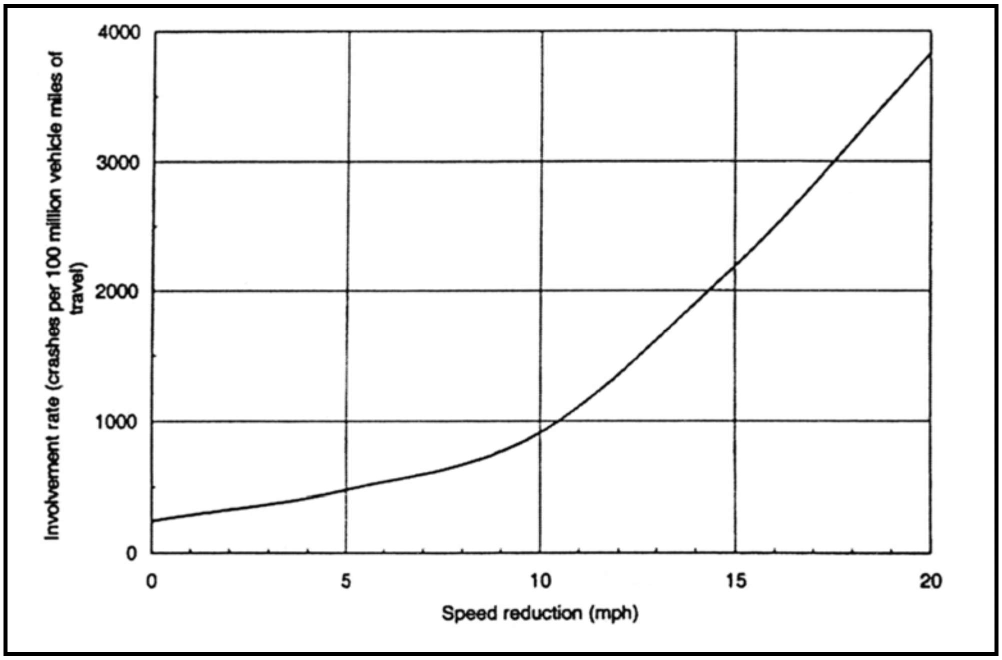


Figure 8. VISSIM Desired Deceleration for Trucks.

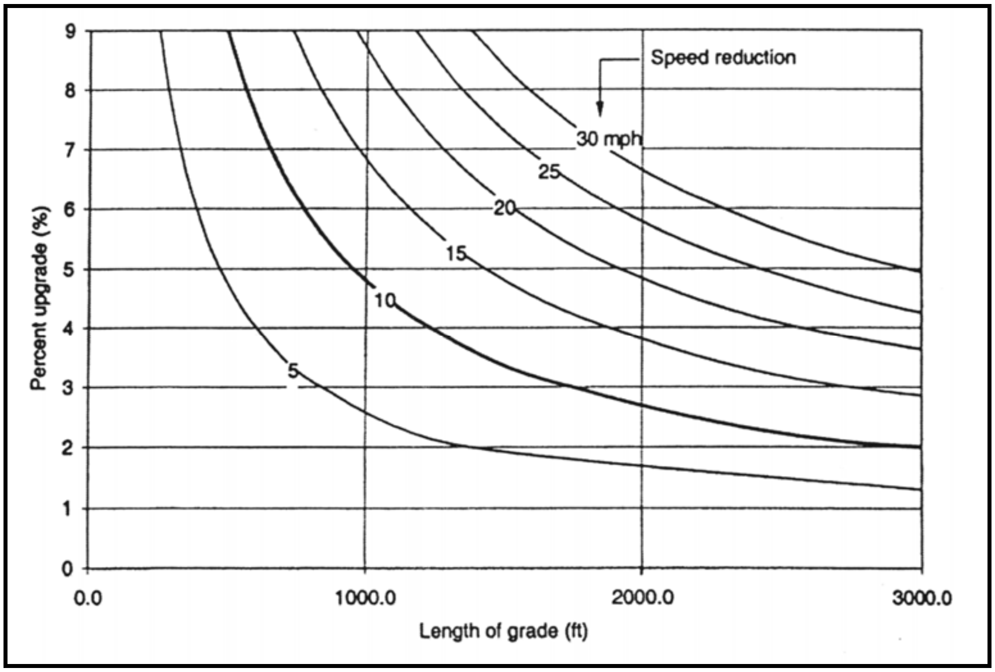
3.3.2.5 Truck Facility Modeling

Before simulation modeling could begin, it was necessary to design a simulation experiment that would produce capacity estimates for the types of terrain expected in rural Texas. Because trucks were the design vehicle and the facility type was access-controlled (i.e., truck-only roadways are currently envisioned as uninterrupted flow facilities), analysts decided on a range of grades from 0 to 4 percent. Information from the *Green Book (58)* provided guidance on lengths and percent of grade that limit speed differentials to 10 mph or less to reduce crash potential (see Figure 9). Figure 10, also from the *Green Book*, provides further information on the maximum lengths of grades that would produce a certain reduction in speeds. To ensure speed reductions of no more than 10 mph, grade lengths can be no more than 0.5 mile on 2 percent grades and 0.25 mile on 4 percent grades.



Source: Reference (58).

Figure 9. Speed Differential Impacts on Truck Crash Involvement.



Source: Reference (58).

Figure 10. Critical Length of Grade for Trucks (200 lb/hp and Entering Speed of 70 mph).

A random number generator identified which segments along the 20-mile section would be upgrade, level, or downgrade in both the 2 percent and 4 percent (graded) simulations. This activity produced a "terrain model" that defined the geometry of the truck lane simulation along its length. For each of the graded simulations, it was also necessary to know how much of the terrain surface would have grade; essentially determining how "rolling" the terrain would be. Analysts used past modeling experience and knowledge of rural Texas terrain to select 20 percent and 40 percent grade coverage. Thus, where grades were present there was either 20 percent of the roadway with an upgrade or a downgrade (to simulate lightly rolling conditions) or 40 percent of the roadway with an upgrade or a downgrade (to simulate rolling conditions). Neither grade nor severity of terrain in Texas warranted simulation of mountainous conditions. Each of the five geometric cases that VISSIM ultimately simulated were:

- 0 percent grade;
- 2 percent grade (low grade), 20 percent coverage (gently rolling);
- 2 percent grade (low grade), 40 percent coverage (rolling);
- 4 percent grade (moderate grade), 20 percent coverage (gently rolling); and
- 4 percent grade (moderate grade), 40 percent coverage (rolling).

Another detail that required resolution was the access density, or the spacing of entrance and exit ramps along the access-controlled truck lanes. Again, the facility purpose—providing trucks with connectivity between major urban areas and/or national borders—guided the simulation design and indicated that ramps would be relatively infrequent. Accordingly, analysts decided to analyze a 20-mile section of truck lane facility with zero, two, and five interchanges.

To simulate realistic truck entry and exit volumes near urban areas, analysts set 1/3 of the freeway volume to exchange within the 20-mile simulation. In other words, 1/3 of the truckway volume would exit in the cases with two or five exit ramps, and that same number of trucks would enter at the entrance ramps. Since the exchange volume was constant and the number of ramps changed across the simulation cases, the simulations with lower numbers of ramps would experience higher entry and exit ramp volumes before reaching LOS E on the mainline.

The three interchange conditions that analysts applied to the five geometric cases were:

- no interchanges in 20 miles,
- two interchanges in 20 miles (two entry and two exit ramps), and
- five interchanges in 20 miles (five entry and five exit ramps).

The final combination of five geometric conditions and three ramp frequency conditions resulted in the creation of 15 simulation cases to be developed in VISSIM.

3.3.2.6 VISSIM Coding

Unlike most other traffic simulation models, VISSIM does not rely on a link-node structure, where links represent roadways and nodes represent junctions. Rather, links are used to represent roadways and are continuous (even through interchanges) as long as the fundamental geometry (i.e., primarily, the number of lanes) remains constant. Where interchanges occur, connectors provide turning and/or merging/diverging vehicles with a path off of one link and onto another.

VISSIM models freeway (in this case, truckway) sections as continuous links to the extent possible. The addition or subtraction of a lane due to lane drops/additions and exit/entrance ramps are cases where link breaks are necessary. If exit or entrance ramps merge/diverge from the freeway and no lane drop or lane addition is necessary, no link break is necessary for the mainlanes. Each of the exit ramps in the truckway simulation was modeled without a link break (i.e., as a simple diverge onto the exit ramp).

For each freeway link, analysts must enter the basic properties of the link, including the number of lanes, whether it is a freeway (rather than an arterial) link, lane width, gradient, and other factors. Link identification is automatically incremented, and the program computes the length of the link from the background scale within the user interface. As a rough rule of thumb, it is desirable to contain as many lanes as possible within the directional roadway section, as lane changing is only allowed within links that have multiple lanes. In other words, any lanes across which lane changing is allowed in the field or design plans must be contained within the cross section of one link. To more realistically represent roadway curvature, the program allows intermediate points within a link for adding curvature and geometric splines to longitudinally smooth the link.

Connectors join together separate links that will ultimately constitute the travel lanes for one direction of flow along the truckway. When placing connectors, the manner of connection (i.e., lane continuity and connectivity) to adjacent upstream and downstream links is specified. Connectors also allow for the junction of ramps with a freeway link. Again, the lane connectivity is specified. In the case of exit ramps, either turning percentages or routing decisions offer ways to deliver the appropriate level of traffic to the ramp. For entrance ramps, the type of entrance ramp dictates how the merge with the freeway is coded. For forced merges that do not have a supplemental or acceleration lane, VISSIM applies yield rules which make the ramp “yield” to the freeway in cases of vehicular conflict. For entrance ramps with a lane addition and/or a significant acceleration lane, the ramp is simply connected to the appropriate lane of the freeway.

Figure 11 includes diagrams of the links and connectors used in the truckway simulation. Note that in the case of the exit ramp, the mainline truckway link is continuous. In the case of the entrance ramp, it is necessary to break the truckway mainlanes to allow for an acceleration lane for the entering vehicles. Links also had to be broken to allow for different grades along separate segments of the truckway.

Analysts used the coding techniques shown in Figure 11 to code all of the geometric and ramp frequency cases. In each case, they reviewed the model as a quality control check, then resolved any discrepancies. To determine the capacity (or maximum flow) in each case, analysts increased the input volume (and ramp volumes changed accordingly so that 1/3 of the volume entered/exited along the length of the 20-mile simulation) until mainline operations could process no more vehicles.

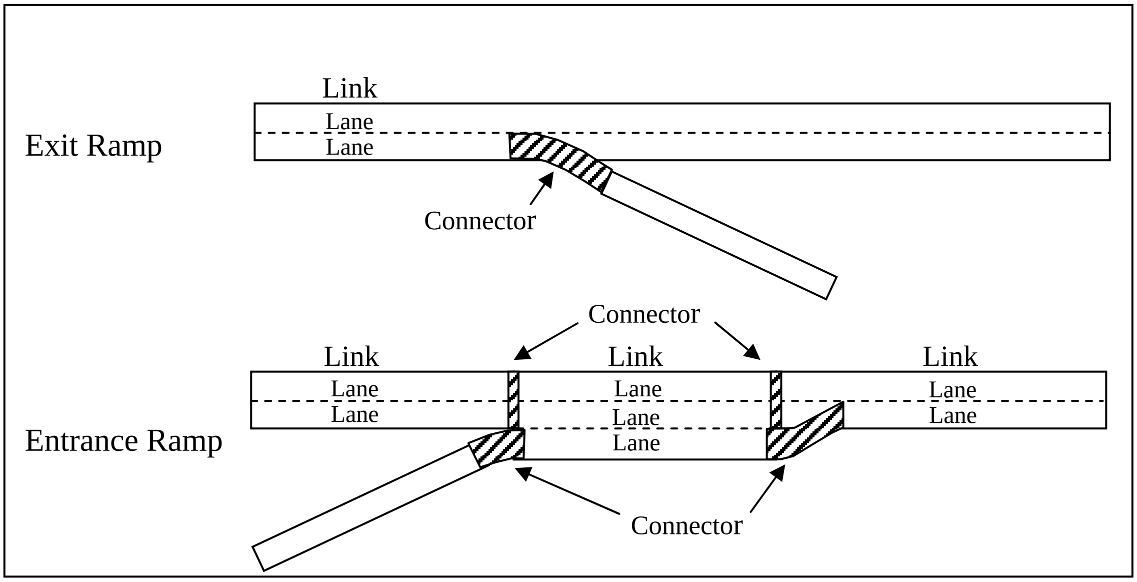


Figure 11. VISSIM Coding of Links and Connectors for Entry and Exit Ramps.

In the base case where no interchanges or grades are present, the capacity value represents true capacity – the maximum number of trucks that can be processed by a lane within an hour. In all of the other cases, the capacity is the maximum flow realized under prevailing conditions of grade, ramp volume, and ramp frequency. The truck distribution which was developed for this analysis and which is intended to represent rural Texas influences all cases.

Figure 12 provides a view of the VISSIM model, showing congestion building at a truckway entrance ramp. Traffic congestion around entrance ramps such as that shown was a major factor (along with truck performance on grade) in determining the capacity of the truckway facility in each of the simulation cases.

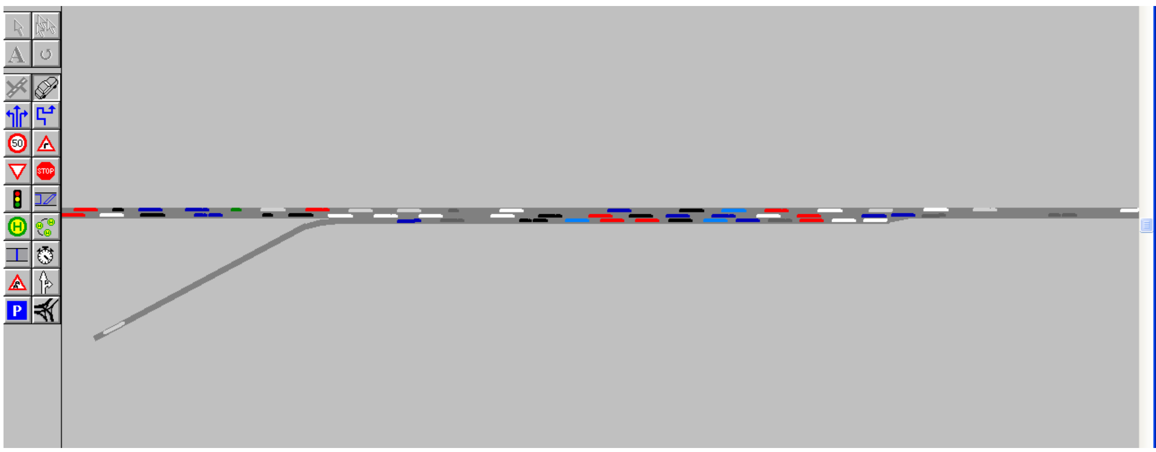


Figure 12. VISSIM Screen Showing Entrance Ramp Congestion.

3.3.2.7 Results

Table 11 indicates capacity values in terms of maximum achievable flow for each of the fifteen simulation cases. The maximum truck capacity achieved was 1475 t/h/l, and the minimum capacity under prevailing conditions was 1025 t/h/l (where the grade was 4 percent, grades were found on 40 percent of the road length, and there were five interchanges per 20 miles). In general, higher volumes per ramp (i.e., the two interchange per 20 mile cases rather than the five interchanges per 20 miles) had a stronger influence on capacity, but closer ramp spacing increased the likelihood that a ramp would merge at an upgrade. In addition to the results, observation of the cases and their performance led to the following general conclusions:

- The maximum desirable entering truck ramp volume under high volume conditions (i.e., v/c ratio 0.85 and above) is 350 t/h/l. Entrance ramp volumes higher than this value tend to create unstable flow, especially in more demanding terrain.

- Designs that include entrance ramps at or approaching a grade on the truck facility disproportionately reduce capacity on the mainlanes. Where grades are low (i.e., 2 percent), capacity is reduced to approximately 950 t/h/l. Where grades are higher (i.e., 4 percent), capacity is reduced to approximately 800 t/h/l. A separation distance of ½ mile or more is recommended between entrance ramp merges and roadway sections with uphill grades.

Table 11. Truck Facility Capacity (t/h/l [a]) Modeling Results from VISSIM.

Geometry (Case) Description	Grade	Longitudinal Coverage of Grade (%)	Interchanges Per 20 Miles		
			0	2 [a] (higher volume per ramp)	5 [b] (lower volume per ramp)
Level	0	0	1475	1175	1200
Low Grades/Gently Rolling	2	20	1425	1125	1175
Low Grades/Rolling	2	40	1425	1125	1175
High Grades/Gently Rolling	4	20	1225	1100	1075
High Grades/Rolling	4	40	1200	1050	1025

[a] t/h/l = trucks per hour per lane
[b] Interchange volume fixed at a level where 1/3 of mainline volume exits/enters over the 20-mile simulation; where fewer interchanges are present, ramp volumes are higher.

3.3.2.8 Truck Facility Design and Operations

With truck facility capacity established and the quantity of trucks (per lane) that can be accommodated under various geometric and weaving conditions known, the next steps of the traffic operations research relate to the basic design of truck facilities. Decision-makers must address the number of lanes necessary to accommodate trucks at a reasonable level of service on their own roadway *(48)*. Likewise, the auto facility will need fewer lanes by removing the volume and operational effects of truck traffic.

The next stages of the analysis, then, were designed to develop a methodology for assigning level of service values to truck-only facilities using the basic capacity values established in this research and following the methodology presented in the HCM *(48)*. Once these values were determined, modeling was used to identify the number of lanes necessary to accommodate varying volumes of traffic, different proportions of heavy vehicles in the vehicle stream, and different quantities of entering and exiting ramp traffic in mixed-flow and truck-only/auto-only freeway corridors with different geometric conditions (terrain and percent of grade). Finally, once all basic design considerations for mixed-flow, truck-only, and auto-only freeway facilities were known, different simulations were performed to develop representative performance data (delay, fuel consumption, and emissions) for each roadway condition.

3.3.2.9 Determining Truck Facility Level of Service

The development of LOS tables for truck-only facilities was a straightforward process once the basic lane capacity value was known. Utilizing the same ratios provided for mixed flow traffic in LOS tables contained in the HCM, LOS ranges for trucks were established for the maximum density, minimum speed, maximum volume/capacity ratio, and maximum service flow *(48)*. After these values were established for 70-mph roadways, they were then developed for 65-mph truck roadways using the same proportions of LOS indicators between the two different design speed tables given in the HCM for mixed flow traffic. Table 12 shows 70-mph LOS values, while Table 13 shows 65-mph values.

Table 12. Truck Facility LOS Criteria – 70 mph.

LOS Criteria	A	B	C	D	E
Max. Density (t/mi/ln)	6	9	13	18	23
Min. Speed (mph)	70.0	70.0	69.2	66.2	62.5
Max. *v/c*	0.32	0.53	0.74	0.90	1.00
Max. Service Flow (t/h/ln)	460	760	1070	1300	1450

Table 13. Truck Facility LOS Criteria – 65 mph.

LOS Criteria	A	B	C	D	E
Max. Density (t/mi/ln)	6	9	13	18	23
Min. Speed (mph)	65.0	65.0	65.0	64.2	61.2
Max. *v/c*	0.30	0.50	0.71	0.89	1.00
Max. Service Flow (t/h/ln)	420	710	1020	1260	1420

3.4 TRUCK CRASHES AS A CRITERION

3.4.1 Introduction

Recent studies that have evaluated the safety effects of truck traffic levels on freeway facilities have been quite sparse *(64, 65, 66)*. In addition, these studies have not provided clear understanding, if not contradictive outcome, on how different truck traffic levels affect the number of crashes. So far, no studies have specifically compared passenger cars-only with mixed traffic freeway facilities. As a result, there is a need to assess whether or not more homogeneous flows of traffic by vehicle type are safer than the current mixed flow scenario.

To accomplish the objective of the study, researchers conducted an exploratory analysis of crash data on a selected number of freeway sections located on the New Jersey Turnpike for the year 2002. These sections operate as a dual-dual freeway facility: divided inner and outer lanes. This type of geometry offers more flexibility in closing part of the freeway for maintenance activities or incidents. The turnpike's traffic operations staff can easily shift traffic from one roadway to the other using changeable message signs. In fact, shifting the traffic need not just occur due to incidents or maintenance; it could happen just to balance the flows. Under normal circumstances, the inner lanes have only passenger cars, so the outer lanes serve commercial vehicles (trucks and buses) plus passenger cars. The selected sections, therefore, offer a good opportunity to compare the crash experience between passenger car-only and mixed traffic rural freeway facilities. Finally, it is important to point out that the dual-dual freeway with exclusive passenger car lanes in New Jersey is the only type of facility of its kind and length in North America.

The next few sections describe the process used to evaluate the crash data. The first section presents a review of previous research on exclusive and mixed traffic facilities and their effects on safety and operations. The next section summarizes the data collection effort and discusses the characteristics of the study sections. The third section describes the results of the exploratory analysis. The last section presents a discussion of important issues and offers avenues for further work on this topic.

3.4.2 Previous Work

Very few studies have examined how the level of truck traffic affects safety on freeway facilities. There exist studies that looked at the safety effects of different truck traffic control strategies (e.g., lane restrictions, exclusive truck lanes, etc.), but very few addressed regular mixed traffic facilities. For instance, Jovanis and Chang studied the safety effects of traffic exposure by vehicle and collision types on Indiana highways *(64)*. They found that increased truck traffic is usually associated with an increase in the number of crashes, although the relationship increases at a decreasing rate for all truck-related crashes. On the other hand, Hiselius reported that as the number of trucks increases a decrease in the number of crashes could be observed on 83 rural highway sections in Sweden *(65)*. She attributed this effect to the lower average vehicle speed in the traffic stream when the proportion of trucks increases. Nonetheless, she indicated that the low sample size may have affected the conclusions of the study.

3.4.3 Data Collection

This analysis used two study sections; they are located on the northern part of the New Jersey Turnpike, near the Garden State Parkway (see Figure 13). The first study section is situated between interchanges 10 (milepost [MP] 88.1) and 11 (MP 90.6) for a total length of 2.5 miles. On this section, both inner and outer segments have three lanes in each direction. The second section is located between interchanges 11 and 12 (MP 95.9) for a total of 5.3 miles. The inner segment contains three lanes per direction, while the outer segment has four lanes per direction. The left lane on the outer segment is used as an HOV lane during the a.m. peak period, and no trucks are allowed to use it. Trucks are restricted to the right two lanes in both the four-lane outer roadway and on the inner roadway if they happen to be diverted for some reason. All sections have 12-ft lanes with 12-ft paved shoulders on the right side of the traveled-way. The posted speed limit is 65 mph for both study sections, but turnpike personnel can reduce the speeds as needed via dynamic speed limit signs.

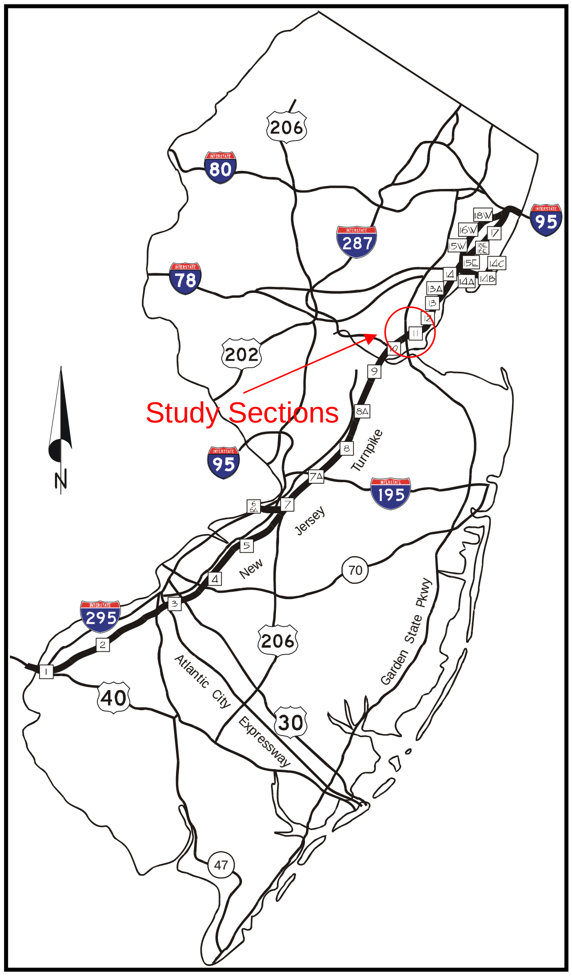


Figure 13. Location of Study Sections on the New Jersey Turnpike.

The study period covered crashes that occurred in year 2002. Crash data contained detailed information about the severity, the location, the crash type, the type of vehicle, the day of the week, the direction of travel, and the time of day, among others. The data were initially obtained as a printed computer output and eventually coded into an electronic database. In 2002, there were 298 crashes, of which 78 involved trucks. The seven crashes that occurred on exit or entrance ramps were eventually removed from the analysis to minimize the influence of these ramps on crashes. Thus, all crashes used in this work occurred on the mainline.

Traffic flows in annual average daily traffic were obtained from the New Jersey Turnpike Authority. The data were available for each section and separated by vehicle class and by direction. The data are collected for nine different vehicle classes (e.g., passenger cars, two-axle trucks, tractor-trailers, two- and three-axle buses, etc.). As stated above, only passenger cars (Class 1) are allowed in the inner lanes (again, except for incidents, maintenance, and lane balancing). The split for passenger car traffic between the inner and outer lanes is about 65 percent and 35 percent, respectively. Table 14 summarizes the AADT by vehicle class (1 = passenger cars; 2 to 9 = trucks and buses). This table shows that about 30 percent of the vehicular traffic on outer lanes is heavy vehicles.

Table 14. AADT by Direction and Type of Traffic.

Interchanges	Inner Lanes Total	Outer Lanes Passenger Cars	Outer Lanes Trucks	Outer Lanes Total
Southbound				
11 to 10	56,074	30,194	10,091	40,285
12 to 11	66,713	35,922	11,839	47,761
Northbound				
10 to 11	59,453	32,013	10,920	42,933
11 to 12	68,611	36,945	11,929	48,874

3.4.4 Crash Data Analysis

This section describes the characteristics of crashes that occurred between mile markers 88.1 to 95.9 on the New Jersey Turnpike in 2002. It first presents information on the general characteristics of crashes occurring on selected sections. Then, it summarizes passenger car and truck-related crashes between the inner lanes (passenger cars only) and outer lanes (mixed traffic).

3.4.4.1 General Characteristics

As reported above, a total of 298 crashes occurred on the New Jersey Turnpike in 2002. Table 13 depicts the number of crashes by collision type and whether the crash occurred in the outer or inner lanes. This table shows that sideswipe collisions occur more frequently than any other type of crashes in both the inner and outer lanes. Table 15 also illustrates that more crashes per mile occur in the outer lanes than in the inner lanes.

Table 15. Crashes by Type and Lane Designation.

Accident Type	Outer Lanes	Inner Lanes	Total
Ran-off-road	11	2	**13**
Collision with an object	22	31	**53**
Collision with a guardrail	29	24	**53**
Rear-end	43	31	**74**
Sideswipe	50	30	**80**
Others	20	5	**25**
Total	**175**	**123**	**298**
Miles	7.8	7.8	**7.8**
Crashes/mile	**22.44**	**15.77**	**38.21**

Also, total rear-end collisions occur more frequently in the outer lanes than inner lanes, which may suggest that traffic flow is subjected to more unstable traffic conditions (or non-homogeneous flow). Similarly, sideswipe collisions occur more frequently in outer lanes. Interestingly, collisions with an object happen more frequently in the inner lanes. This finding may suggest that the lower undercarriage clearance of cars is a contributing factor in object collisions. In fact, the data show that very few heavy vehicles hit an object on the road.

Figure 14 shows the number of crashes by severity and excludes the cross-median collisions (eight) and the uncategorized or unknown crashes (three); these crashes could not be assigned using the criteria defined in this figure. This figure shows the data by direction of traffic, i.e. northbound and southbound, as well as by lane designation, i.e. inner and outer lanes. Figure 14 shows that property damage only (PDO) crashes account for about 75 percent of all crashes; there were no fatal crashes in 2002 on these two sections. Interestingly, there are proportionally more PDO crashes on outer lanes than inner lanes. This indicates that the speed of traffic is probably lower in outer lanes than inner lanes. Higher vehicle speed is associated with higher occupant injury severity *(67)*. Finally, the northbound and southbound lanes experience similar numbers of crashes in both lanes.

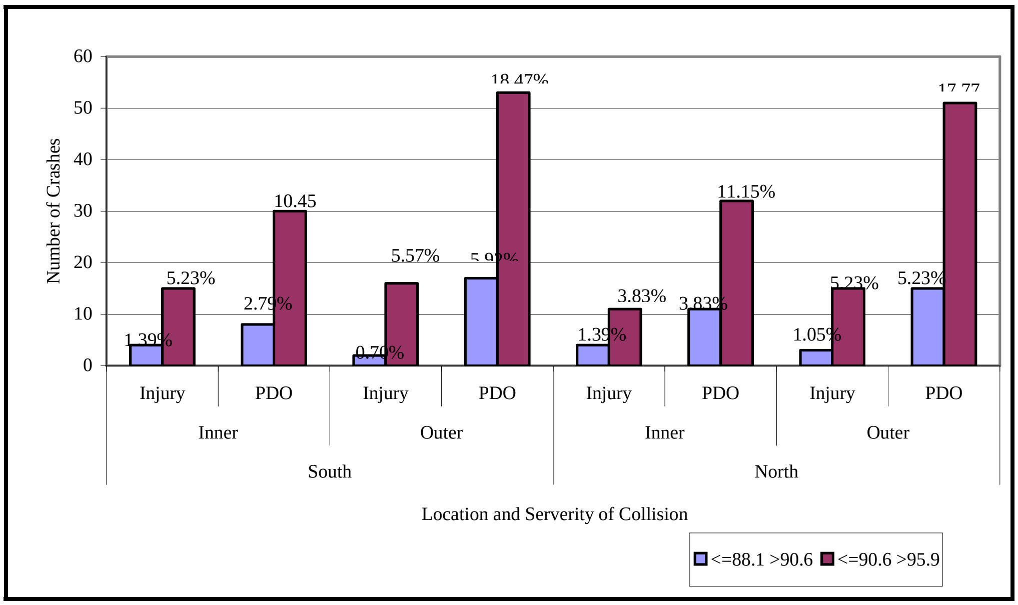


Figure 14. Number of Crashes by Direction, Lane Designation, and Severity.

Figure 15 shows the number of vehicles involved in a crash. The figure reveals that more single vehicle crashes occur on inner lanes than outer lanes with about 30 percent and 50 percent of all crashes, respectively.

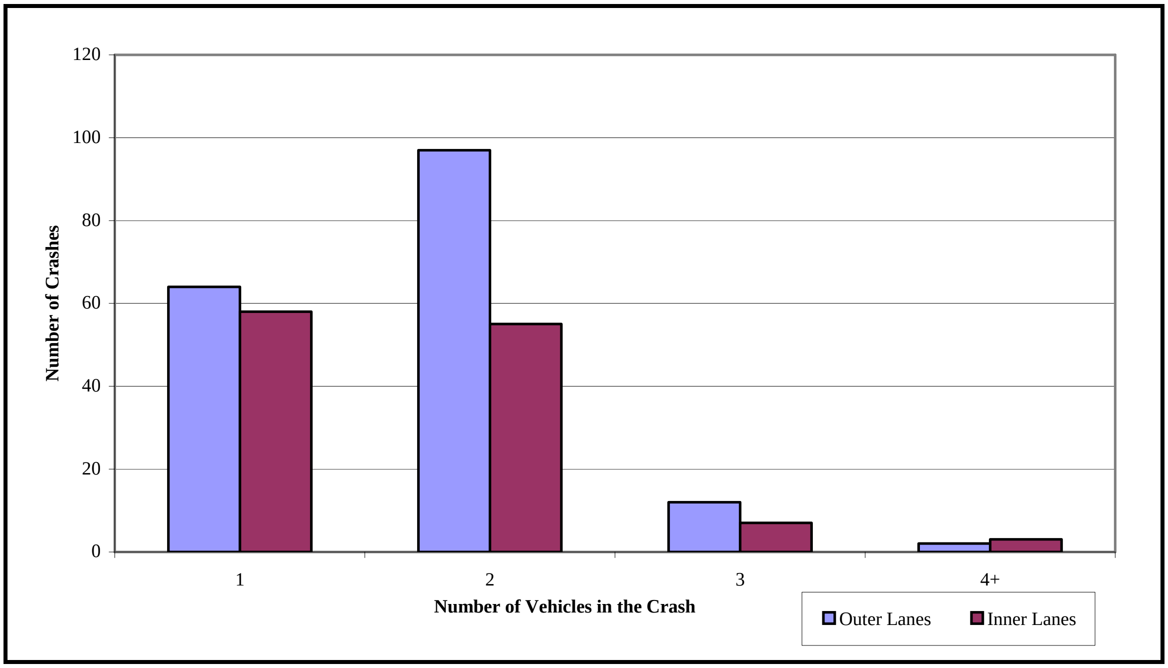


Figure 15. Number of Vehicles Involved in a Crash.

Figure 16 illustrates the number of crashes by weather conditions. This figure shows that more than 80 percent of crashes occurred during clear conditions. As expected, the outer lanes experience more crashes than the inner lanes for all types of weather conditions.

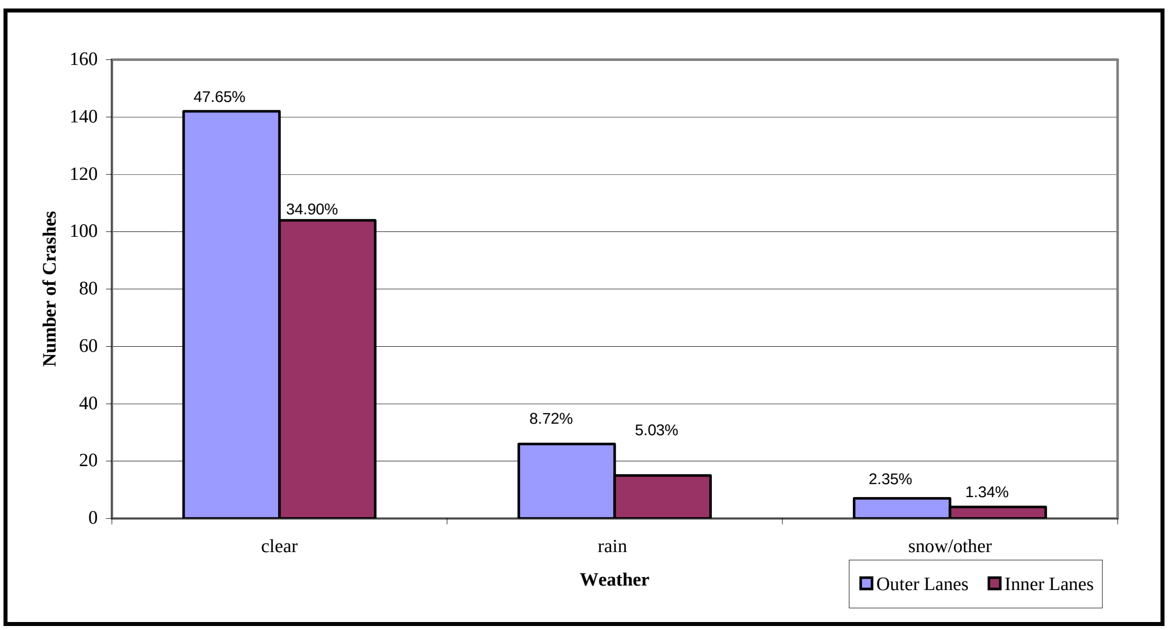


Figure 16. Number of Crashes by Weather Conditions.

Figure 17 shows the number of crashes by day of the week. This figure shows that outer lanes have a higher percentage of crashes occurring during a week day than inner lanes. On weekends, the inner lanes experience more crashes than week days. As shown in the next section, the higher percentage of crashes in the outer lanes on week days may be attributed to truck traffic.

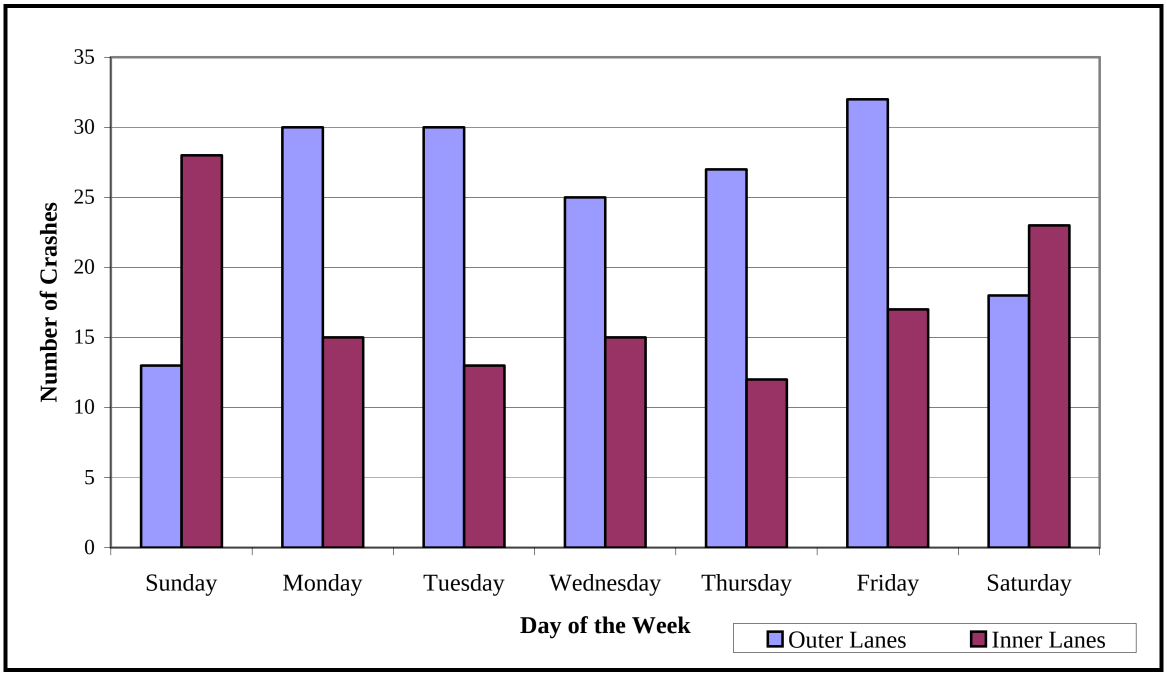


Figure 17. Number of Crashes by Day of the Week.

3.4.5 Truck Related Crashes

Figure 18 illustrates the types of crashes for passenger cars and trucks. As this figure indicates, about 45 percent of all truck-related crashes are categorized as sideswipe collisions. This finding is similar to previous work on this subject *(66)*. However, trucks are not over-involved in rear-end collisions and run-off-the-road crashes, as reported in the referenced research (Golob and Regan). As indicated above, passenger cars collide more frequently with an object on the pavement than trucks. Finally, passenger cars hit the guardrail more frequently than trucks.

Figure 19 illustrates the severity of the crashes as well as the lanes in which they occurred. A few truck crashes occurred on the inner lanes when the outer lanes were closed. The severity pattern for passenger cars is very similar between inner and outer lanes. Figure 20 shows the number of crashes by the day of the week for trucks and cars, respectively, as well as inner and outer lanes. As illustrated in Figure 19 and initially shown in Figure 17, the outer lanes experience a large number of truck-related crashes. If truck-related crashes were removed from the inner lanes, the outer lanes would roughly experience the same amount of crashes during the week days. As expected, very few truck crashes occur during the weekend because trucks travel less frequently during this period.

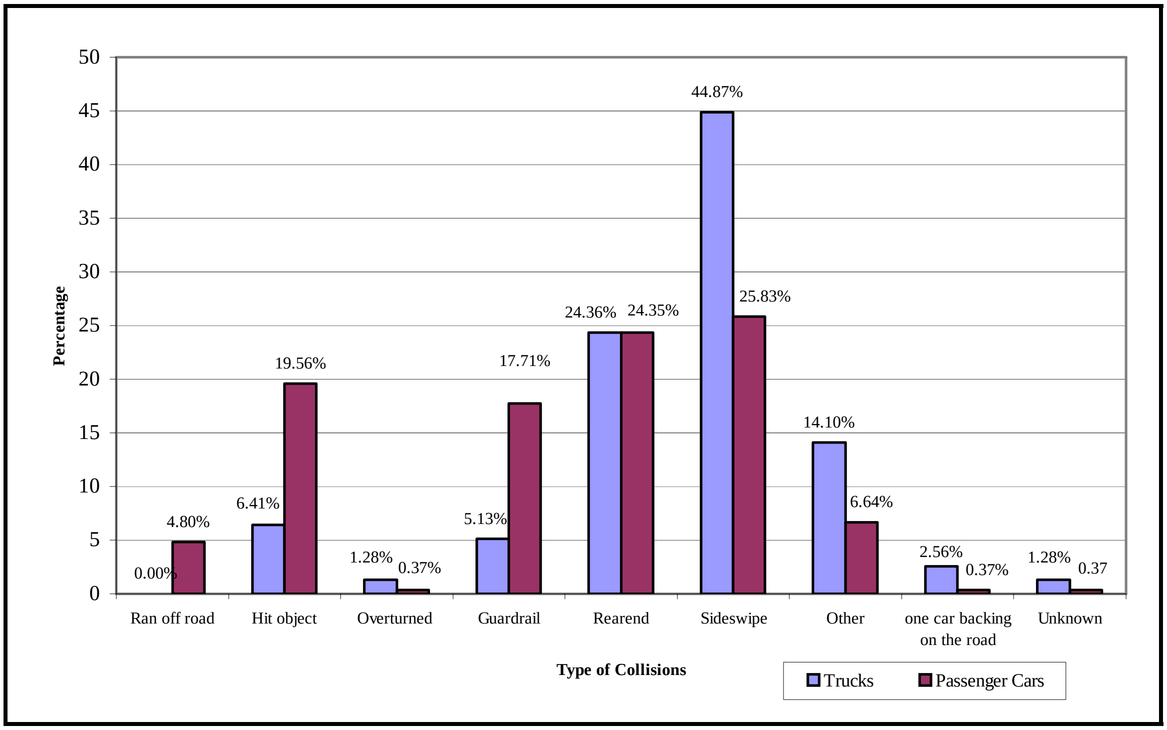


Figure 18. Percentage of Crashes by Collision Type for Trucks and Passenger Cars.

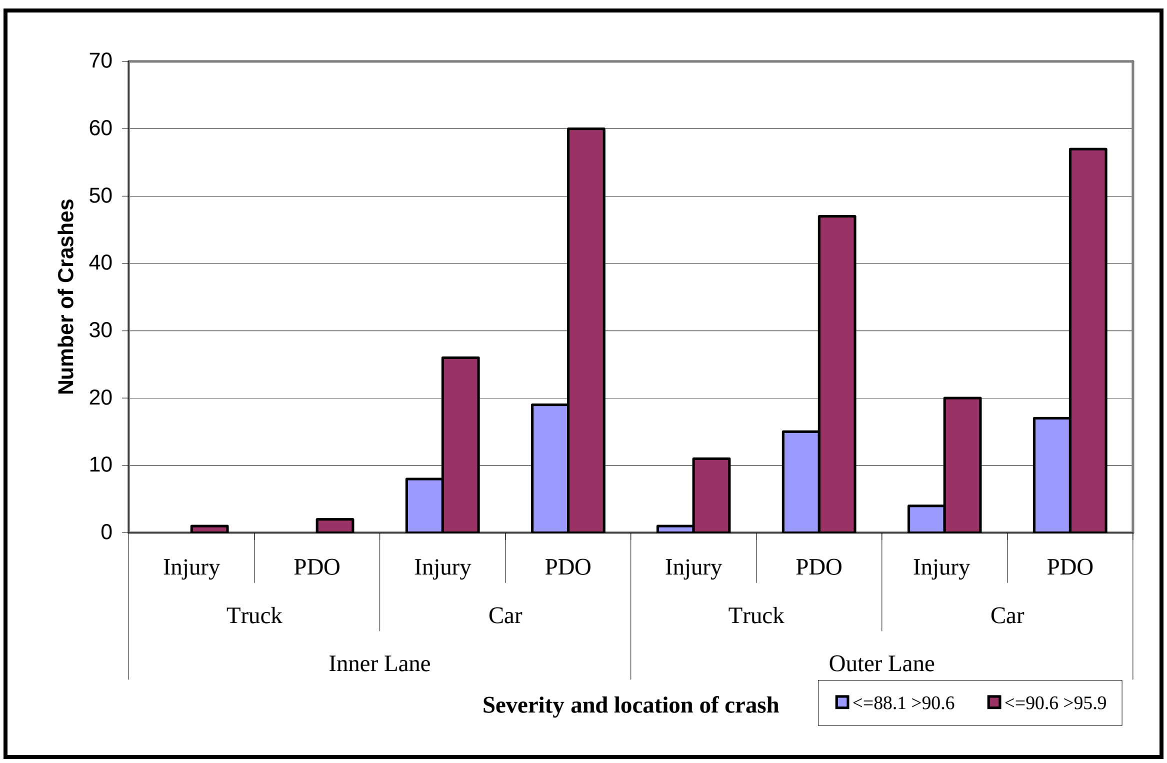


Figure 19. Number of Crashes by Type of Vehicle, Lane Designation, and Severity.

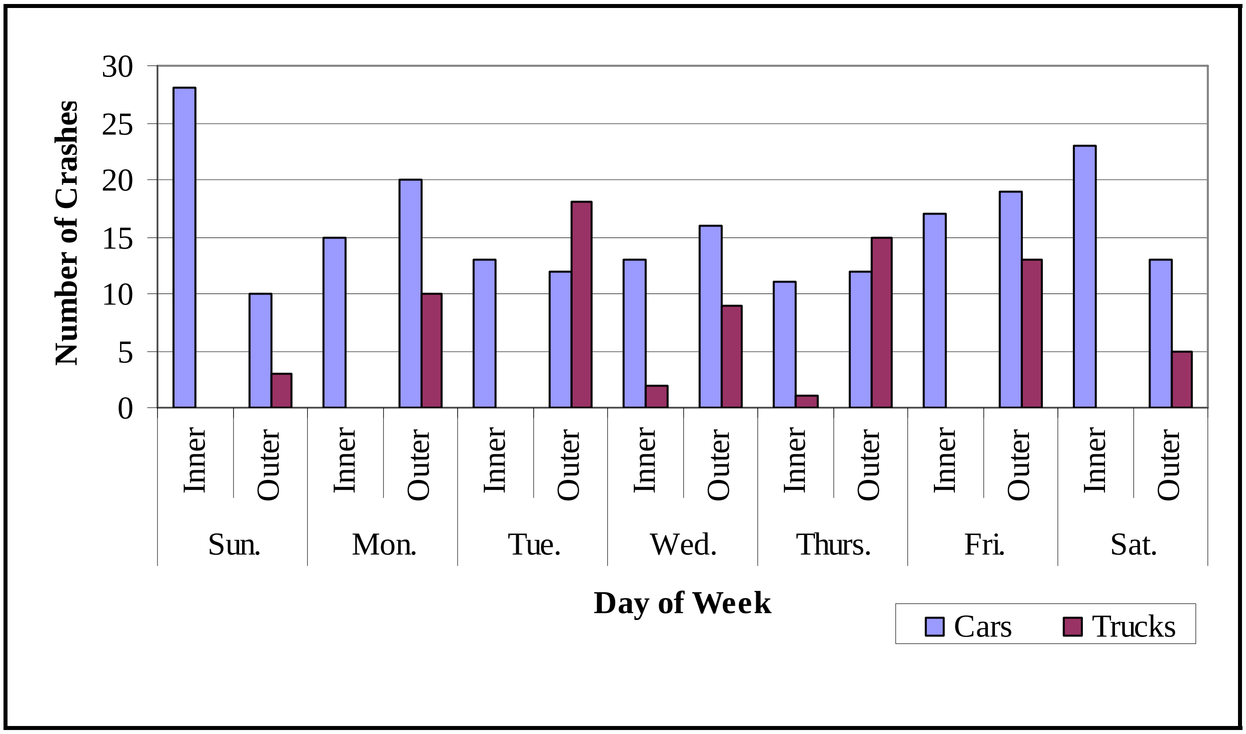


Figure 20. Number of Crashes by Day of the Week, Location, and Vehicle Type.

Figure 21 illustrates the severity of the crash by type of vehicles involved in the collision. As can be observed, a larger proportion of crashes leading to an occupant injury occur when a truck is involved in a collision. Very few single-truck or truck versus truck crashes caused an injury.

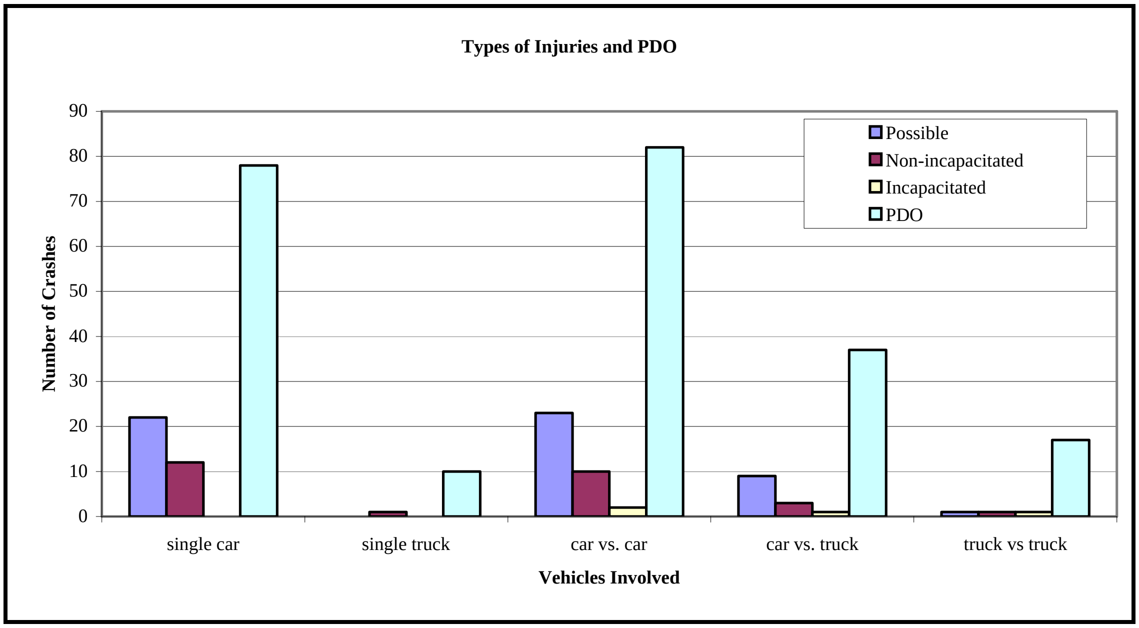


Figure 21. Number of Crashes by Vehicle and Severity Type.

Table 16 summarizes the crash rate (in 10^8 vehicle-miles) by direction of travel and mile markers. This table shows the rates (all crashes) as a function of the combined passenger car, bus, and truck exposure (all vehicles). It is important to point out that the relationship between crashes and exposure has usually been found to be non-linear *(68, 69)*. There were not enough observations, in this study, to properly test this assumption. Thus, a simplification (i.e., using crash rates) had to be made for this part of the analysis. Table 16 suggests that the crash rate in the outer lanes is almost double that in the inner lanes, given the same exposure. This outcome may indicate that truck traffic had an influence on crashes. Finally, the rates for the northbound and southbound traffic provide similar values, similar to what was reported above.

Table 16. Crash Rates for Full Data with Trucks and Cars.

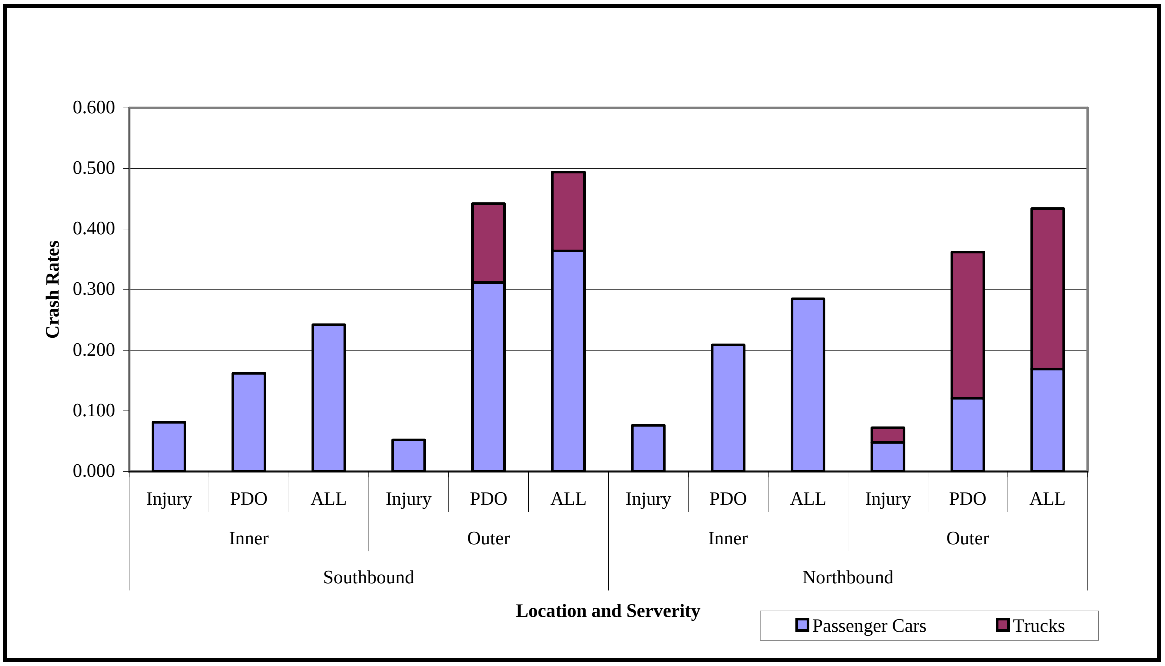
	SOUTHBOUND						NORTHBOUND					
	INNER			OUTER			INNER			OUTER		
Mile Marker	Injury	PDO	ALL	Injury	PDO	ALL	Injury	PDO	ALL	Injury	PDO	ALL
<=88.1 >90.6	0.081	0.162	0.242	0.052	0.442	0.494	0.076	0.209	0.285	0.072	0.362	0.434
<=90.6 >95.9	0.120	0.241	0.361	0.165	0.546	0.711	0.086	0.250	0.335	0.144	0.491	0.635

Table 17 shows the crash rates by isolating the passenger car and truck traffic exposure (no bus exposure). In this table, for three out of four sections, truck-related crashes occur more frequently than passenger car only crashes given the same exposure. In other words, the number of truck crashes per truck is higher than the number of passenger car crashes per passenger vehicle, *ceteris paribus*.

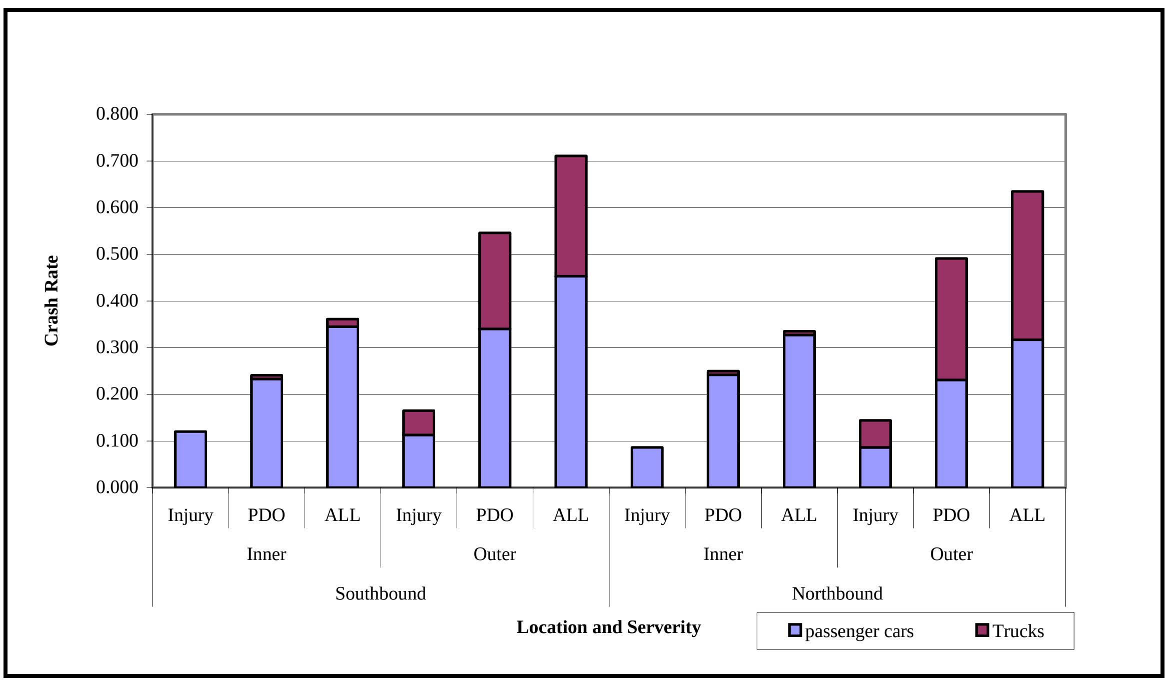
Table 17. Crash Rates for Trucks and Passenger Cars Disaggregated by Exposure.

		SOUTHBOUND						NORTHBOUND					
		INNER			OUTER			INNER			OUTER		
	Mile Marker	Injury	PDO	ALL	Injury	PDO	ALL	Injury	PDO	ALL	Injury	PDO	ALL
Trucks	<=88.1 >90.6	–	–	–	0.000	0.444	0.444	–	–	–	0.079	0.795	0.874
	<=90.6 >95.9	–	–	–	0.181	0.724	0.905	–	–	–	0.200	0.898	1.131
Cars	<=88.1 >90.6	0.081	0.162	0.242	0.075	0.450	0.525	0.076	0.209	0.285	0.071	0.133	0.133
	<=90.6 >95.9	0.112	0.233	0.345	0.164	0.492	0.656	0.078	0.250	0.328	0.130	0.348	0.478

Figure 22 shows the crash rates separated by passenger cars and truck-related crashes. This figure offers a clearer picture about the magnitude of truck-related crashes to the overall crash rate. On two of the four sections, truck-involved crashes are the majority; and on the other two sections, trucks are significant contributors to the overall crash rate. Most of the truck-related rates involve a truck and a passenger car.



a) Mile Marker 88.1 to 90.6



b) Mile Marker 90.6 to 95.9

Figure 22. Crash Rates for Trucks and Passenger Cars by Lane Designation.

3.4.6 Discussion of NJTA Crash Analysis

The results of the exploratory analysis show that the outer lanes experience more crashes than the inner lanes, both when raw numbers are used and when exposure is incorporated into the analysis. Given the outcome of the analysis, there is a need to determine the potential factors that could explain this difference. Possible hypotheses follow.

The analysis performed in this work seems to indicate that trucks have a strong influence on the safety of outer lanes. As a matter of fact, truck-related crashes account for more than 40 percent of all crashes occurring on the outer lanes, yet trucks account for only 30 percent of the traffic traveling on the outer lanes. This means that truck-related crashes are over-represented in outer lanes. Garber and Joshua noted the same outcome in their study of large-truck crashes in Virginia *(70)*. It is unclear whether truck traffic levels, highway geometrics, traffic flow states, or a combination of all these factors play a role in truck-related crashes.

As indicated above, the safety effects of truck levels, defined as homogeneous and non-homogeneous traffic flows, are currently not well understood *(64, 65)*. The two seminal studies arrive at opposite conclusions. Jovanis and Chang found that an increase in truck traffic increases truck-related crashes, whereas Hiselius established no such relationship. Thus, the jury is still out on this effect. If one makes abstraction of vehicle performance and its effects on traffic flow states (addressed below), the exploratory analysis shows that trucks are often involved in sideswipe collisions. It is a known fact that trucks have significant blind spots. Thus, it may be reasonable to assume that increased truck traffic may lead to more sideswipe collisions compared to a similar facility with passenger car only (though other types of crashes are expected to increase, such as run-off-the-road crashes).

Another hypothesis relates to differences in highway geometrics. For instance, controlling criteria governing relevant highway design elements, such as grades, lane widths, lateral sight distances, or horizontal curves, could affect the vehicle performance of trucks, thus negatively influencing the safety of the facility. At the study locations, however, the roadway geometry between inner and outer lanes is very similar. For instance, the typical cross-section, including the lane width, is essentially the same between both sets of roadways. Similarly, the selected study sections do not have any steep grades that would affect the performance of trucks. Perhaps the location of ramps could potentially explain the difference, especially since a large proportion of trucks are involved in sideswipe collisions (e.g., trucks that change lanes near entrance ramps). However, with the current database, it not possible to investigate whether or not crashes occurred near an exit or entrance ramp (i.e., the data do not indicate the lane in which the crash occurred).

The last hypothesis relates to the traffic flow states. A significant amount of research has occurred over the last two or three years on the safety effects of traffic flow states on urban and rural freeways *(71, 72, 73)*. The recent work has shown that vehicle density and volume-to-capacity ratios have a great impact on freeway safety, although the effects are more significant for urban freeways. Some have argued that a greater variance in the speed distribution of vehicles on a freeway segment increases the risk of collisions *(74, 75)*; however, not everybody agrees with this argument *(76)*. It is a well-known fact that increased truck traffic can have a significant impact on freeway operations *(48)*. Nonetheless, although a valid hypothesis, it is impossible to evaluate with the current data.

3.4.7 New Jersey Turnpike Crash Summary and Conclusions

Some of the hypotheses discussed above could potentially be answered through more sophisticated statistical analyses, combined with the use of disaggregated data (e.g., hourly flows, crashes per lane, etc.). For instance, incorporating *v/c* ratio or vehicle density would certainly help determine the safety effects of traffic flow states as a function of truck traffic levels (see *73*). Thus, the authors suggest additional work using disaggregated data in order to understand the characteristics of the differences in safety between outer and inner lanes.

The results of this exploratory analysis seem to suggest that truck-free freeway facilities have a better safety record than mixed traffic facilities. This outcome is consistent with other work on this subject. Using simulation tools, others have suggested that removing trucks from mixed traffic lanes and building exclusive truck facilities would significantly improve operations, which should result in important safety gains *(13, 42)*.

The results of the study showed that the outer roadway experiences more crashes, both when raw numbers are used and when exposure is included into the analysis. The results also show that truck-related crashes contribute significantly to the total number of crashes on the outer lanes. In fact, trucks are over-involved in crashes given the exposure on these sections. Even though the outcome of this section suggests that separating truck traffic from passenger cars for freeway facilities improves safety, further work is needed to understand the contributing factors leading to truck-related crashes in the outer lanes.

3.5 FINANCIAL FEASIBILITY AS A CRITERION

3.5.1 Introduction

The first cost element which researchers investigated was the initial cost of building a truck roadway. The ultimate cost comparison would be between a mixed flow roadway and a roadway where trucks use their own separate facility. Many details remain unknown such as the disposition of smaller "trucks" on a link by link basis. Access is anticipated to be much less frequent on truck roadways (e.g., the Trans Texas Corridor) compared to typical mixed flow freeways, requiring delivery vehicles to use some of the mixed flow roadways parallel to the truck roadways. These mixed flow roadways will probably offer access more frequently than the truck roadways. Some of these trucks might be sub-Class 5 anyway and not fit the truck definition used. Diversion of trucks from the truck roadway is also a consideration (e.g., following an incident or for maintenance purposes). For simplicity, this analysis assumes all Class 5 and larger vehicles use the truck facility all of the time and that smaller vehicles (Class 1 through 4) do not use the truck facility.

Elements of cost which could be evaluated include initial cost of the facility, cost of crashes, cost of delay, and cost of fuel used. In many discussions of truck roadways, it has been assumed that the non-truck roadway would not be designed for trucks, resulting in significant cost savings compared to a roadway built for all traffic. However, based on guidance from the project panel, facility costs in this report keep the pavement and bridge designs the same on both roadways. Reasons for building the non-truck roadway to the same structural standards as the truck roadway include:

- diversion of truck traffic from the truck roadway during incidents,
- future changes in policy regarding truck treatments, and
- smaller incremental cost up-front as opposed to beefing up the design after the initial construction.

3.5.2 Initial Construction Cost

For the immediate analysis covered in this section, analysts compared the initial cost of a mixed-flow facility with a similar facility with an exclusive truck roadway. For the truck roadway, the lanes and outside shoulders are wider than they would normally be for a non-truck roadway. Lane widths are 13 ft and outside shoulders are 12 ft. Truck roadways are always separated from other lanes by a barrier as well. The number of lanes on a truck roadway is also an important issue. Truck drivers insist upon being able to pass slower vehicles, so there must always be at least two lanes. The capacity analysis will investigate the need for more than two lanes. Therefore, the total pavement width on the truck roadway is the sum of the two 13-ft lanes, a 12-ft outside shoulder, and a 6-ft inside shoulder (sum = 44 ft), and the pavement is 14-inch thick continuously reinforced concrete on both roadways.

The space between the truck roadway and the other roadway must create a positive deterrent, preventing vehicles from either roadway from crossing over. TxDOT's experience with HOV lanes without this positive deterrent has been significantly increased crash rates, so there must be a means of keeping the two traffic flows separated. The barrier separating the truck roadway from the non-truck lanes is assumed to be the "standard" safety shape at 32 inches tall and a cost of $25 per linear foot. In Research Project 0-4364, one of the recommendations pertaining to heavy flows of trucks, and especially for separating opposing flows of traffic, was that a 42-inch barrier should be used *(2)*. The New Jersey Turnpike uses a heavy-duty 42-inch barrier to separate the interior northbound and southbound lanes, but it uses "W-Beam guardrail" to separate inner (car) lanes from outer (truck, bus, and car) lanes. Figure 2 in Chapter 2 shows a plan view of the turnpike lane layout.

For determining the initial cost of truck roadways, analysts used TxDOT planning cost estimates *(77)*. The objective is not to develop a detailed final cost breakdown but to estimate the initial cost of a truck roadway and compare it with combinations of mixed flow (car and small truck lanes). Promising results may warrant more detailed subsequent analysis. Appendix A shows a tabulated list of the items used in the estimate, indicating that a truck roadway with four total lanes has an estimated cost approaching $11 million per mile.

The comparison of costs for mixed flow lanes used the same TxDOT planning cost estimates. In all cases the mixed flow facility had 12-ft lanes, 10-ft outside shoulders, and 14-

inch continuously reinforced concrete pavement. Table 18 shows a cost comparison of several scenarios comparing per-mile costs of mixed and separated facilities. The "Mixed" column shows the cost of a traditional roadway, and the "Separated" column shows the cost of the same number of total lanes where two of those lanes constitute a separate truck roadway. As expected, the cost is always higher where the separated truck roadway is provided. If more total lanes are needed for the "Separated" category than the "Mixed," then the cost discrepancies will be even greater than if they involve the same number of lanes. As an example of an equal number of total lanes, building five contiguous lanes of freeway per direction would cost a total of $16,018,968 per mile compared to building three mixed freeway lanes and two truck roadway lanes per direction (still five total lanes) at a total cost of $19,767,232 per mile. As an example of more lanes with "Separated," a "2 + 3" roadway would cost $19,767,232 per mile and a four-lane "Mixed" facility would cost $10,699,845 per mile, resulting in a difference of $9,067,387 per mile. Table 19 shows several combinations and cost differences. The extreme right column of "Difference" is omitted because it is simply the per-mile cost of a two-lane truck roadway or $11,000,000 per mile. Using this table, one can quickly compare costs of "Mixed" versus "Separate" where the total number of lanes is different.

Table 18. Initial Construction Cost per Mile with Equal No. Lanes (Both Directions).

No. Lanes by Direction	Mixed	Scenario	Separated	Difference
4	$10,699,845	2+2	$16,964,429	$6,264,584
5	$16,018,968	2+3 [a]	$19,767,232	$3,748,264
6	$16,518,089	2+4	$21,699,845	$5,181,756
7	$19,069,090	2+5	$27,018,968	$7,949,878
8	Unavailable	2+6	$27,518,089	N/A
9	Unavailable	2+7	$30,069,090	N/A

[a] 2+3 is two truck lanes and 3 mixed lanes by direction.

Table 19. Initial Construction Cost per Mile with Different No. Lanes (Both Directions).

Lanes by Direction	Cost Mixed	Separated Scenario	Cost Separated	Difference	Separated Scenario	Cost Separated
4	$10,699,845	2+3 [a]	$19,767,232	$9,067,387	2+4	$21,699,845
5	$16,018,968	2+4	$21,699,845	$5,680,877	2+5	$27,018,968
6	$16,518,089	2+5	$27,018,968	$10,500,879	2+6	$27,518,089
7	$19,069,090	2+6	$27,518,089	$8,448,999	2+7	$30,069,090

[a] 2+3 is two truck lanes and 3 mixed lanes by direction.

The initial cost of the truck roadway (or the incremental cost over a mixed flow roadway) would be amortized over some expected life. This analysis uses a 20-year life since the pavement is 14-inch continuously reinforced concrete pavement. There will also be a maintenance cost associated with the roadway, but this comparison simply transfers the maintenance damage due to large trucks from the mixed flow facility to the truck-only facility with a net result of zero. Table 20 shows a summary of the annualized costs for each of the scenarios with total number of lanes from four to seven where the number of lanes remains the same. Chapter 6 will develop some truck facility analysis tools which will use a benefit/cost approach to determine the overall societal cost of these scenarios. Table 21 uses a 5 percent rate of return and converts the incremental costs from Table 19 to annualized cost per mile. Again, in the extreme right column, the difference is always the annualized cost of a two-lane truck roadway, so this difference is constant. Costs in this table are for both directions.

Table 20. Incremental Cost Converted to Annualized Cost/Mile for Equal No. Lanes.

Total Lanes	Rate of Return	2%	3%	4%	5%	6%	7%
	Cap.Recov.Factor	0.06116	0.06722	0.07358	0.08024	0.08719	0.09439
4	$6,264,584	$383,142	$421,105	$460,948	$502,670	$546,209	$591,314
5	$3,748,264	$229,244	$251,958	$275,797	$300,761	$326,811	$353,799
6	$5,181,756	$316,916	$348,318	$381,274	$415,784	$451,797	$489,106
7	$7,949,878	$486,215	$534,391	$584,952	$637,898	$693,150	$750,389

Table 21. Incremental Cost Converted to Annualized Cost/Mile for Different No. Lanes.

Lanes by Direction	Cost Mixed	Separated Scenario	Cost Separated	Annual Payment	Separated Scenario	Annual Payment
2	$5,964,429	2+2	$16,964,429	$882,640	N/A	N/A
3	$8,767,232	2+2	$16,964,429	$657,743	2+3	$882,640
4	$10,699,845	2+3 [a]	$19,767,232	$727,567	2+4	$882,640
5	$16,018,968	2+4	$21,699,845	$455,834	2+5	$882,640
6	$16,518,089	2+5	$27,018,968	$842,591	2+6	$882,640
7	$19,069,090	2+6	$27,518,089	$677,948	2+7	$882,640

[a] 2+3 is two truck lanes and 3 mixed lanes by direction.

3.5.3 Crash Cost

3.5.3.1 Crash Cost by Severity

The most recent crash cost information available to the research team came from TxDOT's latest accident cost calculations. The most recent TxDOT costs for crashes are $854,000 for combined fatal and incapacitating injury accidents, $41,500 for combined non-incapacitating and possible injury accidents, and $1400 for property damage only accidents. Table 22 shows the cost of hazardous materials spills and incidents associated with them. Even though crashes involving hazardous materials are rare, they are costly and generate much media attention.

There will be other costs considered later which rely upon an analysis of crashes under the two scenarios of mixed and separated traffic and upon the VISSIM model to generate outputs with each scenario run in Chapter 5. The VISSIM outputs will include delay costs and fuel consumption costs. These other costs must be based upon the same scenarios developed by the research team in Chapter 6 in developing truck facility analysis tools. The matrices in Chapter 6 result from VISSIM output for selected input values of truck and non-truck volumes, terrain, and percent entering/exiting traffic.

Table 22. Number and Cost of Texas Hazardous Materials Crashes.

Year	Incidents	Injuries		Fatalities	Incident Cost
		Major	Minor		
1999	1166	14	11	0	$4,323,615
2000	1210	3	18	1	$4,353,278
2001	1055	5	11	2	$3,977,809
2002	1035	1	5	1	$3,510,563
2003	1097	2	7	0	$3,904,839
2004	1124	0	11	0	$3,458,029

Source: http://hazmat.dot.gov/pubs/inc/data/2004/2004frm.htm, accessed June 16, 2005.

3.5.3.2 Prediction of Crashes on Truck Roadways

The New Jersey Turnpike Authority is the best known source of data for evaluating the effects of trucks in a mixed traffic stream compared to a traffic stream with cars only. However, these data are still not what is really needed—data comparing the safety of a roadway with trucks only to one without any trucks. To fill this void, two options appealed to researchers in this research project: 1) develop a mathematical model to predict truck crashes, and 2) use a simpler approach which would remove most of the truck-car crashes since truck-car interactions would be minimal. The second approach, while not as glamorous as the first and not fully considering all the factors that affect crashes, won out as the available method for this research. In either case, the change in crashes expected with separating trucks from other vehicles would be converted to a societal cost and added with other costs and benefits to determine a benefit/cost relationship. Overall reductions in crashes due to separating trucks would be viewed as a reduction in cost, and therefore as a benefit. Chapter 6 has examples of how these crash costs would be applied on a segment-specific basis.

Table 23 summarizes the vehicle types from the crash database as defined by the Texas Department of Public Safety (DPS). It eliminates smaller or inappropriate vehicles and is a close approximation of the “Class 5 and above” definition adopted in this research.

Table 23. Vehicles Used in the Crash Analysis.

DPS Designation	Description	DPS Designation	Description
20	Beverage Truck	31	Pole (Log) Truck
21	Bob-Tail Truck	32	Refrigerator Truck
22	Dump Truck	33	Stake Truck
23	Fire Truck	34	Tank Truck
24	Flatbed Truck	36	Van (Furniture)
25	Float Truck	37	Wrecker Truck
26	Garbage Truck	39	All Others
27	Mixer Truck		

3.6 USER PERSPECTIVES AND PUBLIC SATISFACTION MEASURES

Even though user and general public satisfaction are important, they are difficult to quantify for comparison purposes. TTI has conducted other research projects where motorist interviews indicated that the separation of trucks from passenger vehicles would be very desirable *(2, 21, 39)*. For this discussion, truck roads are closely correlated with HOV lanes with respect to their full utilization. Where there was not reasonably full utilization of Texas HOV lanes, other motorists—especially ones stuck in traffic—complain loudly that the public investment was unwisely spent. The same reactions will undoubtedly be voiced for truck roadways if they are underutilized.

This research conducted interviews with enforcement personnel and motor carrier representatives to determine their position and solicit their input regarded separated truck roadways. Researchers also learned from minutes of public meetings held recently by the Texas Turnpike Authority Division of TxDOT pertaining to the Trans Texas Corridor, TTC-35. Some of the major comments are available in the text which follows.

3.6.1 Texas Department of Public Safety

The overall response from the Department of Public Safety Commercial Vehicle Enforcement (CVE) unit was that separating trucks from passenger vehicles is a good idea. Furthermore, truck lane restrictions seem to improve overall safety and operations on roads over an extended period of time. At the San Marcos truck enforcement facility, the lane restriction has helped to keep cars in the left lanes as the trucks exit and reenter the freeway.

It is possible that the DPS will provide enforcement for commercial motor vehicles (CMV) and other vehicles on portions of the TTC in a way similar to that currently used on the Dallas North Tollway and the George Bush Tollway. The DPS also enforces the Camino Columbia toll road now that it is owned by TxDOT. The Webb County Sheriff's Department enforced it when it was a private facility. The decision has already been made for DPS to provide CMV enforcement for the new S.H. 130 facility once it opens to traffic. This action transpired through an interagency agreement between DPS and TxDOT. If DPS does not provide CMV enforcement throughout the TTC-35, it will probably train the personnel who do the actual enforcement. DPS has provided CMV training to personnel from a number of agencies around the state but none along the I-35 corridor from Waco to Dallas-Ft. Worth.

Even though much of CMV enforcement still occurs on a roving basis, DPS likes to use stationary sites where truck flows are heavy and especially if bypass routes are limited. The TTC should be a good candidate for fixed facilities due to the anticipated heavy flows of trucks. DPS expects that the use of ITS will increase as the TTC comes into operation, although this increase will likely happen with or without the TTC. Examples of systems which have already been investigated and which would be appropriate for truck roadways are transponders and weigh-in-motion (WIM) systems. DPS has deployed WIM at Divine on I-35 south of San Antonio and near New Waverly on I-45 and is using WIM along the border with Mexico to assist in identifying trucks that are overweight. The agency also plans to deploy transponders along the border to expedite movements of Mexican trucks through the border clearance process. DPS recently purchased 15,000 TransCore transponders to be given to Mexican carriers at no charge to the carrier. The first ones will be handed out in El Paso. In determining which tags to use, DPS coordinated with U.S. Customs, which was using TransCore tags.

Away from the border, DPS will continue to consider which of the methodologies for pre-clearing trucks will work best for Texas. PrePass, NorPass, and Oregon Greenlight have all made pitches for the potentially large Texas market, but a decision has not been made at this point in time. PrePass wants the data to be proprietary because some carriers who are sensitive to "big brother" issues might fear that the state enforcement agency would simply use the timestamps from point "A" to point "B" to determine their speed and use that information against the carrier, causing PrePass to lose business. NorPass and the Oregon Greenlight options pose no similar restrictions, but the carrier or the state must pay for transponders. Prepass would be installed at no charge to the state, earning a return on investment by charging carriers for each truck which bypasses an enforcement area. The decision about which of the three is best for Texas will probably be forthcoming soon because DPS is anxious for this to happen. Funding and possibly legislative action will be needed to make it a reality. DPS accountants have not encouraged activities in which actual money is collected, so cashless transactions would be more desirable. That challenge will be another possible sticking point that will need to be worked out.

Implementation of the Commercial Vehicle Information Systems and Networks (CVISN) has not happened in Texas to this point. TxDOT hired a consultant to prepare a business plan (a requirement of participation in related federal programs) a few years ago, so that prerequisite has been met. DPS would like to have the various processes pertaining to International Fuel Tax Agreement (IFTA), vehicle registration, International Registration Plan (IRP), and so forth, be required to be streamlined and interconnected. CVISN is now handled through the Federal Motor Carrier Safety Administration (FMCSA) rather than through the Federal Highway Administration as is previously was, so getting Texas involved in CVISN should be easier now. Two other programs in which DPS is very interested are Performance and Registration Information System Management (PRISM) and Inspection Selection System (ISS). Through PRISM, the state can invoke sanctions pertaining to vehicle registration which can have a powerful effect on motor carrier safety efforts. The ISS is an automated system which can operate on a PC onsite and assist enforcement personnel in making the best choice of which vehicles to choose for safety inspections. It enables rapid screening of vehicles based on DOT number, carrier name, or other identifier.

The spacing of interchanges may be a factor in determining how to enforce an exclusive truck roadway in terms of how truckers might try to avoid enforcement activities. Historically, fixed enforcement sites have not been provided on a new facility until after the initial roadway construction is completed, although the DPS has requested that a fixed site be built along S.H. 130 to include WIM. Sometimes TxDOT will build fixed sites via a construction change order, and in other cases they are an entirely separate contract.

3.6.2 Texas Motor Transport Association

The Texas Motor Transport Association (TMTA) represents a wide range of motor carriers operating in Texas and understands issues from the motor carrier perspective related to exclusive truck roadways. Overall, the TMTA thinks the concept of barrier-separated truck roadways is a good idea. However, there are also some issues to be resolved in the current planning of the TTC to make it more closely reflect what would most benefit all users.

The first big issue, of course, is having to pay a toll for the use of the truck roadways. Perhaps all motorists feel like they pay twice for the use of toll roads (through fuel taxes, etc., plus tolls), but motor carriers are paying much more to use toll roads compared to automobiles and they pay much more in taxes. There has been some speculation and discussion in recent years concerning ways to reduce certain taxes or reimburse users of toll roads so they only pay once. Whether any motor carrier or other vehicle owners will see a reduction in the non-toll costs of transportation is unknown. Truckers are more likely to use toll roads if non-toll alternatives are very congested or if other impediments to maintaining reasonable speeds exist. Shippers place many demands on carriers to deliver shipments within a concise time window, so if non-toll roads do not allow timely deliveries, truckers will probably increase their use of toll roads.

Toll roads may attempt to attract more trucks by allowing higher speeds and/or heavier weights. Indeed, both might attract more trucks, but they should not be implemented without careful and thorough consideration of all the issues. This section covers speed first, followed by increased weights. Speed limits on the TTC for trucks and cars are being considered at around the 85 mph range. However, there will be higher costs associated with increased speeds that are not well understood by planners and policy-makers. Higher speed limits have the potential to increase truck operating costs in two ways—they significantly reduce fuel mileage, and they will almost certainly increase the cost of insurance. In an industry which operates under extremely narrow profit margins and with the increasing cost of fuel, the fuel mileage issue is large.

On the cost of insurance, recent discussions with an insurance executive on the subject of insurance for motor carriers indicate that if speeds increase, the company will likely increase premiums to cover motor carriers. Higher speeds commonly result in crashes with increased severity. Also, an outcome of allowing higher speeds will likely be a large increase in speed differentials, and speed differentials also contribute to increased crashes. A segment of the motor carriers can be expected to take advantage of the higher speed limits and go faster but the larger carriers are not expected to modify their trucks to increase their top speeds. The largest carriers like J.B. Hunt, Schneider National, and Swift are self-insured above a certain limit, but carriers with up to 150 power units are more likely to be insured through some type of insurance company. Another consideration for the bigger carriers in not increasing their trucks' governed speeds is that they have more exposure on the roadway due to the number of units. The image of the carrier in the courtroom may be diminished by having a policy which allows its trucks to travel at higher speeds.

Driving faster on the TTC and having a truck with the horsepower to maintain 85 mph has implications for the way these same drivers approach other roadways (where speed limits are less). Some truck drivers may reach a certain comfort level for that speed and have a tendency to driver faster on the other roads which are not designed for the higher speeds. Adding the speed differential factor complicates matters even more on these non-TTC roads.

A factor which may figure into the speed issue is the severe driver shortage. Some carriers might attempt to lure the available drivers by this incentive of driving at the higher speeds. However, this exception will probably still not apply to the large carriers.

Under House Bill 3588, there is a possibility of the TTC allowing increased truck weights compared to weights currently allowed on highways throughout Texas. The extra weight might be attractive to some carriers if the distance is very long, although an issue that needs to be addressed is how to get heavier loads from the loading point to the TTC and how to finish the delivery from where the truck exits the TTC. The positive attributes of increased weight must outweigh the negatives. One negative is having to break down the load at intermediate points to keep the vehicle legal as it leaves the TTC network. The trucking industry does not have the assets to accomplish the modifications that will be necessary. Besides, there is additional delay and cost associated with such changes to the vehicle and/or the shipment at these intermediate points. There would also be a strong temptation for drivers hauling heavier loads to risk being detected and continue the trip beyond the TTC on pavements and bridges not designed for the heavier loads. Finally, the benefits of heavier weights will be realized in rural areas but not in urban areas where the number of trucks will remain about the same. The heavier weights and higher speeds will not be a sufficient "carrot" to a carrier for a trip of say 300 miles; it would have to be a much longer trip, say approaching 1000 miles.

Moving beyond the speed and weight issues, the degree of usage of exclusive truck roadways could become an issue. There could be negative perception by the public if truck facilities are underutilized, especially when other motorists are in congested traffic and they see lanes that are not being adequately utilized. Texans have experienced that issue with HOV lanes that are not adequately utilized. The other issue which could be applied to truck roadways and also correlates with HOV facilities is variable tolls based on usage and time of day. The concept of high occupancy toll (HOT) lanes establishes a variable toll by level of congestion and perhaps other factors. Reducing the toll encourages increased usage during periods of low usage and increasing the toll discourages usage when traffic is heavy. The same concept could be applied to truck roadways to attract more trucks during periods of low natural demand.

The amount of time actually saved by toll facilities or by any of the other innovative concepts being considered needs to be closely scrutinized. In situations where only a few minutes are saved by toll facilities, usage by trucks will be low. Some indicators suggest that the amount of time saved in managed lanes applications is very modest.

This research project has addressed truck lane restrictions in a limited way, but it is a hot topic among motor carriers. One option pertaining to lane restrictions which might warrant further investigation is restricting trucks from the right lane instead of from the left lane, especially in urban areas. Trucks tend to move to the left naturally in urban areas to avoid entering and exiting vehicles in the extreme right lane which often impedes other vehicles. If trucks only have two lanes in which to legally operate, this avoidance of the right lane further reduces the number of lanes. Of course, the lane restriction from the right lane would have to be relaxed near interchanges to allow trucks to move into the right lane to exit and to use the right lane for a short distance upon entering the freeway. Motor carriers are against lane restrictions but recent studies *(11, 12)* that have shown reduced crashes due to this countermeasure will probably only increase the number of lane restrictions initiated in Texas. Motor carriers are opposed to lane restrictions because they believe these restrictions can interfere with efficient and timely delivery of freight. Trucks still compete with rail, especially at distances above 500 miles, so interferences are viewed as reducing their competitive edge. This type of restriction would likely only be possible on facilities with four or more lanes by direction, considering the large volume of traffic on urban freeways and the implementation of left lane truck restrictions.

There has been talk in Texas about building new intermodal facilities near large urban areas, although their proximity to the TTC is unknown. Building these centers would undoubtedly lead to reducing the number of trucks in rural areas across the state, but trucks must still deliver goods from the centers to the urban areas. Therefore, truck traffic between the centers and urban destinations would still be mandatory and would not reduce the number of trucks in those urban areas. The arrival of a train to the intermodal center would require many trucks to deliver from the intermodal center to the urban area, much like what happens at a large port when a ship arrives. As the ship or train is off-loaded, all of the trucks leave the dock at about the same time, possibly creating an even bigger problem than if the trucks arrived more randomly as they do now. Besides, increasing the number of trains will have a negative impact on highway traffic at grade crossings across the state. Trains are at capacity now so the number of trains must increase, and increasing the number of trains means double tracking or other capacity enhancing measures which will further impede highway traffic and especially emergency vehicles.

Overall, the trucking industry likes the idea of separate or exclusive truck roadways. Trucks have very different operating characteristics compared to cars, and car drivers do not generally understand these differences. Truck drivers have to be very cautious because of cars operating in “blind spots” near trucks. When it comes to vehicle interactions, truck drivers help each other, especially in more demanding environments such as congested urban areas, by using citizen’s band (CB) radios and by other means known and understood among truck drivers. By the same token, car drivers would prefer that trucks be separated because of their much greater size and weight and the damage potential to the car and its occupants in crashes with trucks. In summary, both car drivers and truck drivers want to be separated from each other.

Finally, the views of elected officials pertaining to truck roadways are important since they make decisions that affect all Texas residents and users of Texas highways. These officials view car drivers as voters (whom they want to please) and trucks as perhaps necessary to a degree but also a challenge. Some truck drivers are voters in the local area as well, but some of these drivers are just passing through the state and do not vote here. On the subject of truck roadways, both car drivers and truck drivers see the concept of truck roads as a means of separating them from each other and therefore agree that it as a good thing.

3.6.3 Trans Texas Corridor Consulting Team

3.6.3.1 Meeting with TTC-35 Consulting Team

The primary purpose in meeting with members of the TTC-35 consulting team was to coordinate activities between this research project and ongoing planning efforts for the TTC by comparing some of the findings. Much of the discussion focused on the TTC-35 since it will be the first corridor to be built. TTI findings indicated that indeed this corridor will be the most congested truck corridor in the state unless projects like the TTC-35 are built to relieve the congestion.

One of the major discussion points was truck demand on various corridors across the state. One of TxDOT's consultants for the TTC compared the modeling effort his firm is using—the Statewide Analysis Model (SAM)—with TTI results, indicating that the SAM outputs generally produced similar results in truck growth. SAM output predicted some years with truck traffic growth as high as 6 to 8 percent, but that high growth was not sustained over a 10 to 15 year period. Over this longer period, some years declined to around 2 to 4 percent. The I-35 SAM runs indicated population growth in the 2 to 4 percent range. Besides the modeling (engineering) component, the overall analysis conducted for the TTC relies on revenues and costs since the project will involve private investment. The primary goal of the TTC is to minimize public funding, so it is very important to maximize private investor interest and participation.

The TTI results pertaining to truck growth use only historical growth for each segment of corridor, projecting truck traffic on that basis alone, so the results may not fully represent all the changes which could occur. For example, shifts of truck traffic from one corridor to another if one corridor gets very congested are not shown by the TTI results. The SAM output indicates that some trucks shift from the I-35 corridor to the proposed I-69 corridor under some conditions such as heavy congestion along the I-35 corridor. Also, a non-toll facility becoming a toll facility would probably cause some trucks to shift to a non-toll freeway, all other factors equal.

Motorist safety is always of paramount concern on all projects and especially on projects of the magnitude of the TTC. This research project and a parallel effort by the Battelle Memorial Institute are investigating the expected crash experience on truck-only roadways. At a minimum, providing separate barrier-protected truck roadways would drastically reduce truck-car interactions (expected truck-car crashes would not be zero assuming a scenario used by the New Jersey Turnpike where trucks would occasionally be allowed onto car lanes if a major incident occurred on the truck roadway). Truck operating characteristics are much different from smaller vehicles, so separating vehicles of similar size, weight, and acceleration characteristics is anticipated to improve both safety and operations. Providing a barrier between the truck roadway and the car roadway should be considered an important safety feature since HOV experience in Texas has clearly shown a significant increase in crashes when such positive measures are not taken. Without barriers, motorists can easily move from one set of lanes to another upon perceiving an advantage in doing so.

An important element of the TTI research will be overall societal cost of transportation facilities. The higher initial cost of a minimum four-lane truck roadway (two lanes in each direction) of about $11 million per mile is anticipated to be offset to some degree by reductions in some types of crashes and reductions in overall delay. Past discussions of the cost of separate truck roadways has assumed that pavements and bridges on car lanes would be designed for cars only. However, the TTI research has taken a more conservative approach and assumed that the car roadway will occasionally serve large trucks. If nothing else, some smaller trucks with heavy axle loads will probably use the facility on a daily basis. This research used the simulation package VISSIM to run a variety of scenarios which reflect Texas conditions in terms of terrain, interchange spacing, and percent of traffic entering and exiting the freeway. The result will be submitted as a series of matrices that can be used by TxDOT in the decision process, with each matrix cell comparing LOS A through E for each traffic condition for mixed versus separated flows of traffic. The final comparison is anticipated to be a cost of each scenario of mixed flows compared to separated flows. If costs look attractive to TxDOT or to a private investor, the next step will be to use site-specific data for input into CORSIM since TxDOT typically uses this software for such applications.

Interchange spacing will be important for trucks to be able to access important destinations and will be an important criterion to motor carriers in using the TTC. Spacings that are farther apart reduce construction costs but may not serve the needs of enough trucks to make the facility attractive to them. In some cases, closer spacing may increase costs unnecessarily. House Bill 2702 stipulates that interchanges for the TTC will be spaced no more than 5 miles apart; however, it does not require separate ramps for trucks and cars. The interchanges could be of any type deemed feasible through an engineering study.

House Bill 3588 has provisions for facilities such as the TTC to allow heavier trucks. Larger and heavier trucks could be an option if the developer proposes that option in its Comprehensive Development Agreement (CDA). The developer must submit a master development plan at the beginning and must follow the plan. In the past, there has been opposition to heavier and larger trucks by other motorists due primarily to safety concerns, but placing these trucks on their own barrier-protected facility may reduce some of these concerns.

Keeping trucks (and other vehicles) moving freely and without delay will be important to the success of the TTC. Therefore, automated systems which can allow payment of tolls at highway speeds with equipment that is compatible across the state will be a goal of the TTC. The Texas Turnpike Authority (TTA) Division wants the toll collection process to be all electronic on the TTC and have equipment across the state that is interoperable, but there are issues that must be worked out. The S.H. 130 facility will have a mix of automated and manual toll collection systems like the current toll roads being operated in Texas.

The TTA Division's consultants need design criteria for the higher anticipated speeds to be allowed on the TTC. Speeds of 85 mph are being considered. TTI recently completed a study of geometric design needs for facilities that serve a high number of large trucks, but the design speeds did not reach 85 mph *(2)*.

There was discussion pertaining to truck lane restrictions being implemented in Texas—trucks being restricted to the left lanes versus the right lanes. Truck drivers seem to be most comfortable driving in the right lanes except when they are in urban areas where they tend to move left one lane to avoid traffic entering and exiting. As a general rule, truck drivers stay in the right lane in rural areas except to pass perhaps due to automobile drivers getting in a "blind spot" and increasing the probability of a lane-changing crash. Truck lane restrictions might remain an issue even after construction of the TTC. As noted earlier, there may be short time intervals during which trucks are allowed to use the car facilities and there may be a need to restrict trucks to the right lanes. Also, if truck roadways exceed two lanes in each direction, there will probably be a need to maintain the extreme left lane for the fastest vehicles and for passing only.

3.6.3.2 TTC-35 Public Meetings

TxDOT's TTA Division and its consulting team conducted a round of scoping meetings and two rounds of public meetings as part of the TTC-35 Tier 1 Study process to inform attendees and to listen to input from interested individuals and organizations. A brief summary of each of these meetings is provided below.

The outcome of the 26 Public Scoping meetings held within and adjacent to the proposed TTC-35 Study Area between April 7 and June 15, 2004, was approximately 31 percent supportive of the TTC-35 project, 23 percent neutral, and 46 percent opposed. Many of the favorable comments related to shifting the corridor in a specific direction. The neutral comments ranged from requests for more information and concerns about future project coordination to concerns for local environmental resources and habitat. The negative comments varied in nature, ranging from personal property impacts to specific environmental concerns to more statewide issues. Many individuals expressed concerns relating to the loss of prime farmland property, emergency service access, and the loss of species habitat, while others expressed a general opposition to tolling.

The outcome of the 44 public meetings conducted within and adjacent to the proposed TTC-35 Study Area between October 19 and November 18, 2004, indicated approximately 27 percent supporting the project, 24 percent neutral, and 49 percent opposing the project. Of comments in favor of the project, many persons wanted to alter the location while others recognized the need for separate truck lanes on existing IH-35 to increase safety. Many of the neutral comments included requests for maps and copies of meeting hand-outs, while others expressed their reservations to support or oppose TTC-35 until more specific information is available. Many of the opposing comments expressed a preference for the "No Build" option, or to have existing I-35 upgraded with separate "truck only" and/or HOV lanes. Many individuals also expressed concern relating to the loss of prime farmland property, the creation of property barriers, the disruption of existing road networks, the restrictions of emergency service access, and the general degradation of agricultural and rural ways of life.

TxDOT and its consultants held a series of 47 public scoping meetings in the spring of 2005 within and adjacent to the proposed TTC-35 Study Area between February 7 and March 31, 2005. At the time of this writing, the final results were not available so the percentages should be considered approximate. Approximately 17 percent of those submitting comments expressed support for the proposed project; approximately 38 percent were neutral; and approximately 45 percent were opposed. Many of the favorable comments expressed the desire to separate truck and car traffic in an effort to relieve congestion and increase safety. Numerous individuals conveyed a desire to have TTC-35 located close to them, citing economic prosperity for their individual communities. Many supporters also expressed positive feedback concerning the freight and passenger rail components of the proposed project, as well as the proposed project's general multimodal concept. Neutral comments included requests to be added to the project mailing list and copies of meeting hand-outs, while others expressed their reservations to support or oppose TTC-35 until more specific information could be available.

Many individuals opposing the project expressed a preference for the "No Build" option, or to have existing I-35 upgraded with separate "truck only" and/or HOV lanes. Others emphasized their objection to foreign consortiums economically gaining from eminent domain proceedings, as well as to tolling in general. Many individuals also expressed concern relating to the loss of prime farmland property, the creation of large property barriers, the disruption of existing road networks, the general degradation of agricultural and rural ways of life, the removal of large tracts of land from local tax rolls, the impact to historical resources and cemeteries, and the destruction of natural habitats, water resources, and endangered species.

Overall, many of the comments pertaining to trucks and truck facilities were similar. Table 24 summarizes statistics pertaining to the comments according to the series of meetings in which they were heard.

Table 24. Summary of Truck-Related Comments from TTA Division Public Meetings.

Meeting Series	Comment Statistics
Scoping 2004 (364 total comments)	• 19 comments mention trucks
Fall 2004 (918 total comments)	• 96 comments mention trucks • 5 supporting comments specifically logged as "separate truck lanes would reduce congestion" • 5 supporting comments specifically logged as "separate truck lanes would increase safety" • 1 opposing comment specifically logged as "tolling would be uneconomical for trucks" • 2 opposing comments specifically logged as "trucks should pay for their use and/or damage"
Spring 2005 (2660 total comments) [a]	• 295 comments mention trucks • 33 [a] supporting comments specifically logged as "separate truck lanes would reduce congestion" • 36 [a] supporting comments specifically logged as "separate truck lanes would increase safety" • 9 [a] opposing comment specifically logged as "tolling would be uneconomical for trucks" • 6 [a] opposing comments specifically logged as "trucks should pay for their use and/or damage" • 14 [a] opposing comments specifically logged as "trucks should be better regulated"

[a] Comments received from the Spring 2005 round of public meetings are currently under quality assurance/quality control (QA/QC) review. The final number of comments received and percentages of individuals supporting or opposing the project are subject to change. Numbers represented in this summary for the Spring 2005 meetings are emphasized as approximations.

CHAPTER 4. PLAN FOR CLASSIFYING TRUCK ROADWAYS

4.1 INTRODUCTION

This chapter describes the procedure the research team followed to determine roadways that could potentially become candidates for truck treatments. The procedure involved selecting a roadway network for truck traffic analysis purposes, overlaying TxDOT count stations on the selected highway network, extracting annual growth rates from relevant count stations, evaluating growth scenarios, and estimating future truck traffic volumes.

4.2 METHODOLOGY

To facilitate the analysis, the research team followed a GIS-based approach to select the truck traffic roadway network, overlay count stations to the highway network, estimate the spatial distribution of truck traffic growth rates, and map those growth rates to all segments within the selected roadway network. Using a GIS approach facilitated the analysis given the large number of count stations and the extent of the roadway network the research team had to use for the analysis.

The research team also used a traffic simulation environment to determine maximum truck traffic service flows for different level of service values. Chapter 3 contains a complete explanation of how VISSIM was used to develop the capacity of a two-lane truck roadway under a variety of representative conditions.

4.3 SELECT 2002 TRUCK ROADWAY NETWORK

The research team developed a first iteration roadway network by starting with the entire on-system road network and eliminating road segments with less truck activity. The source data for the highway network was the TxDOT 2002 "End of Year" centerline file. For each segment on the network, this file contained general location information (such as highway number, reference marker identification, and functional system classification), basic geometric information (such as number of lanes, lane width, shoulder type and width, median type and width, curb type, and surface type), as well as 10-year average annual daily traffic history, year 2002 truck percentage, and load limits.

From the 2002 truck percentages, the research team calculated average annual daily truck traffic values for the entire TxDOT network (Figure 23). Based on discussions with TxDOT personnel, the research team selected a minimum AADTT value of 1000 trucks per day for the selection of the preliminary truck traffic roadway network. For completeness, in addition to segments with at least 1000 trucks per day, the research team included interstate highway (IH)—all volumes, US highway (US)—all volumes, state loop (SL)—all volumes, and state highway (SH) segments. The query the research team used to select the network for analysis purposes was as follows:

```
SELECT *
FROM ROAD_NETWORK
WHERE (ROUTE_NM LIKE 'IH*' OR ROUTE_NM LIKE 'US*' OR ROUTE_NM LIKE 'SL*')
OR ([AADTT] > 1000 AND ROUTE_NM LIKE 'SH*')
OR [AADTT] > 1000
```

The research team defined the initial tentative truck network on the basis of truck volume since truck volume is readily available. It can be predicted with some accuracy, and it directly influences truck roadway LOS. Figure 23 shows the resulting baseline network in darker lines with the lower truck volume roadways in the background. The roadway network in Figure 23 does not represent the network that would be subject to truck treatments, but rather the roadway network the research team used to conduct the truck traffic analysis.

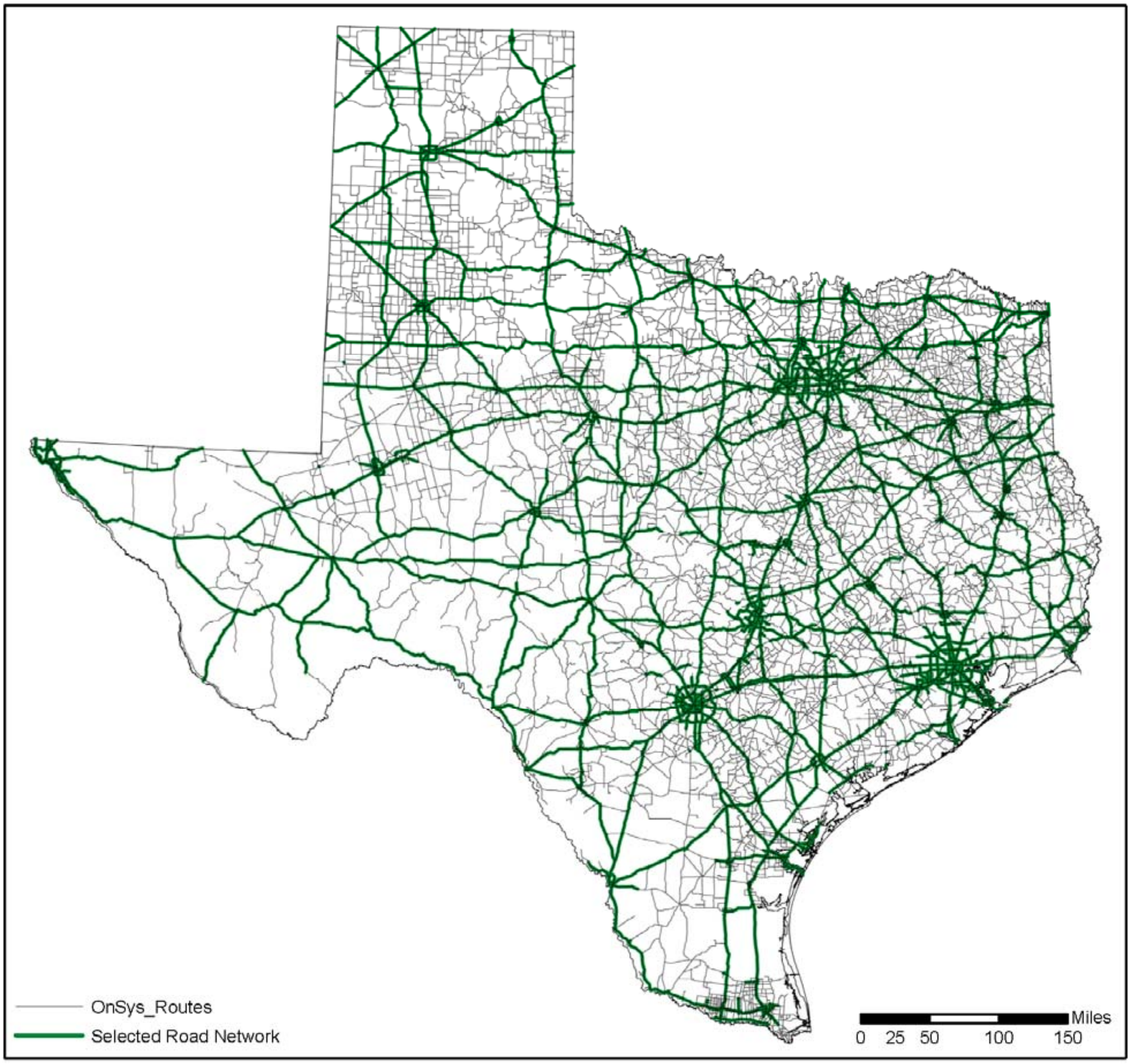


Figure 23. Selected Baseline Road Network.

4.4 EVALUATE GROWTH SCENARIOS

The next step involved determining growth rates for individual corridor segments on the selected roadway network to establish a 20-year growth pattern. The most recent traffic data available to researchers was 2002 data, making 2022 the "design year." Some of the analysis also predicts traffic for the year 2032 using this same methodology, but 20-year projections are probably more realistic from the standpoint of accuracy. The research team used historical count data from the Transportation Planning and Programming (TPP) Division to establish growth rates for every segment of roadway in the network.

Table 25 summarizes the type of count station data that were typically available. TxDOT count stations have identifiers that generally consist of a prefix, a count station number, and a suffix (e.g., LW-502, LW-510-A). Count station data are directional, with count data for all pertinent directions provided separately. As an example, Table 25 shows year 1990 eastbound and westbound count data from Station LW-502, located on the IH-10 mainlanes west of Seguin near San Antonio.

Table 25. Count Station Data Available.

Available Count Station Data		First Direction	Second Direction
Station identification		LW-502	LW-502
Direction of travel		E	W
County in which the site is located		Guadalupe	Guadalupe
District in which the site is located		San Antonio	San Antonio
Physical description of the site		IH0010 W of Seguin	IH0010 W of Seguin
Posted route sign in which the site is counting traffic		IH	IH
Posted route number in which the site is counting traffic		10	10
Date when the 24-hour count was taken		3/6/1990	3/6/1990
24-hour total volume for that road in the particular direction of travel		7650	7741
24-hour total truck volume for that road in the particular direction of travel		1789	1921
Percentage of truck volume in the total volume for that 24-hour count. Trucks volumes exclude pick-ups and buses		23.4	24.8
24-hour volume by vehicle class:			
Texas 6 Class	**FHWA Class**		
1: Passenger cars	**1:** Passenger cars	3763	3764
2: 2 axles, 4-tire single units	**3:** 2 axles, 4-tire single units, pickup or van with 1- or 2-axle trailers	2098	2056
3: Buses	**4:** Buses	24	27
4: 2D– 6-tire single units (includes handicapped-equipped buses and mini school buses)	**5:** 2D – 2 axles, 6-tire single units (includes handicapped-equipped buses and mini school buses)	346	368
5: 3 axles, single units	**6:** 3 axles, single units	53	47
6: 4 or more axles, single units	**7:** 4 or more axles, single units	3	0
7: 3 axles, single trailers	**8:** 3 to 4 axles, single trailers	33	32
8: 4 axles, single trailers	**8:** 3 to 4 axles, single trailers	71	50
9: 5 axles, single trailers	**9:** 5 axles, single trailers	1194	1343
10: 6 or more axles, single trailers	**10:** 6 or more axles, single trailers	15	15
11: 5 or less axles, multi-trailers	**11:** 5 or less axles, multi-trailers	27	23
12: 7 or more axles, multi-trailers	**12:** 7 or more axles, multi-trailers	23	14
13: 6 axles, multi-trailers	**13:** 7 axles, multi-trailers	0	2

The research team received count station data for 1008 stations throughout the state, spanning 13 years from 1990 through 2003. As Table 26 shows, some count stations did not have data for all years. Also, not all count stations were of interest to the research. Of the 1008 count stations, the research team selected 406 stations located on the selected road network shown in Figure 23.

Table 26. Distribution of Count Stations with Different Number of Years of Data.

Number of Years with Data	Percentage of Count Stations
1	3
2	1
3	1
4	1
5	2
6	5
7	19
8	2
9	2
10	3
1	11
12	20
3	31

Because the count data were directional and the roadway network was centerline-based, the research team combined directional counts to obtain bidirectional counts. For consistency, they only used main lane count data in the case of freeway facilities and removed data from intersecting streets in the case of stations that were close to intersections. For the analysis, the research team used truck count data associated with Texas 6 Class 5 (FHWA Class 6) vehicles and above (i.e., they excluded 2D vehicles from the analysis).

After generating bidirectional count data, the research team followed a two-step procedure to estimate historical truck traffic growth trends. The first step involved estimating growth trends for individual count stations, and the second step involved applying the growth trend data from individual count stations to segments on the roadway network. For estimating growth trends for individual count stations, the research team considered a number of approaches, including linear regression, power regression, and constant annual growth rate. A cursory examination of the data quickly revealed that historical growth patterns varied greatly from count station to count station and that a single growth trend estimation procedure would not produce the best results for all cases. However, because the purpose of the analysis was to provide measures of growth trends that, to the extent possible, could be used throughout the network as consistently and automatically as possible, the research team ultimately decided to use a single approach for all count stations—the constant annual growth rate approach.

Figure 24 illustrates the process as applied to count data from Count Station LW-510. The research team extracted the starting and ending years, as well as the corresponding truck traffic volumes, and calculated an equivalent constant annual growth rate using the following equation:

$$i = \left[\frac{AADTT_e}{AADTT_s} \right]^{\frac{1}{n-1}}$$

where,

i = equivalent constant annual growth rate,
$AADTT_s$ = AADTT for starting year
$AADTT_e$ = AADTT for ending year, and
n = number of years between starting year and ending year.

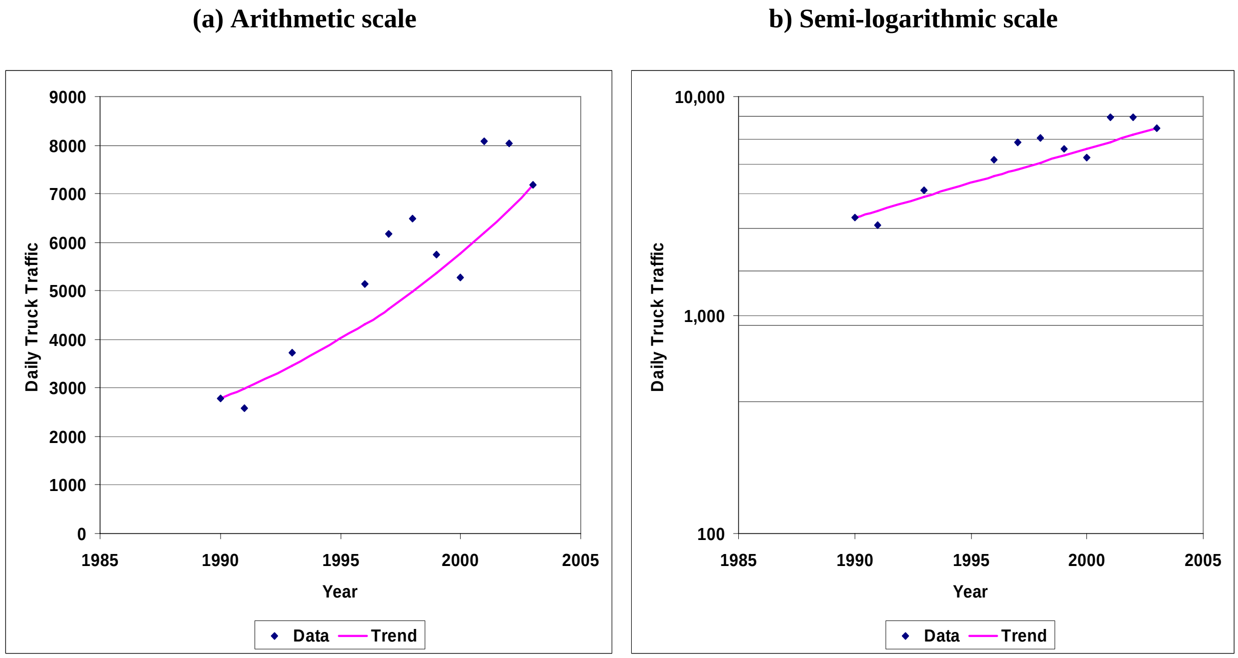


Figure 24. Historical AADTT Data for Count Station LW-510.

The next step involved generating growth rate surfaces in the GIS using the annual growth rate data from individual count station locations. This process involved the creation of a raster layer using the "Interpolate to Raster, Inverse Distance Weighting" function in the three dimensional (3D) Analyst extension of ArcGIS and the growth rate values from the count station table. For simplicity, the researchers used default parameter values for the generation of the raster growth rate surface. Figure 25 shows a view of this surface.

For comparison purposes, the research team developed a second surface using a triangulated irregular network (TIN) instead of a raster layer. A comparison of the result of these two processes showed negligible differences.

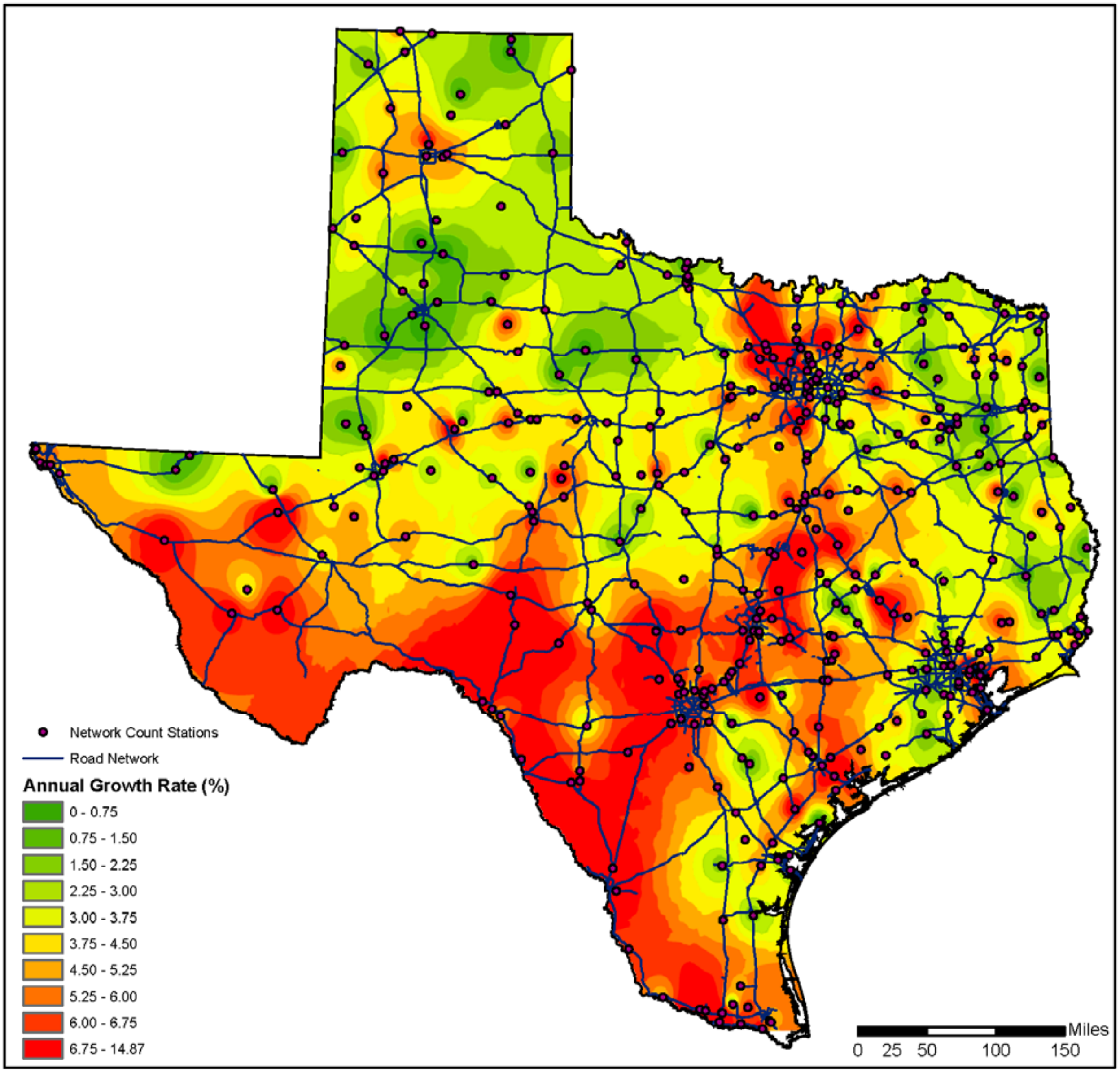


Figure 25. Growth Rate Surface Map for the Base Truck Network.

The next step involved overlaying the roadway network on the 3D surface map to assign growth rate values to each individual roadway segment. First, it was necessary to use the ArcGIS 3D Analyst function "Convert – Features to 3D" to convert roadway features from "polylineM" to "polylineMZ" because the roadway network originally received from TxDOT did not provide 3D support. Then, the research team applied the following Visual Basic script to extract "Z" values from the 3D surface map to each converted "3D" roadway segment:

```
On Error Resume Next
Dim pMxDoc As IMxDocument
Dim pMap As IMap
Dim pCurve As ICurve
Dim pMiddlePoint As IPoint
Dim dZMiddle As Double
Dim dDistance As Double
Dim bAsRatio As Boolean
Dim pZAware As IZAware
Dim bSrefFromMap As Boolean
'======================
'adjust the parameters below
'bSrefFromMap = True ==> the length will be calculated in the projection of the Map
'bSrefFromMap = False ==> the length will be calculated in the projection of the data
'bSrefFromMap needs to be True only if a real distance in Map units will be used - bAsRatio = False
bSrefFromMap = False
dDistance = 0.5 'when bAsRatio = True identifies the middle point of the polyline
bAsRatio = True
'=======================
Set pMxDoc = ThisDocument
Set pMap = pMxDoc.FocusMap
If (Not IsNull([Shape])) Then
  Set pCurve = [Shape]
  If (Not pCurve.IsEmpty) Then
    If (bSrefFromMap) Then
      Set pMxDoc = ThisDocument
      Set pMap = pMxDoc.FocusMap
      pCurve.Project pMap.SpatialReference
    End If
    Set pMiddlePoint = New Point
    pCurve.QueryPoint 0, dDistance, bAsRatio, pMiddlePoint
    Set pZAware = pMiddlePoint
    If (pZAware.ZAware) Then
      dZMiddle = pMiddlePoint.Z
    Else
      dZMiddle = -1
    End If
  End If
End If

__esri_field_calculator_splitter__
dZMiddle
```

This script takes the average of all “Z” values within each polylineMZ segment and assigns that value to the segment. To apply the script, the research team added a field to the roadway network attribute table to store growth rate values and, then, within editing mode, right clicked on that field, selected “calculate values,” and entered the script name.

4.5 APPLY GROWTH RATES

After assigning historical growth rate values to individual roadway segments, the research team evaluated a variety of future growth rate scenarios. Scenarios included growing individual segment AADTTs by 100 percent, 90 percent, 80 percent, and 60 percent of historical values. Plotting and viewing each scenario allowed analysts to visualize how well each growth scenario would represent the anticipated reality. The use of GIS made this process feasible due to the large number of segments and several iterations which were required. Researchers felt that future truck growth would probably not keep pace with historical growth, so they used 90 percent of the historical values rather than 100 percent or one of the other options. Figure 26 shows the 2002 AADTT values, and Figure 27 shows 90 percent of the 2022 AADTT estimates based on the procedure described above. For the sake of continuity, these maps show AADTT line widths and colors as if truck roadways pass through large urban areas. This portrayal is contrary to the plan for the Trans Texas Corridor, so in reality the truck volumes will probably not be as large as shown in or near these urban areas because the TTC will bypass them.

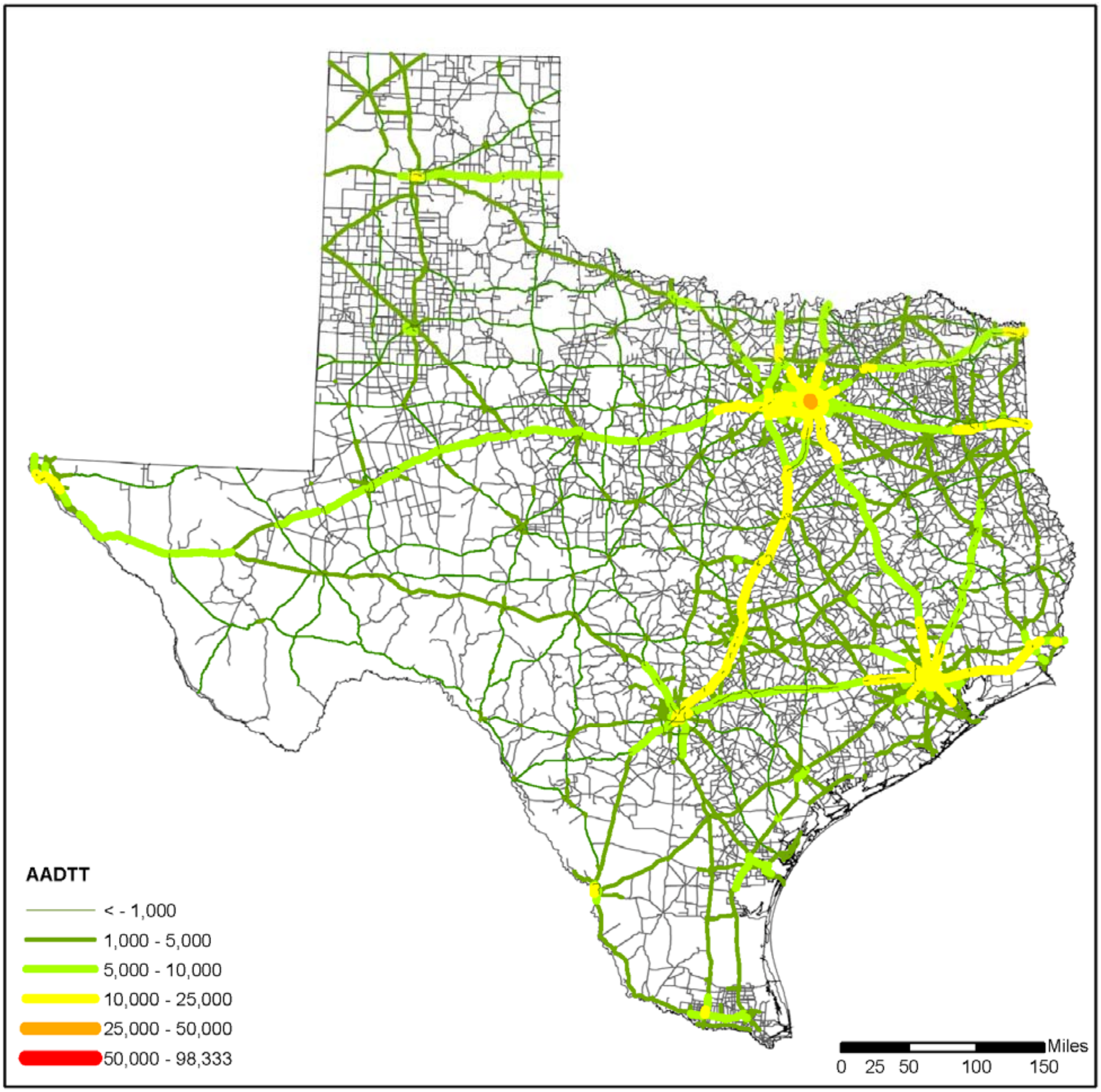


Figure 26. 2002 Truck Roadway AADTT.

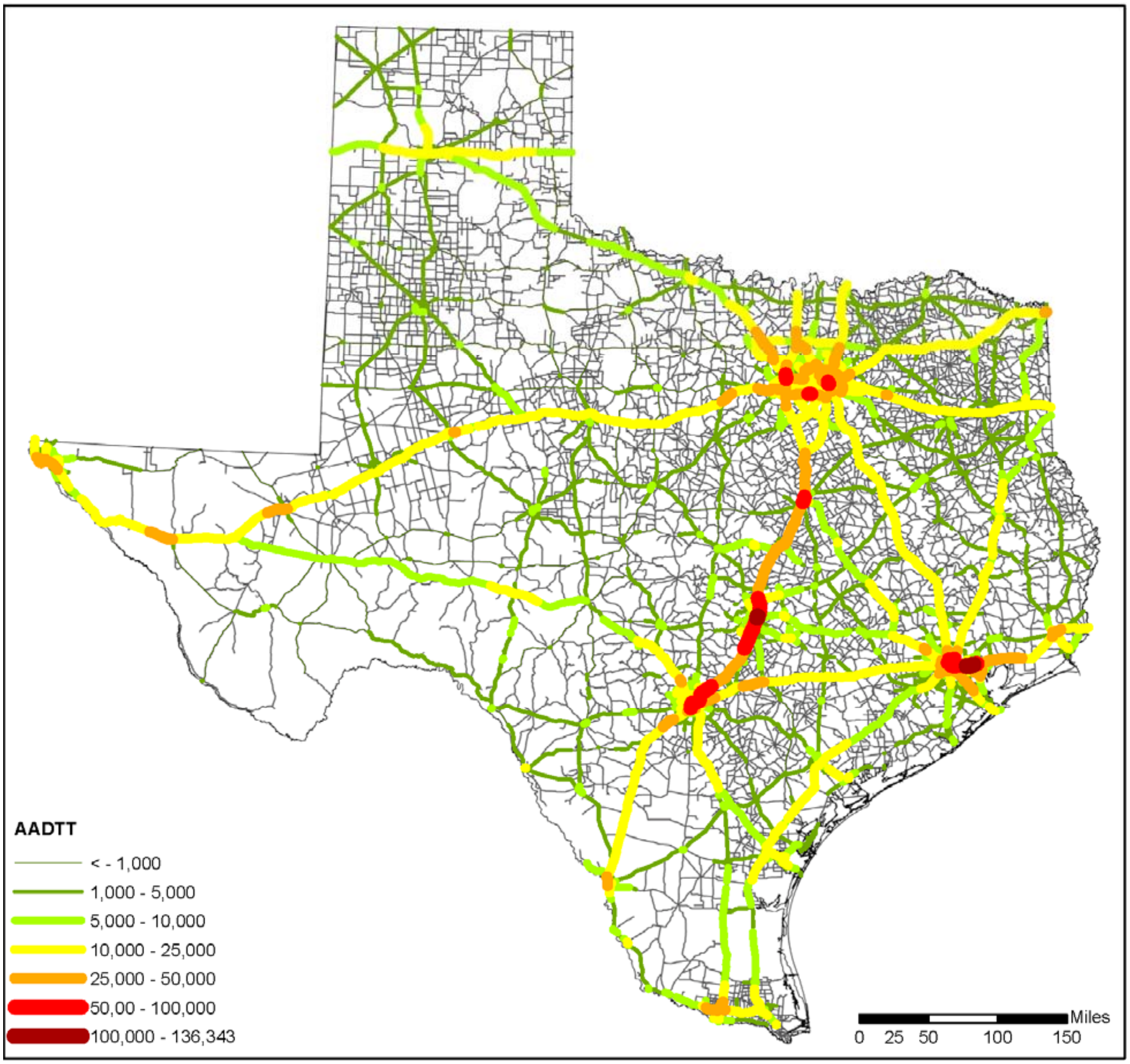


Figure 27. 2022 Truck Roadway AADTT.

4.6 RESULTING 2022 TRUCK ROADWAY NETWORK

The final maps had to show more than just traffic volume, since descriptors of traffic flow or traffic operations typically deal with geometric information as well. Given that the objective of this step was to develop a truck roadway network for four-or-more-lane truck roadways, researchers had to utilize level of service relationships developed in Chapter 3 along with projected truck traffic on the system of truck-only roadways.

For developing level of service relationships, researchers used the capacity values from VISSIM and HCM *v/c* relationships to establish the other maximum service flows. Truck roadways should have a minimum of two lanes in each direction to allow faster trucks to overtake slower trucks. The LOS of this two-or-more-lane truck roadway became the focus of further capacity analysis in this research.

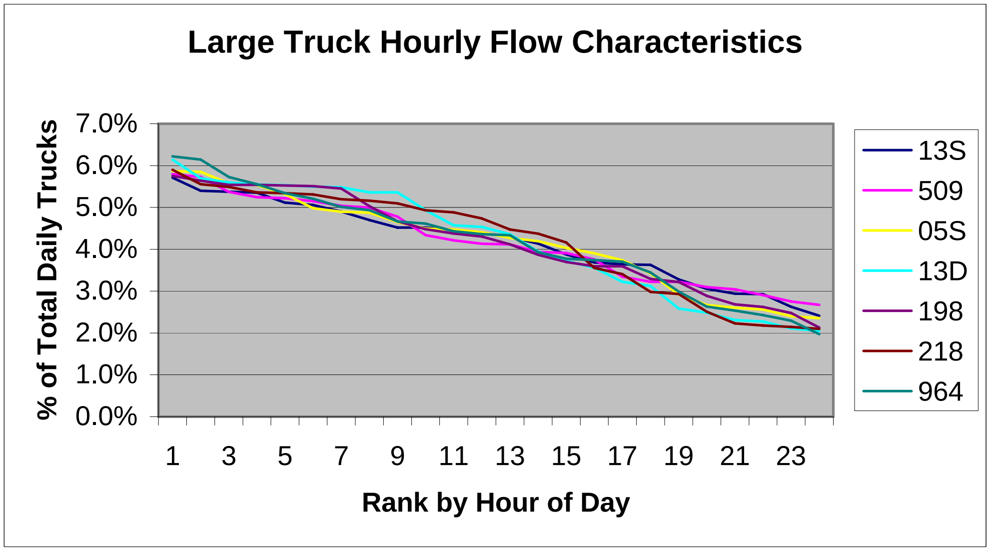
The process also considered Trans Texas Corridor routes, hazardous materials routes, and corridors designated by legislation (e.g., I-69 and Ports-to-Plains). However, final decisions utilizing "hard data" resulted in the most objective evaluation. If information on major truck traffic generators is available to analysts, it should also be considered.

4.6.1 Level of Service Analysis

As the process advanced, the research team refined the daily volumes to determine and utilize peak hourly flows to determine level of service. Translating from AADTT to hourly truck flows requires knowledge of large truck peaking characteristics. Data from a previous project indicated that the peak hour truck volumes were about 6 percent of the daily truck flows *(2)*. Figure 28 graphically depicts the hourly percent of total daily (AADTT) values for these seven sites arranged from high to low. All seven sites represented by Figure 28 (Stations 13S to 218) fall into the AADTT range of at least 5000 trucks per day. Figure 28 indicates a very consistent pattern for percentages by ranked hour of day for all sites represented. The consistency of these data suggests the use of these sites to represent other relatively high-volume sites throughout the state. Unfortunately, these data may not represent an entire year, so the user must still be cautious. However, for this analysis, a "typical" peak hourly bi-directional truck demand can be taken as about 6 percent of the AADTT. Also, the average hourly flow is 4.25 percent of AADTT.

The next step was establishing maximum service flows for each level of service. Based on the VISSIM modeling reported in Chapter 3, the per-lane capacity of truck roadways with level terrain, one-third of the trucks entering or exiting at interchanges, and interchange spacing averaging 10 miles is 1175 trucks per lane per hour. Since much of the terrain in Texas can be characterized as low grades and gently rolling, the capacity would decrease to 1125 trucks per lane per hour (again, assuming interchanges spaced 10 miles apart and same enter/exit percentage). By using this capacity value and the same *v/c* ratios as used in the *Highway Capacity Manual,* one can compute the maximum flow rates for each level of service on a truck facility. Table 27 summarizes the results for a four-lane truck roadway and Table 28 shows similar results for a six-lane truck roadway. For example, for a four-lane truck road, LOS B represents a maximum service flow of 630 trucks per lane per hour, translating into a four-lane AADTT of 42,000 trucks per day assuming a 50/50 directional split. The tabulated values will be slightly on the conservative side for the flattest areas of the state.

Figures 29 and 30 show the resulting levels of service and numbers of lanes on the truck roadway network in Texas to serve predicted 2022 truck flows. Figures 31 and 32 represent forecast year 2032. Again, these results should be viewed in the context of the Trans Texas Corridor, which means the truck facilities will, in all likelihood, not pass through large urban areas. Therefore, the LOS shown passing through urban areas will probably not be as bad as it appears. Table 29 summarizes the number of miles of truck roadways needed by four-lane, six-lane, or eight-lane facilities, assuming traffic growth occurs at the same 90 percent of historical growth and other assumptions befitting most of Texas.



Source: TxDOT.

Figure 28. Bi-directional Hourly Truck Percentages at Seven High-Volume Sites.

Table 27. Maximum Flow Rates and AADTTs on Four-Lane Truck Facilities.

LOS	Maximum *v/c*	Maximum Hourly Flow (per lane)	Corresponding AADTT (Four-Lane Facility)
A	0.34	383	0 to 25,500
B	0.56	630	25,500 to 42,000
C	0.76	855	42,000 to 57,000
D	0.90	1013	57,000 to 67,500
E	1.00	1125	67,500 to 75,000

Table 28. Maximum Flow Rates and AADTTs on Six-Lane Truck Facilities.

LOS	Maximum *v/c*	Maximum Hourly Flow (per lane)	Corresponding AADTT (Six-Lane Facility)
A	0.34	383	0 to 38,300
B	0.56	630	38,300 to 63,000
C	0.76	855	63,000 to 85,500
D	0.90	1013	85,500 to 101,300
E	1.00	1125	101,300 to 112,500

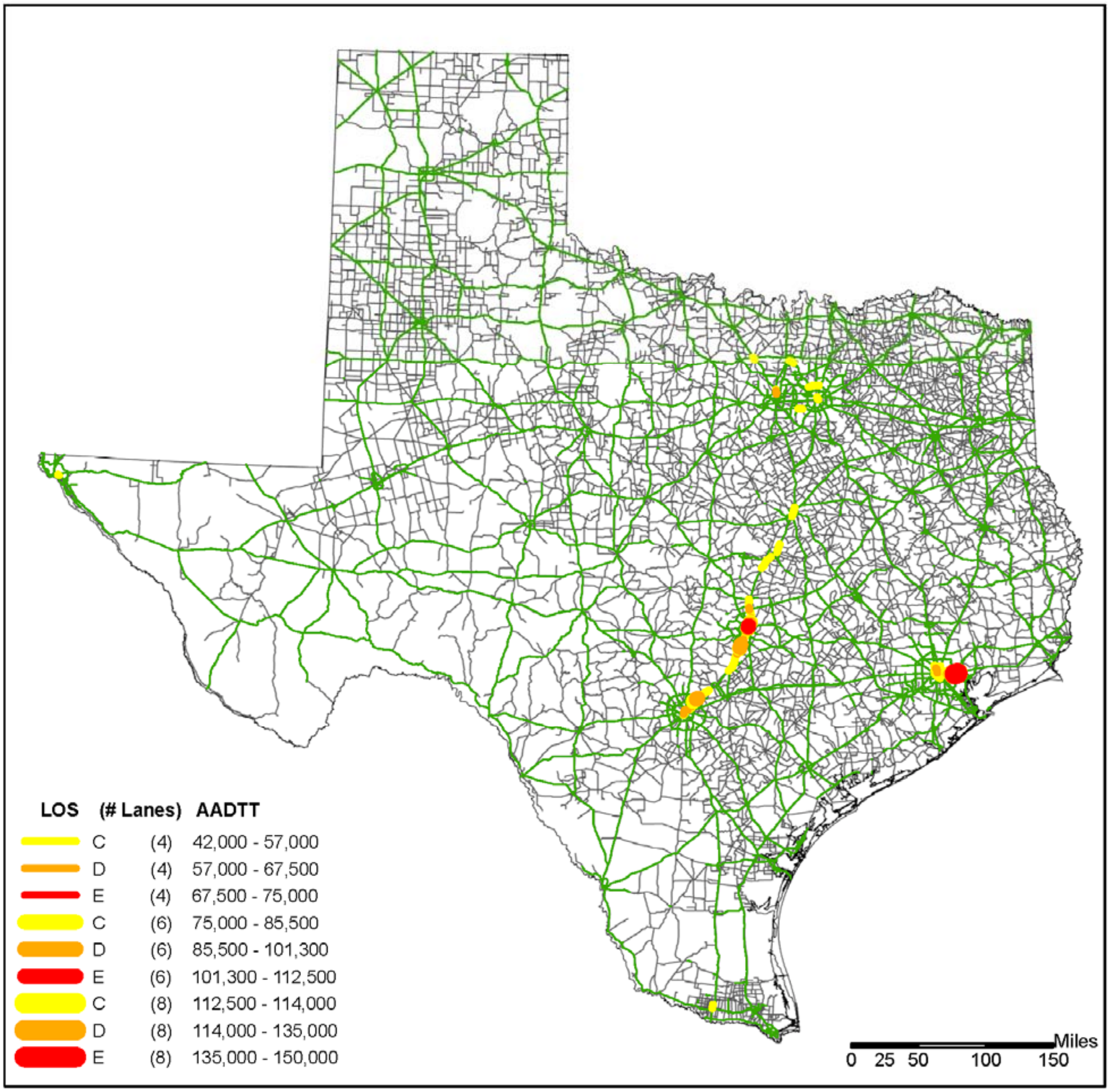


Figure 29. 2022 Statewide Truck Roadway AADTT and LOS.

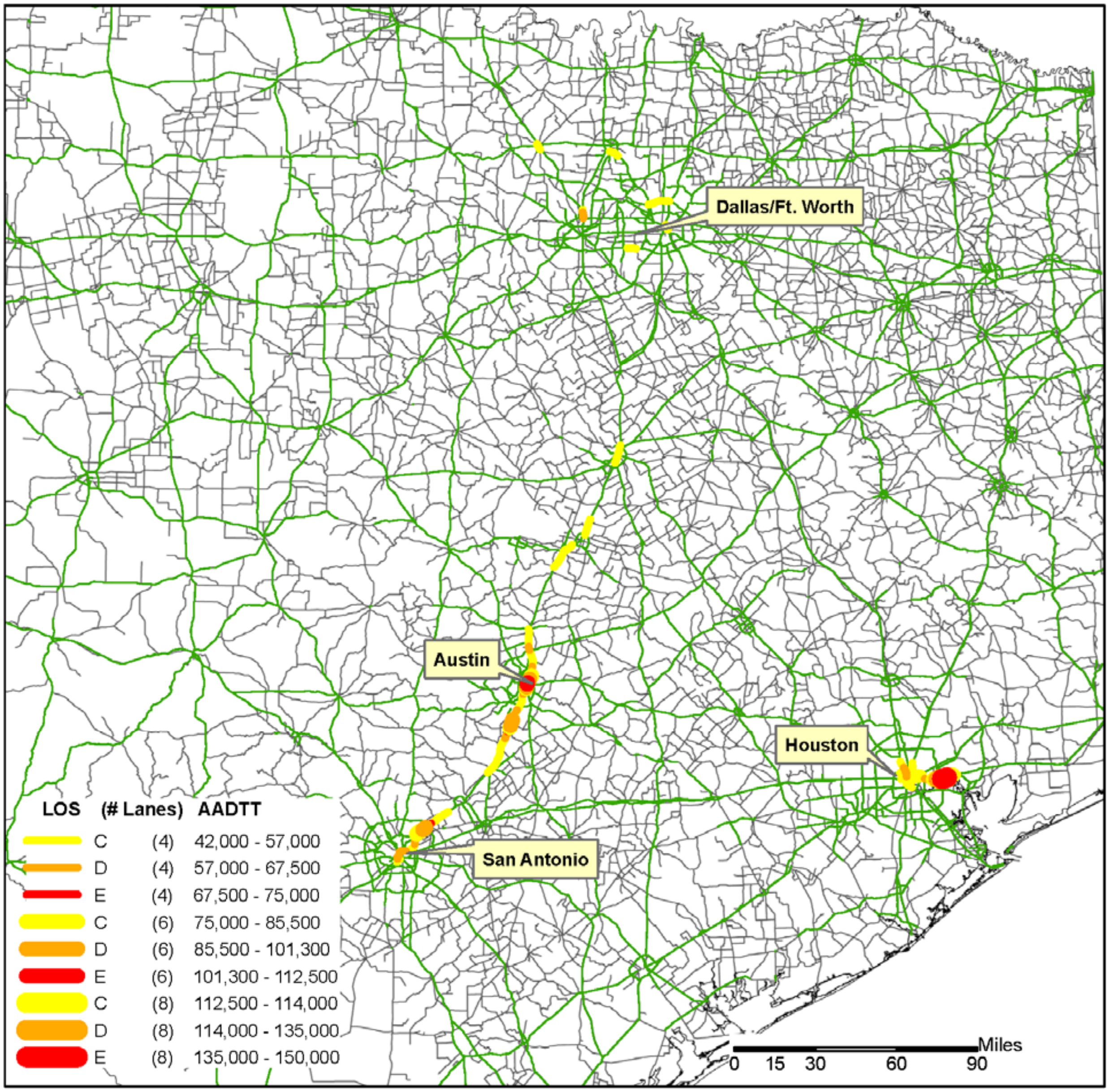


Figure 30. 2022 Central Texas Truck Roadway AADTT and LOS.

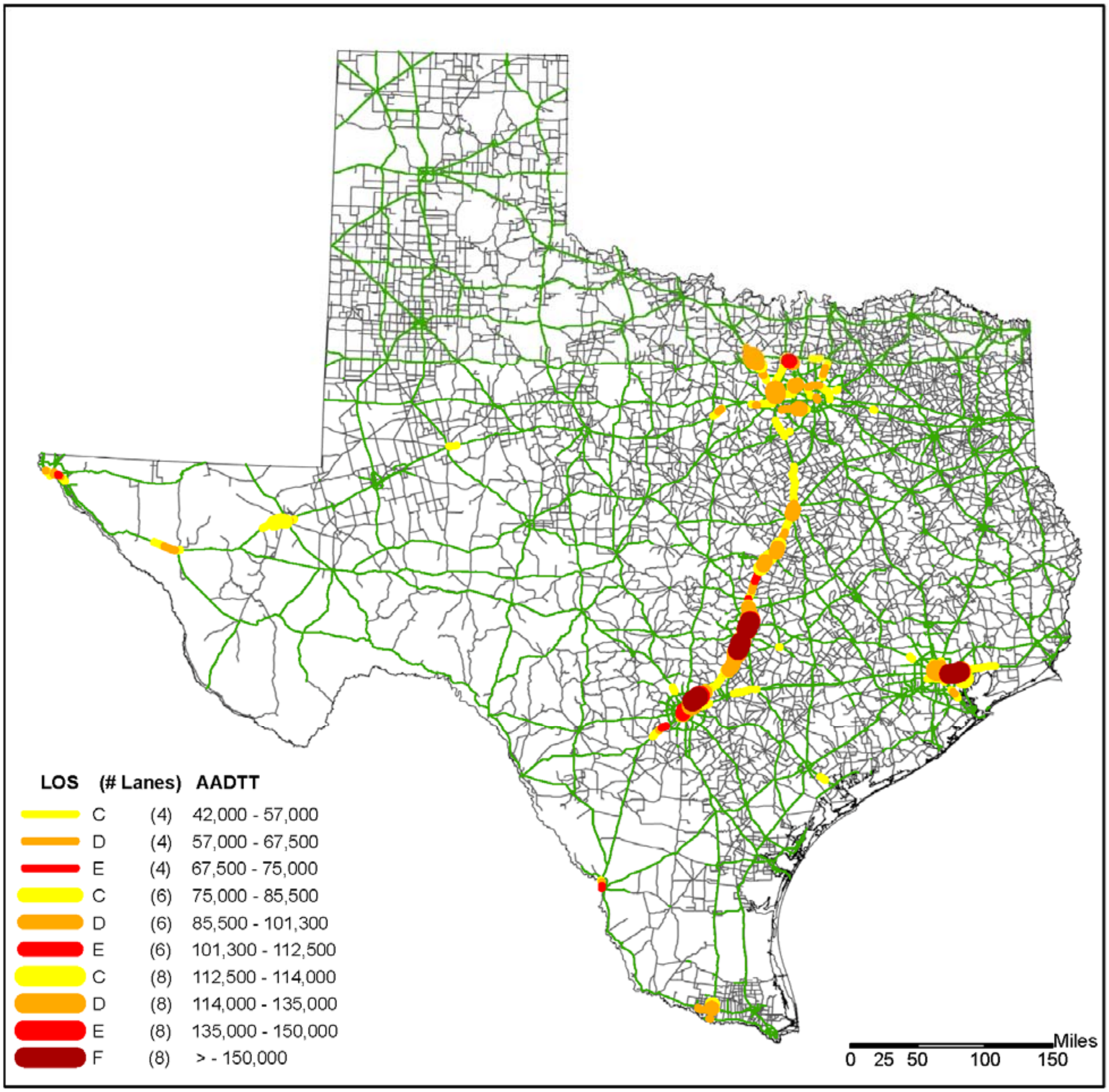


Figure 31. 2032 Statewide Truck Roadway AADTT and LOS.

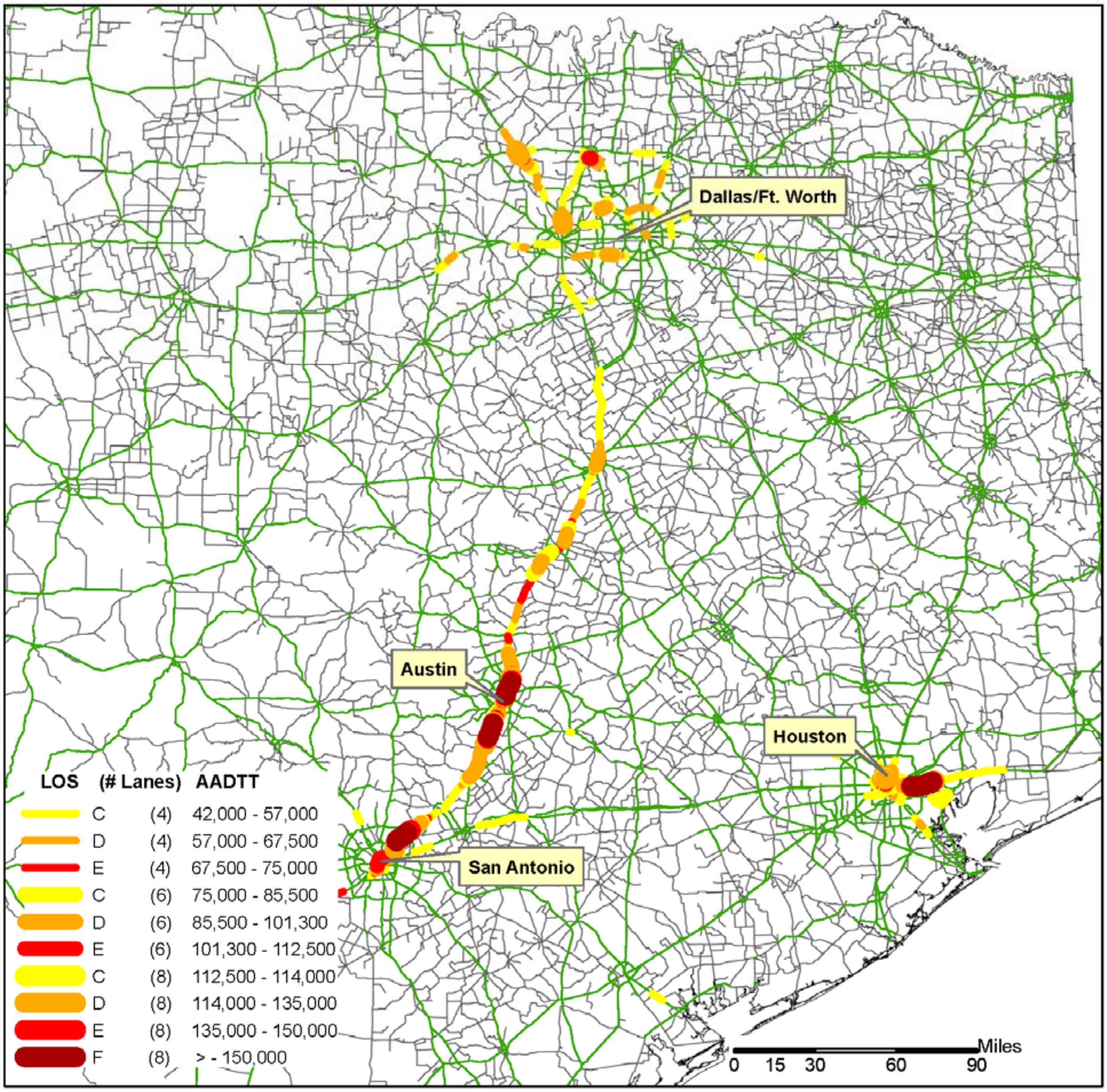


Figure 32. 2032 Central Texas Truck Roadway AADTT and LOS.

Table 29. Truck Roadway Mileage by No. of Lanes, LOS, and Forecast Year.

Truck Roadway	LOS	AADTT	Forecast Year	
			2022	2032
Four-Lane	A	0 to 25,500	18,567	17,383
	B	25,500 to 42,000	478	1175
	C	42,000 to 57,000	130	330
	D	57,000 to 67,500	25	120
	E	67,500 to 75,000	9	50
Six-Lane	A			
	B			
	C	75,000 to 85,500	8	52
	D	85,500 to 101,300	7	63
	E	101,300 to 112,500	2	15
Eight-Lane	A			
	B			
	C	112,500 to 114,000	0	0
	D	114,000 to 135,000	1	15
	E	135,000 to 150,000	2	4
	F	>150,000	0	22
Sum of Values by Year:			19,229	19,229

CHAPTER 5. EVALUATION FRAMEWORK

5.1 INTRODUCTION

Using the criteria established in earlier tasks, TTI developed an evaluation framework to assess the system of truck-only roadways developed earlier. The evaluation plan accomplishes two objectives: a) assessment and fine-tuning of the corridor(s) under study, and b) development of information and data that can be readily and prospectively transferred to other corridors. The plan which came out of this task focuses primarily on the criteria used to select treatments, such as safety, level-of-service (mixed and truck facilities), and financial feasibility. In addition, the plan includes public satisfaction measures and measures of acceptability to trucking interests.

5.2 METHODOLOGY

The research team began the evaluation framework by knowing what information and data would be readily available and what would best describe the feasibility or need for a truck facility. Traffic safety is of utmost importance in developing criteria for truck facilities. Traffic volume is a key criterion due to its availability, frequency of updates, and its predictability. Level of service was another important criterion which takes traffic volume and, together with geometric features, determines the quality of traffic operations on a facility. Finally, financial feasibility is a good criterion because it alone can reflect safety, initial cost, delay, and other factors for comparisons between mixed flow roadways and roadways with truck-only facilities. Given these criteria, one must develop some relationships between them to serve the needs of decision-makers. There must be acceptable ranges of all criteria that become the goals of a truck roadway program. These ranges became more evident as the project progressed and researchers gained a better understanding of the conditions that might warrant truck roadways from earlier tasks.

5.3 EVALUATION FRAMEWORK COMPONENTS

The following list provides the components of the evaluation framework followed by a discussion of each and general ranges for some criteria to help decision-makers determine general needs.

- acquire truck and non-truck volume,

- project truck and non-truck growth,

- determine desired level of service,

- determine number of lanes,

- acquire crash data and estimate crashes,

- determine financial feasibility, and
- determine user perspectives and other measures of acceptability.

5.3.1 Acquire Truck and Non-Truck Volume

Use Transportation Planning and Programming Division's latest vehicle classification counts for the corridor. Begin by defining vehicles by type that will be allowed to use the facility. Typically, vehicles with three or more axles are the ones that will use intercity corridors, whereas delivery vehicles which have two axles have a much greater impact in urban areas.

5.3.2 Project Truck and Non-Truck Volume

General truck growth rates in the 1 percent to 5 percent per year can be expected in a reasonably strong economy. Historical growth values are good predictors of future growth, along with knowledge of the corridor. TxDOT's Statewide Analysis Model is also a good tool for estimating future growth on corridors. Locations of major truck traffic generators, along with national and international trends, come into play for long design periods.

5.3.3 Determine Desired Level of Service

In the context of the Trans Texas Corridor, truck roadways will generally serve intercity corridors and avoid urban areas. Therefore, the desired LOS in the design year (usually 20 years hence) will be LOS C to LOS E. Use simulation results to determine LOS under expected 20-year conditions. This research project used VISSIM to determine LOS values based on prevailing vehicle characteristics, terrain factors, interchange spacing, and truck volume. Chapter 6 provides results of the simulation efforts in the form of matrices comparing mixed and separated vehicle flows.

5.3.4 Determine Number of Lanes

Truck roadways should have a minimum of two lanes in each direction to facilitate passing. Otherwise, motor carriers will not use them. To some degree, the design LOS and projected truck volume will determine the need for truck facilities. Using Tables 11 and 12 in Chapter 3, one can determine the truck demand that must exist before building a two-lane truck roadway (based on truck volume alone). This example assumes 70-mph design speed, two or five interchanges per 20 miles, gently rolling terrain (typical Texas terrain), and one-third of truck volume entering and exiting at interchanges. LOS E or capacity is 1125 trucks per lane per hour for two interchanges per 20 miles and 1175 trucks per lane per hour for five interchanges per 20 miles. The VISSIM simulation input used a percent of mainline volume exiting and entering, so fewer interchanges result in higher ramp volumes. Scaling the other LOS values to maximum service flows uses the HCM values for *v/c*. Developing daily two-way truck volumes assumes 50 percent directional splits and 6 percent peak hour factors. Tables 30 and 31 provide the maximum AADTT values by LOS for four- and six-lane truck roadways for the assumed conditions of terrain, interchange spacing, and entering/exiting volumes.

Table 30. Maximum AADTT for Four Lanes by LOS.

LOS	Two Ramps per 20 miles	Five Ramps per 20 miles
A	24,000	25,067
B	39,750	41,517
C	55,500	57,967
D	67,500	70,500
E	75,000	78,333

Table 31. Maximum AADTT for Six Lanes by LOS.

LOS	Two Ramps per 20 miles	Five Ramps per 20 miles
A	36,000	37,600
B	59,625	62,275
C	83,250	86,950
D	101,250	105,750
E	112,500	117,500

Based on this example and perhaps 20-year projections for the design year, decision-makers would probably not plan on building four-lane truck roadways unless truck volumes were about 60,000 trucks per day. The number of trucks at some locations might require even more than four lanes. Designing for more than about 75,000 trucks per day under the conditions assumed above would require six (or more) lanes. Chapter 6 provides many combinations of truck and total traffic volume, terrain factors, and enter/exit percentages to facilitate such decisions.

5.3.5 Acquire Crash Data

Determine truck-car crash history for the corridor. Historical data do not exist for this purpose except for the number of truck-car crashes. Reducing these crashes by a reasonable proportion and determining the cost savings from the reduced crashes is one way to estimate the impacts of truck roadways.

5.3.6 Determine Financial Feasibility

The process used in this research bases the final feasibility of a truck roadway on a benefit/cost relationship. The minimum value of the B/C for such decisions is often significantly greater than 1.0 if some of the variables are not well known or understood. For example, a B/C value of 1.5 to 2.0 is probably appropriate for building truck roadways, given the uncertainties related primarily to crash reductions. The primary components of the analysis are initial construction cost, delay and fuel consumption cost, and crash cost. Other considerations are user and public satisfaction and air quality.

5.3.6.1 Initial Construction Cost

Based on TxDOT planning estimates, the initial cost of building a two-lane truck roadway is $11 million per mile. This cost includes two 13-ft lanes, a 12-ft right shoulder, a 6-ft left shoulder, and 14 inches of continuously reinforced concrete pavement. Since the surface dimensions have been set by the TTC design and thinner pavement would not be appropriate for a truck roadway, the construction cost of the two-lane facility will remain fixed in this analysis. The cost comparison will actually be between expanding and maintaining a mixed facility versus adding a separate truck roadway and leaving cars (and small trucks) on the older mixed facility.

5.3.6.2 Crash Cost

The cost of crashes must be approximated based on expected crash rates because there are no pure truck roadways in the United States from which to gather historical crash data. The crash estimates will be segment-specific with variable costs by crash type. TTI used the current TxDOT cost of crashes as follows:

- average fatal accident cost: $3,850,848;
- average incapacitating injury accident cost: $228,267;
- average non-incapacitating injury accident cost: $65,018; and
- average possible injury accident cost: $31,379.

Cost of hazardous materials spills and incidents associated with them must also be considered.

5.3.6.3 Delay and Fuel Consumption

Costs associated with changes in delay and fuel consumption are available from the VISSIM model or from the CORSIM model. Estimates of costs associated with these changes can then become a contribution to the financial feasibility equation.

5.3.7 Public Satisfaction Measures

Interviews conducted as part of this research and public meetings held by TxDOT as part of the Trans Texas Corridor planning process are helpful in understanding the views of the public related to truck roadways. Future planning of these roadways must always include input from user groups and the public at large to ensure maximum success. The general reaction from both automobile and truck drivers is that the separation would be very beneficial. Automobile drivers are not comfortable operating near large trucks because of size and weight differences. Truck drivers would rather operate with other truck drivers because they understand truck operating characteristics. Most automobile drivers do not.

CHAPTER 6. TRUCK FACILITY ANALYSIS TOOLS

6.1 INTRODUCTION

Using the criteria, classification, and framework developed earlier in this research, TTI developed tools to evaluate levels of service on exclusive truck facilities. These tools resulted from the use of VISSIM to simulate a variety of truck scenarios expected to represent Texas freeway conditions. In the results of this task, TTI is including a process for measuring the success of exclusive truck facilities, comparing their operation and performance to the "base case" (no truck facility option) by using computer simulation software. Even though TTI used VISSIM, the plan is for TxDOT to utilize these research findings in CORSIM for future final evaluations which are freeway segment specific.

6.2 METHODOLOGY

The goal of Chapters 2, 3, 4, and 5 was to lay the foundation for this chapter. The preliminary truck network was all state highways with daily truck volume of at least 1000 trucks per day. From that network, researchers evaluated present and future truck/non-truck volume and vehicular crashes, with the aim of developing financial feasibility relationships to establish the viability of truck roadways. Establishing level of service relationships was an important use of the truck and non-truck volumes. Locations where the LOS analysis indicated poor operations for trucks during the 20-year design period would indicate likely candidates for truck roadways if their net costs made them a viable solution to congestion and safety concerns. The final determinant for truck roadways was financial feasibility.

6.3 LOS FOR MIXED AND SEPARATED FACILITIES

With guidance from the HCM on providing LOS for different flow and geometric conditions for mixed-flow and auto-only freeway facilities and guidance from the current research on providing LOS for truck-only roadways, it became possible to establish the basic design, in terms of the number of lanes, required to accommodate different combinations of auto and truck volumes under varying volume, ramp demand, grade, and terrain conditions. Such data are ultimately necessary to evaluate whether or not a roadway corridor would operate better if a truck-only facility were designed to service its truck traffic, and to estimate the benefits and costs of creating a truck-only roadway on both the original freeway and the new truck facility.

This research examined a broad range of possible operating conditions to simplify the evaluation of roadway corridors for truck-only roadways. The following aspects of the model were all varied with respect to one another, creating a total of 675 different scenarios that required modeling:

- input traffic volume of 3000, 4500, 6000, 7500, and 9000 vehicles per hour;
- within that traffic flow, a truck volume of 300, 600, 900, 1200, and 1500 trucks per hour;

- ramp volumes of 10, 20, and 30 percent of through-vehicle flow;
- grades of 0, 2, and 4 percent; and
- terrain that was flat, gently rolling, or rolling.

When performing the simulations of these scenarios, researchers used the vehicle distributions and vehicle performance data as those established for the capacity modeling earlier in this investigation. The primary outcome of this effort, the number of lanes for any combination of the above modeled aspects, was tabulated and rendered in graphical format for ease of reference. Tables 32 through 40 summarize the results, and Appendix B indicates similar results graphically. When reviewing these results, it is possible at times to view an interesting phenomenon where (due to the volume and vehicle mix levels for a particular scenario) five lanes of capacity would be necessary to maintain LOS E or better operations in a mixed flow situations whereas a combination of six lanes would be necessary for separate facilities (i.e., two lanes for a truck-only freeway and four lanes for an auto-only freeway). The reverse of this situation can also be observed in the results, wherein the total number of lanes for a mixed flow facility is greater than the sum of the numbers of lanes required for separate truck and auto facilities.

In addition to identifying the number of lanes required to provide reasonable quality of flow (defined as LOS E or better), the tables can also be used to estimate the expected LOS performance of an auto-only, truck-only, or mixed-flow freeway under the specified loading and geometry condition. The intent was to design results to easily indicate the number of lanes required for LOS E or better operations for each scenario; they do not contain adequate detail to identify the LOS for any combination of total facility volume, truck volume, terrain type, and grade.

The concluding simulation analysis effort of this research investigation into the impacts and benefits of truck-only roadways was designed to provide analysts with performance data to compare truck-only/auto-only roadway design scenarios with mixed-flow designs. The desired output from this analysis was representative delay, fuel consumption, and emissions data from the VISSIM modeling scenarios for truck-only/auto-only and mixed-flow cases that analysts could use to compute the operational costs (delay time value and cost of fuel consumption) of each design under the broad range of operating conditions examined in this research. With these values calculated, analysts could, in a generic overview way, easily evaluate the operational performance of truck-only roadway and conventional designs and assess the cost of operations for these different situations. In all cases and for all outputs reported, unit measures are in quantities per mile of roadway, per hour of analysis time.

Table 32. LOS for Mixed and Separated Flows (Level Terrain, 10% Enter/Exit).

AADTT	Truck Peak Hr. Volume[1]	Total ADT and Peak Hour Volume[2]				
		60,000	90,000	120,000	150,000	180,000
		3000	4500	6000	7500	9000
10,000	300	C	E	D (3)	D (4)	D (5)
		C	D	D (3)	D (4)	D (4)
		A	A	A	A	A
20,000	600	C	C (3)	E (3)	D (4)	D (5)
		C	D	D (3)	D (4)	D (4)
		A	A	A	A	A
30,000	900	C	C (3)	C (4)	D (4)	C (6)
		B	D	D (3)	C (4)	D (4)
		B	B	B	B	B
40,000	1200	C	C (3)	C (4)	E (4)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C
50,000	1500	C	C (3)	C (4)	C (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C

Table 33. LOS for Mixed and Separated Flows (Level Terrain, 20% Enter/Exit).

AADTT	Truck Peak Hr. Volume[1]	Total ADT and Peak Hour Volume[2]				
		60,000	90,000	120,000	150,000	180,000
		3000	4500	6000	7500	9000
10,000	300	C	E	E (3)	E (4)	D (5)
		C	D	D (3)	D (4)	E (4)
		A	A	A	A	A
20,000	600	C	C (3)	C (4)	E (4)	D (5)
		C	D	D (3)	D (4)	E (4)
		A	A	A	A	A
30,000	900	C	C (3)	C (4)	C (5)	C (6)
		B	D	D (3)	C (4)	D (4)
		B	B	B	B	B
40,000	1200	D	C (3)	C (4)	C (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C
50,000	1500	B (3)	C (3)	C (4)	C (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C

[1] Conversion from AADTT to peak hour using a 50 percent directional split and a 6 percent peak hour factor.
[2] Conversion from ADT to peak hour using a 50 percent directional split and a 10 percent peak hour factor.

Where (in each cell): Numbers in parentheses = number of lanes (2 lanes if no parentheses).

= LOS of the entire vehicle stream (trucks and cars) on a mixed-flow freeway facility
= LOS of the vehicle stream (with no trucks) on an otherwise mixed-flow freeway facility
= LOS of trucks on a two-lane exclusive truck freeway facility

Table 34. LOS for Mixed and Separated Flows (Level Terrain, 30% Enter/Exit).

AADTT	Truck Peak Hr. Volume[1]	Total ADT and Peak Hour Volume[2]				
		60,000	90,000	120,000	150,000	180,000
		3000	4500	6000	7500	9000
10,000	300	C	C (3)	C (4)	C (5)	C (6)
		C	D	D (3)	D (4)	D (5)
		A	A	A	A	A
20,000	600	D	C (3)	C (4)	C (5)	C (6)
		C	D	D (3)	D (4)	D (5)
		A	A	A	A	A
30,000	900	D	D (3)	C (4)	C (5)	C (6)
		B	D	D (3)	D (4)	E (4)
		B	B	B	B	B
40,000	1200	B (3)	C (3)	C (4)	D (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C
50,000	1500	B (3)	B (4)	C (4)	D (5)	E (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C

Table 35. LOS for Mixed and Separated Flows (2% Grade Terrain, 10% Enter/Exit).

AADTT	Truck Peak Hr. Volume[1]	Total ADT and Peak Hour Volume[2]				
		60,000	90,000	120,000	150,000	180,000
		3000	4500	6000	7500	9000
10,000	300	C	C (3)	D (3)	D (4)	C (6)
		C	D	D (3)	D (4)	D (4)
		A	A	A	A	A
20,000	600	C	C (3)	C (4)	D (4)	C (6)
		C	D	D (3)	D (4)	D (4)
		A	A	A	A	A
30,000	900	C	C (3)	C (4)	E (4)	C (6)
		B	D	D (3)	C (4)	D (4)
		B	B	B	B	B
40,000	1200	C	C (3)	C (4)	C (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C
50,000	1500	C	C (3)	C (4)	C (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C

[1] Conversion from AADTT to peak hour using a 50 percent directional split and a 6 percent peak hour factor.
[2] Conversion from ADT to peak hour using a 50 percent directional split and a 10 percent peak hour factor.

Where (in each cell): Numbers in parentheses = number of lanes (2 lanes if no parentheses).

= LOS of the entire vehicle stream (trucks and cars) on a mixed-flow freeway facility
= LOS of the vehicle stream (with no trucks) on an otherwise mixed-flow freeway facility
= LOS of trucks on a two-lane exclusive truck freeway facility

Table 36. LOS for Mixed and Separated Flows (2% Grade Terrain, 20% Enter/Exit).

AADTT	Truck Peak Hr. Volume[1]	Total ADT and Peak Hour Volume[2]				
		60,000	90,000	120,000	150,000	180,000
		3000	4500	6000	7500	9000
10,000	300	C	C (3)	C (4)	D (4)	D (5)
		C	D	D (3)	D (4)	E (4)
		A	A	A	A	A
20,000	600	C	C (3)	C (4)	D (4)	D (5)
		C	D	D (3)	D (4)	E (4)
		A	A	A	A	A
30,000	900	C	C	C (4)	C (5)	C (6)
		B	D	D (3)	C (4)	D (4)
		B	B	B	B	B
40,000	1200	C	C (3)	C (4)	C (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C
50,000	1500	B (3)	C (3)	C (5)	C (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C

Table 37. LOS for Mixed and Separated Flows (2% Grade Terrain, 30% Enter/Exit).

AADTT	Truck Peak Hr. Volume[1]	Total ADT and Peak Hour Volume[2]				
		60,000	90,000	1200,000	150,000	180,000
		3000	4500	6000	7500	9000
10,000	300	C	C (3)	C (4)	C (5)	C (6)
		C	D	D (3)	D (4)	D (5)
		A	A	A	A	A
20,000	600	C	C (3)	C (4)	C (5)	C (6)
		C	D	D (3)	D (4)	D (5)
		A	A	A	A	A
30,000	900	C	C (3)	C (4)	C (5)	C (6)
		B	D	D (3)	C (4)	E (4)
		B	B	B	B	B
40,000	1200	B (3)	B (4)	C (4)	C (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C
50,000	1500	B (3)	B (4)	C (5)	C (5)	C (6)
		B	C	C (3)	C (4)	C (5)
		C	C	C	C	C

[1] Conversion from AADTT to peak hour using a 50 percent directional split and a 6 percent peak hour factor.
[2] Conversion from ADT to peak hour using a 50 percent directional split and a 10 percent peak hour factor.

Where (in each cell): Numbers in parentheses = number of lanes (2 lanes if no parentheses).

= LOS of the entire vehicle stream (trucks and cars) on a mixed-flow freeway facility
= LOS of the vehicle stream (with no trucks) on an otherwise mixed-flow freeway facility
= LOS of trucks on a two-lane exclusive truck freeway facility

Table 38. LOS for Mixed and Separated Flows (4% Grade Terrain, 10% Enter/Exit).

AADTT	Truck Peak Hr. Volume[1]	Total ADT and Peak Hour Volume[2]				
		60,000	90,000	120,000	150,000	180,000
		3000	4500	6000	7500	9000
10,000	300	C	C (3)	C (4)	C (5)	C (6)
		C	D	D (3)	D (4)	D (4)
		A	A	A	A	A
20,000	600	C	C (3)	C (4)	C (5)	C (6)
		C	D	D (3)	D (4)	D (4)
		A	A	A	A	A
30,000	900	C	C (3)	C (4)	C (5)	C (6)
		B	D	D (3)	C (4)	D (4)
		B	B	B	B	B
40,000	1200	C	C (3)	C (4)	C (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C
50,000	1500	C	C (3)	C (4)	C (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C

Table 39. LOS for Mixed and Separated Flows (4% Grade Terrain, 20% Enter/Exit).

AADTT	Truck Peak Hr. Volume[1]	Total ADT and Peak Hour Volume[2]				
		60,000	90,000	120,000	150,000	180,000
		3000	4500	6000	7500	9000
10,000	300	C	C (3)	C (4)	C (5)	D (5)
		C	D	D (3)	D (4)	E (4)
		A	A	A	A	A
20,000	600	C	C (3)	C (4)	C (5)	C (6)
		C	D	D (3)	D (4)	E (4)
		A	A	A	A	A
30,000	900	C	C (3)	C (4)	C (5)	C (6)
		B	D	D (3)	C (4)	D (4)
		B	B	B	B	B
40,000	1200	B (3)	B (4)	C (4)	D (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		B	C	C	C	C
50,000	1500	B (3)	B (4)	C (5)	E (5)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C

[1] Conversion from AADTT to peak hour using a 50 percent directional split and a 6 percent peak hour factor.
[2] Conversion from ADT to peak hour using a 50 percent directional split and a 10 percent peak hour factor.

Where (in each cell): Numbers in parentheses = number of lanes (2 lanes if no parentheses).

= LOS of the entire vehicle stream (trucks and cars) on a mixed-flow freeway facility
= LOS of the vehicle stream (with no trucks) on an otherwise mixed-flow freeway facility
= LOS of trucks on a two-lane exclusive truck freeway facility

Table 40. LOS for Mixed and Separated Flows (4% Grade Terrain, 30% Enter/Exit).

AADTT	Truck Peak Hr. Volume[1]	Total ADT and Peak Hour Volume[2]				
		60,000	90,000	120,000	150,000	180,000
		3000	4500	6000	7500	9000
10,000	300	C	C (3)	C (4)	C (5)	C (6)
		C	D	D	D (4)	D (5)
		A	A	A	A	A
20,000	600	B (3)	C (3)	C (4)	D (5)	D (6)
		C	D	D (3)	D (4)	D (5)
		A	A	A	A	A
30,000	900	B (3)	B (4)	C (4)	E (5)	C (6)
		B	D	D (3)	C (4)	E (4)
		B	B	B	B	B
40,000	1200	B (3)	B (4)	C (4)	C (6)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C
50,000	1500	B (3)	B (4)	C (5)	C (6)	C (6)
		B	C	C (3)	C (4)	D (4)
		C	C	C	C	C

[1] Conversion from AADTT to peak hour using a 50 percent directional split and a 6 percent peak hour factor.
[2] Conversion from ADT to peak hour using a 50 percent directional split and a 10 percent peak hour factor.

Where (in each cell): Numbers in parentheses = number of lanes (2 lanes if no parentheses).
= LOS of the entire vehicle stream (trucks and cars) on a mixed-flow freeway facility
= LOS of the vehicle stream (with no trucks) on an otherwise mixed-flow freeway facility
= LOS of trucks on a two-lane exclusive truck freeway facility

6.4 DELAY COST FOR MIXED AND SEPARATED FACILITIES

Delay and its complement, speed, are the primary measures of roadway system performance. In the current investigation, delay was calculated from VISSIM outputs as the aggregated time that vehicles were not traveling at their free flow speed. This measure was then converted to a distance unit output measure so that the results could be easily applied and interpreted.

As analysts review the simulation output delay data for the separated truck roadway and the mixed flow scenarios, several aspects of the simulation methodology should be kept in mind. First, the total volume (found within the row headings) is kept constant as the truck volume (found within the column headings) is changed. Accordingly, the auto-only volume decreases in the simulations as the truck volume increases, and the delay data show a reduction in auto delay (as truck volume increases) in the auto-only facility results. Second, the number of lanes increases at intermittent times so that the overall performance of any of scenario does not fall below LOS E density levels. The impact of a change in the number of lanes with increasing volume can be seen in the results as a counterintuitive improvement in performance despite volume increases. The "cost" of improving performance was the construction of an additional through lane on the facility.

6.5 FUEL CONSUMPTION COST FOR MIXED AND SEPARATED FACILITIES

Another measure of performance for roadway networks is the quantity of fuel consumed in providing the mobility level present under prevailing operating conditions. Fuel consumption values, generally given in gallons of fuel consumed per (unit) mile of travel, can then be used to assess operational efficiency (fuel consumed versus vehicle-miles of travel) or for calculating roadway user costs (fuel consumed multiplied by fuel cost).

As with the delay results, some seemingly unusual trends can be observed in the data due to the fact that the number of lanes is not consistent as either the total network volume or the volume of trucks in the traffic stream are varied. Again, this is due to the fact that the number of lanes was increased to ensure that the LOS for any given scenario was E or better. Appendix C has the fuel consumption results for all of the scenarios; the reporting unit is gallons of fuel per mile.

6.6 COMBINED DELAY AND FUEL CONSUMPTION COSTS

Appendix C contains the results of comparing cost information for mixed flow versus separated roadways based on the delay and fuel values reported from VISSIM. The methodology used these values and created cost tables for each, and then created the noted tables that subtract costs for separated facilities from costs for a mixed facility (mixed minus separated). Numbers in black indicate volume conditions where mixed flow is more expensive (and red [numbers in parentheses] indicates separated is more expensive) under those volume conditions. The analysis used the following costs to develop these comparisons:

- 1.25 persons per passenger vehicle *(79)*,
- $14.40 per person per hour *(79)*,
- $76.30 per truck per hour (includes driver) *(79)*,
- $2.16 per gallon unleaded gasoline cost *(80)*, and
- $2.29 per gallon diesel cost *(80)*.

All costs are hourly costs per mile of freeway, based on the volumes shown in the row and column totals of Tables 32 through 40.

Researchers produced tables of delay and fuel consumption based on the outputs of the simulation models for the different facility types (mixed flow versus separate truck facility) and different conditions (total volume, truck volume, grade, and quantity of ramp traffic). The process involved review of the tables for consistency where delay and fuel consumption were anticipated to increase as volumes increased. However, some inconsistencies in data trends developed due in part to the stochastic, or internally variable, nature of the VISSIM model used for the analysis and in part due to the fact that the number of lanes changed (increased) as volumes increased so that no condition exhibited LOS worse than E.

As analysts reviewed simulation results, they found that the impacts of roadway congestion on delay and fuel consumption were more dramatic at LOS D and E than originally anticipated, resulting in large cost "penalties" for congestion. Since later portions of the analysis involved assigning cost to delay and fuel consumption (in addition to other parameters), researchers decided to employ a normalizing procedure to mitigate the cost impact fluctuations of congestion. Thus, high delay in one scenario for either mixed flow or separate truck and auto facilities would not lead to erroneous conclusions about the overall cost savings to be realized on the more efficient facility types. The basic method employed was to limit delay and fuel consumption values so as to preserve general trends of increasing fuel consumption and delay with increasing volume, while simultaneously preserving the highest reasonable delay for each condition's output that could be expected where LOS was D or E (i.e., where congestion costs were so high as to bias the comparison between facility types).

6.7 AIR QUALITY FOR MIXED AND SEPARATED FACILITIES

Air quality is another often-used measure of comparison of roadway design alternative performance, especially for projects in air quality non-attainment areas. VISSIM was capable of producing a broad range of air quality pollutant output data, but analysts for the current project chose to report those most commonly used in air quality studies: carbon monoxide (CO), hydrocarbons (HC), nitrous oxides (NO_x), and particulates.

For each pollutant and for each link of the traveled network, VISSIM output a unit quantity pollutant in milligrams per meter per second (mg/m/s). Since the links were all of the same length (a feature used for ease of network coding and data processing), the pollutant level per link was easily averaged and used to calculated a final mean measure. Also, the "meter" length and "seconds" time references in the unit output were derived by dividing the total pollutant per link by the link length and data recording time, making conversion to English units a simple measure of adjusting meters to miles and seconds to hours. The final units detailing the emissions outputs for each scenario, are grams per mile (g/mi). As with both the delay and fuel consumption outputs, the fact that the number of lanes present in each scenario changes as both the total volume and truck volume increase, though in a non-patterned way, the outputs may appear inconsistent in some locations until the number of lanes for any two scenarios being compared is known and factored into the output evaluation. There was no attempt in this research to convert pollutants to costs.

6.8 TEST OF ANALYSIS TOOLS

TTI applied the analysis tools developed in previous tasks to the following three corridor segments in order to evaluate the utility of the truck-segregated concept:

- I-35 between U.S. 83 and Loop 20 (near Laredo),
- I-10 east in Houston (near ship channel), and

- I-45 near Huntsville.

The Project Management Committee provided the input for identifying these candidate corridors at its May 5, 2005, meeting. For each of the selected corridors, the research team used the modeling environment developed earlier and evaluated traffic flow conditions under existing and future truck and non-truck volumes and treatments of truck segregation.

6.8.1 Case Study of I-10 in Houston

Table 41 summarizes traffic growth on the selected freeway segment in Houston on I-10, which has 16 sub-segments and is 8.57 miles in length. The analysis used four traffic count stations along this selected length to do the truck facility analysis. Before pursuing the analysis, one must realize that this freeway segment will be contrary to the general TTC concept since it is located in the Houston metro area and will serve a significant number of short-distance trips, many oriented to the Port of Houston. Maps shown in Chapter 4 affirm this notion by indicating extremely heavy truck traffic for a short distance along I-10 in the forecast years. In this case, use of the maximum ADT and AADTT values would not be economically viable simply because traffic projections (especially trucks) would overwhelm a single facility. The short distance of the congestion suggests that a separate route might be built to keep some truck traffic away from I-10. A more detailed study would be necessary to determine its orientation and whether it should have a direct connection from the port to I-10.

Table 41. 2022 AADT and AADTT Summary for I-10 in Houston.

Minimum ADT	Maximum ADT	Average ADT	Minimum AADTT (90%)	Maximum AADTT (90%)	Average AADTT (90%)
81,570	168,510	133,620	16,721	18,367	17,339
116,543	240,758	190,909	64,036	136,343	96,050
139,304	287,779	228,194	122,276	383,481	230,628
199,030	411,164	326,032	445,838	3,033,652	1,381,722

Perhaps a more realistic approach in this case would be to plan a truck facility with three lanes in each direction (due to limited right-of-way constraints in urban areas) and design based on LOS E. Based on the VISSIM modeling reported in Chapter 3, the per-lane capacity of truck roadways with level terrain, one-third of the trucks entering or exiting at interchanges, and interchange spacing averaging 10 miles is 1175 trucks per lane per hour. Therefore, the two-way capacity of this truck facility would be 7050 trucks per hour or 117,500 trucks per day. For the other roadway which carries smaller trucks and passenger cars, the demand on all but one of the sub-segments will not exceed 290,000 vehicles per day during the 20-year design period. Again, depending on the spacing of ramps and other unknowns in the flat terrain of Houston, the number of lanes needed for non-truck traffic at LOS E or better would be about seven per direction.

The extremely high traffic forecast on one element of this 8.57-mile segment of freeway indicates a weakness of simply projecting traffic and not using a transportation modeling approach in which roadways would have constraints (represented by their capacity), forcing traffic above a certain limit to flow on other roadways. This case study does not include a cost comparison of separated and mixed flows due to the uncertainties already noted.

Table 42 is a summary of the crashes that occurred on this segment of I-10 in Houston for the three years 1999, 2000, and 2001, with more detail on each severity category provided in Appendix D. The total cost of these crashes for all three years is $36,406,600, so the average annual cost would be $12,135,533. Assuming that 75 percent of these costs could be saved by separating trucks from cars, the resulting benefit would be $9,101,650 per year. Dividing by the 8.57-mile length of this segment gives an approximate reduction in cost per mile of $1,062,036. The crash database does not provide information on whether hazardous materials involvement could have increased this value even more.

Table 42. Houston I-10 Crash Summary.

Crash Type	Fatal/Incap. Injury	Non-Incap. Injury/ Possible Injury	Non-Injury
No. Crashes	24	376	459
Cost by Type	$840,000	$41,500	$1,400
Subtotal	$20,160,000	$15,604,000	$642,600

6.8.2 Case Study of I-45 near Huntsville

Table 43 summarizes traffic growth on the selected freeway segment near Huntsville on I-45, which has 12 sub-segments and is 8.87 miles in length. The tabulated values indicate the results from four count stations and the variation in traffic along the segment. The ADT and AADTT values shown in bold are the maximum values along the selected segment of freeway of about 100,000 vehicles per day and about 45,000 trucks per day, respectively. The LOS matrices provided earlier in this chapter indicate that for ramp volumes in the 20 percent range, the mixed scenario (ADT plus AADTT or 145,000 vpd) will operate at LOS C on five lanes and the separated scenario will require four lanes for cars and two lanes for trucks, both operating at LOS C.

Table 43. 2022 AADT and AADTT Summary for I-45 near Huntsville.

Minimum ADT	Maximum ADT	Average ADT	Minimum AADTT (90%)	Maximum AADTT (90%)	Average AADTT (90%)
26,580	41,020	31,790	7,074	9,005	8,344
37,976	58,607	45,420	12,526	17,142	15,005
45,393	70,053	54,291	16,668	23,652	20,133
64,855	**100,089**	77,567	29,513	**45,026**	36,285

Having a “4 + 2” cross-section in each direction instead of a five-lane by direction mixed roadway adds $5,680,877 per mile to the initial cost. Over a 20-year expected life, this incremental cost, at a 5 percent rate of return, would amount to $455,834 per mile per year. Savings due to reduced delay and fuel consumption at these volumes would be $357 per hour per mile of roadway. Since the $357 value is based on peak periods, one must reduce it to an average daily value to reach an annual value. Based on TxDOT count data along corridors with high truck flows, the average hourly value is 71 percent of the maximum flow, so the average hourly savings would reduce $357 per hour per mile to $253 per hour per mile. To convert the hourly value to an annual value, multiply by 8760 hours per year. The savings amounts to $2,216,280.

Table 44 is a summary of the crashes that occurred on this segment of I-45 near Huntsville for the three years 1999, 2000, and 2001, with more detail on each severity category provided in Appendix D. The total cost of these crashes for all three years was $10,968,600, so the average annual cost would be $3,656,200. Assuming that 75 percent of these costs could be saved by separating trucks from cars, the resulting benefit would be $2,742,150 per year. Dividing by the 8.87-mile length of this segment gives an approximate reduction in cost per mile of $309,149. The crash database does not provide information on whether hazardous materials involvement could have increased this value even more.

Table 44. Huntsville I-45 Crash Summary.

Crash Type	Combined Fatal and Incap. Injury	Non-Incap. Injury/ Possible Injury	Non-Injury
No. Crashes	8	96	109
Cost by Type	$854,000 [a]	$41,500 [a]	$1,400 [a]
Subtotal	$6,832,000	$3,984,000	$152,600

[a] *Source:* TxDOT.

6.8.3 Case Study of I-35 near Laredo

Table 45 summarizes traffic growth on the selected freeway segment near Laredo on I-35, which has 21 sub-segments and is 10.83 miles in length. The table shows the counts at four locations along the selected length. The ADT for this segment of freeway ranges from a low of 19,960 vpd to a high of 154,525 vpd. Likewise, the AADTT has a wide range from a low of 4,930 tpd to 238,113 tpd. Given the wide range in both cases, this analysis uses the average ADT and AADTT. Therefore, the total ADT to be used in the LOS matrices would be 108,787 plus 172,157 or about 281,000 vpd. The tabulated LOS values provided earlier in this chapter (Tables 34 through 42) did not anticipate truck volumes of this magnitude, so a direct comparison of separated versus mixed flows cannot be done on the highest volume of this segment.

The number of truck lanes needed on the separated flow facility in the flat terrain near Laredo assumes that enter/exit volumes do not exceed 20 percent and interchanges are spaced 10 miles apart. Capacity would be 1175 trucks per lane per hour, so the number of lanes in each direction would be six. The number of car lanes for this roadway with separated flows at the maximum ADT would be four.

Table 45. 2022 AADT and AADTT Summary for I-35 near Laredo.

Minimum ADT	Maximum ADT	Average ADT	Minimum AADTT (90%)	Maximum AADTT (90%)	Average AADTT (90%)
19,960	63,330	44,585	4,930	11,223	8,114
28,518	90,483	63,700	16,731	38,088	27,538
34,087	108,154	76,141	30,822	70,165	50,729
48,702	**154,525**	108,787	104,597	**238,113**	172,157

Table 46 is a summary of the crashes that occurred on this segment of I-35 near Laredo for the three years 1999, 2000, and 2001, with more detail on each severity category provided in Appendix D. The total cost of these crashes for all three years was $32,589,800, so the average annual cost would be $10,863,267. Assuming that 75 percent of these costs could be saved by separating trucks from cars, the resulting benefit would be $8,147,450 per year. Dividing by the 10.83-mile length of this segment gives an approximate reduction in cost per mile of $752,304. The crash database does not provide information on whether hazardous materials involvement could have increased this value even more.

Table 46. Laredo I-35 Crash Summary.

Crash Type	Fatal/Incapacitating Injury	Non-Incap. Injury/ Possible Injury	Non-Injury
No. Crashes	22	318	432
Cost by Type	$854,000	$41,500	$1,400
Subtotal	$18,788,000	$13,197,000	$604,800

6.8.4 Case Study Summary

The three case studies provide relevant information to real-world application of the procedures developed in this research. The *Truck Facility Guidebook (81)* provides additional details for unfamiliar users as well. Two of the case studies—I-10 in Houston and I-35 near Laredo—will serve extremely high truck volumes in 20 years. However, they do not necessarily represent conditions that will be served by the Trans Texas Corridor. The annual per-mile costs of crashes for the most recent three years varied considerably at $1,062,036 for Houston, $309,149 for Huntsville, and $752,304 for Laredo. The average for these three sites is $707,829. These three sites do not necessarily represent roadways where separate truck facilities will be built. It is likely that the two highest volume sites will best represent future truck roadways, but the average for all three should be more conservative and, if anything, underestimate the savings due to providing truck roadways. Therefore, further analysis in this report will use a rounded cost savings of $700,000 per mile due to crash reductions.

6.9 OVERALL RESULT OF COST ANALYSIS

The cost factors considered in this research were:

- initial construction cost,
- maintenance costs,
- fuel cost,
- delay cost,
- emission cost, and
- crash cost.

Maintenance costs are expected to be about the same with truck roadways as with mixed traffic flows; the impact of heavy axle loads applied by trucks will simply be shifted from the mixed facility to the truck roadway. Historical crash costs for a corridor or for a segment are expected to be reduced by putting trucks on a separate roadway. The magnitude of the reduction comes into question since there are no data to guide decision-makers. It would not be appropriate to remove all truck-car crashes, so this analysis removed 75 percent in the three case studies. The remaining major factors are initial construction cost, fuel cost, and delay cost.

Combining all the factors used in this analysis will provide the final answer regarding benefit/cost relationships for the truck and non-truck volume levels investigated. Appendix E has the details of the final costs and the final outcomes. Tables 47, 48, and 49 summarize the final benefit/cost results.

Table 47. Benefit/Cost Summary for Flat Grades.

			Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**300**	**600**	**900**	**1200**	**1500**
0	**10**	**3000**	2.37	2.57	2.41	2.70	6.66
		4500	2.30	4.69	3.12	3.22	7.98
		6000	2.44	5.17	3.12	3.49	4.99
		7500	3.20	4.55	4.28	5.12	5.60
		9000	1.09	4.07	2.48	8.10	5.57
			Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**300**	**600**	**900**	**1200**	**1500**
0	**20**	**3000**	2.35	2.50	3.09	2.66	6.38
		4500	3.44	4.72	4.40	3.60	6.47
		6000	2.76	4.00	6.32	10.43	17.23
		7500	3.08	5.56	6.33	11.71	15.22
		9000	(0.65)	1.86	2.19	8.98	19.66
			Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**300**	**600**	**900**	**1200**	**1500**
0	**30**	**3000**	2.53	4.18	5.44	5.77	3.45
		4500	3.13	5.13	6.07	8.95	4.36
		6000	2.19	4.28	5.17	16.72	16.49
		7500	3.56	3.33	6.65	20.39	27.68
		9000	3.37	7.05	5.80	17.22	20.65

Table 48. Benefit/Cost Summary for 2 Percent Grades.

			Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**300**	**600**	**900**	**1200**	**1500**
2	**10**	**3000**	2.48	3.88	2.60	2.25	17.01
		4500	3.70	4.78	4.34	3.62	5.00
		6000	3.12	4.45	4.19	4.21	8.31
		7500	5.00	6.68	6.22	7.14	10.97
		9000	(0.16)	1.44	3.42	4.75	11.95
			Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**300**	**600**	**900**	**1200**	**1500**
2	**20**	**3000**	2.52	4.98	3.84	5.54	6.07
		4500	2.93	5.28	6.55	5.78	6.85
		6000	2.73	4.45	6.76	10.57	7.03
		7500	4.68	8.42	6.45	11.72	14.04
		9000	3.06	2.95	5.65	8.66	15.56
			Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**300**	**600**	**900**	**1200**	**1500**
2	**30**	**3000**	2.72	4.80	4.87	4.99	2.87
		4500	3.20	6.06	6.46	5.83	2.36
		6000	3.08	5.31	7.51	10.83	6.98
		7500	2.03	7.01	7.72	18.41	21.12
		9000	3.35	7.41	13.44	9.23	8.60

Table 49. Benefit/Cost Summary for 4 Percent Grades.

			Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**300**	**600**	**900**	**1200**	**1500**
4	**10**	**3000**	2.40	3.86	3.34	4.66	4.12
		4500	3.67	4.96	4.06	7.86	6.55
		6000	2.84	4.86	4.05	7.40	5.70
		7500	3.67	4.46	5.21	5.67	15.99
		9000	0.61	4.00	3.78	6.42	16.13
			Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**300**	**600**	**900**	**1200**	**1500**
4	**20**	**3000**	3.92	6.19	5.11	3.67	6.07
		4500	4.62	7.30	6.05	6.15	4.75
		6000	2.58	5.77	4.13	3.75	5.85
		7500	4.18	5.92	7.82	8.65	7.47
		9000	6.57	11.08	7.46	11.57	11.87
			Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**300**	**600**	**900**	**1200**	**1500**
4	**30**	**3000**	3.71	4.06	3.87	5.45	1.81
		4500	4.50	5.84	4.31	7.08	1.73
		6000	3.72	11.05	8.88	9.94	7.62
		7500	8.40	14.10	9.17	11.33	10.15
		9000	5.96	8.80	3.13	9.98	16.27

6.10 USE OF CORSIM FOR TRUCK ROADWAYS

Taking the findings from this research and creating a method by which candidate primary roadway corridors can be evaluated for truck roadway potential may require the use of CORSIM. Preliminary analysis will require the application of the tables and figures relating to operations impacts (delay and fuel consumption), crash impacts, and design and construction cost impacts. In a generic sense, these tables can be applied to segments of freeway in mostly rural conditions that are many miles in length. The unit costs from the tables are simply multiplied by the length of roadway segment containing a roughly consistent cross section and the overall operations, crash, and design and construction costs are produced. In more detailed and complicated freeway sections, however, a more rigorous analytical process may be desirable.

Where weaving sections exist, and in portions of freeway corridors where ramps and interchanges are frequent, the unit cost impact tables will not be sufficiently flexible to estimate the realistic field impacts of truck roadway operations. In these situations, it may be desirable to perform more detailed modeling of truck roadway operations. In these instances, the lowest cost and most readily available tool for performing these analyses is CORSIM. Researchers used CORSIM side-by-side with VISSIM to establish basic capacities for truck roadways. It has demonstrated capabilities for modeling trucks and truck roadways. Details on running CORSIM for truck roadway applications are available in Appendix E and in the *Truck Facility Guidebook (81)*.

CHAPTER 7. ACTION PLAN FOR RESEARCH IMPLEMENTATION

7.1 INTRODUCTION

This Action Plan is intended to assist TxDOT and other stakeholders in the implementation of this research. It will assist stakeholders in the use of the information and data gathered in this research project. Since the project has immediate implementation value related to the Trans Texas Corridor, the Action Plan development process coordinated with personnel who are directly involved with the TTC. Therefore, the Action Plan is based upon this coordination, stakeholder input, and other information gathered from TTC public hearings. The Action Plan includes timelines and suggested routes for implementation of truck strategies.

7.2 METHODOLOGY

Developing the Action Plan required the technical processes developed in this research along with input from the various stakeholders. Consideration of the initiatives already underway pertaining to the TTC is of utmost importance since the TTC will likely involve truck treatments of the type considered in this research. The input from stakeholders included the following:

- input based on public meetings held by the TxDOT TTA Division,
- input from the TMTA, which represents many Texas motor carriers,
- input from the Texas DPS related to motor carrier enforcement, and
- input from TxDOT's TTA Division or its consultants.

7.3 ISSUES ASSOCIATED WITH TRUCK TREATMENTS

The three treatments investigated in this project were: truck lane restrictions, dedicated truck lanes, and exclusive truck roadways. The basic objective with these treatments is to separate trucks from cars since the two groups of vehicles have very different operating characteristics. Due to concerns with implementing dedicated truck lanes, this action plan and the research in general only cover lane restrictions and exclusive truck roadways. Because lane restrictions already exist in Texas and the level of understanding is greater for lane restrictions, this research emphasized truck roadways. The following section relies on previous studies on lane restrictions; it is followed by information on exclusive truck roadways based primarily on this research.

7.3.1 Lane Restrictions

There are differing opinions and different perspectives on the effectiveness of truck lane restrictions in improving safety and/or operations. Perhaps the first consideration should be that it only partially accomplishes the objective of separating trucks from smaller vehicles. It does, however, provide at least one freeway lane which is free of trucks. Car drivers still have to drive between and beside trucks, but at least one lane free of trucks seems to provide them some measure of relief.

Chapter 2 of this report refers to a survey by the Federal Highway Administration to determine why states had implemented truck lane restrictions. This survey indicated a total of 26 states used lane restrictions, and the most common reasons for implementing lane restrictions were improved highway operations and reduced crashes *(5)*. Various jurisdictions had implemented lane restrictions in numerous situations; however, they had collected little data to document the actual effectiveness of the strategy. From the literature search, one study concluded that when properly implemented, adequately publicized, and sufficiently enforced, truck traffic strategies could effectively increase safety, improve traffic operations, and decrease the pavement deterioration rate on interstate highways *(15)*. Two recent studies of lane restrictions in Texas found reductions in crash rates, although a contributing factor in one was almost certainly the high enforcement presence *(11, 12)*.

Of course, there are some negative aspects of truck lane restrictions. The first negative aspect is from the perspective of truck drivers. Being excluded from one or more lanes of the freeway limits a truck driver's options with regard to lane changing and overall freedom to maneuver. If a freeway has three lanes in each direction, trucks can only use two of these lanes, typically the right two lanes. In urban areas, trucks typically move to the center lane to avoid the interference caused by other traffic entering and exiting the freeway in the right lane. With close interchange spacing, trucks become more concentrated in the center lane, reducing their ability to maneuver to an even greater extent. The end result of most trucks using the center lane is greater difficulty for other vehicles to weave from the left lane to the right lane and vice versa. In cases where trucks do not migrate to the center lane, there can still be a "barrier effect" created where large numbers of trucks are traveling in close proximity and cars need to weave between them. Trucks can limit the visibility and maneuverability of smaller vehicles attempting to enter and exit the freeway system. An indication of the barrier effect is an over-involvement of trucks in weaving area crashes, rear-end collisions, and side collisions *(6, 7)*.

Previous TTI research recommended the following criteria to determine where to implement lane restrictions:

- The roadway should first meet the requirements of Texas Transportation Code Section 545.0651 or 545.0652 (See Appendix A of the *Truck Facility Guidebook*).

- The minimum number of trucks in the traffic stream is 4 percent (defined as three or more axles) for every hour of a continuous 24-hour period.

- At least 10 percent of the total number of trucks currently using the lane from which trucks will be restricted (usually the left inside lane).

- Begin or end the restriction a minimum of 1 mile from the nearest entry or exit ramps to allow sufficient distance for traffic to enter or exit the lane.

- The minimum continuous length of the restriction should be 6 miles.

- Place signs at 1-mile intervals throughout the restricted area to notify trucks that might enter at any point along the restriction. Placement should include right side, overhead, and left side locations to maximize visibility.

- The law applies to three-or-more axle vehicles and to truck tractors regardless of whether they are pulling a trailer.

7.3.2 Exclusive Truck Roadways

7.3.2.1 Findings from the Literature

Based on the literature search, the most prominent factors used to determine the need for truck treatments are: truck volume, truck percent, or level of service; truck-involved crash rates; and total traffic volume. Some sources use modeling techniques to convert these factors to benefits and costs *(13, 42)*. Other sources use a "rule of thumb" approach to establish more general criteria, derived either by modeling techniques or judging from existing facilities. Battelle and Douglas are two examples.

- The Battelle criterion for traffic volume is an AADT of at least 100,000 vpd and 25 percent trucks on a facility with four or more lanes in each direction *(42)*.

- The Douglas criterion for traffic volume is an AADT of at least 120,000 vpd and 20,000 (large) trucks per day where there are at least four lanes in each direction and the traffic demand occurs over at least a 10-mile length or has a large truck traffic generator at one terminus *(47)*.

7.3.2.2 Findings from Texas Traffic Forecast

The forecasts of truck volume for 20 and 30 years used 90 percent of the historical growth rates for each segment of roadway. The modeling using VISSIM indicated that the capacity of a roadway with 100 percent trucks (defined as three or more axles) in 20 percent (and coincidentally 40 percent as well) rolling terrain and with two ramps per 20-mile segment is 1125 trucks per lane per hour. Using LOS C as the design level of service, the maximum flow rate would be 855 trucks per lane per hour. The highest hourly volume at representative sites in Texas was 6.0 percent of the 24-hour AADTT value. Using this value and converting from peak hour flows to AADTT, TxDOT engineers should anticipate LOS C conditions for a four-lane truck roadway when the truck traffic projections reach 57,000 trucks per day.

The busiest truck corridor in Texas is the I-35 corridor. Table 29 in Chapter 4 indicates that 130 miles of roadway will reach the LOS C range by 2022 and 330 miles will reach this level by 2032. The various corridor maps provided in this report assign all large trucks to four-or-more-lane truck roadways and indicate the resulting LOS. In almost all cases, the congested truck forecasts occur near large urban areas. Figure 27 in Chapter 4 illustrates the 2022 segments and corresponding level of service predictions. The segments on I-35 that fit the criteria are those that exceed 50,000 trucks per day. As Figure 27 shows, the need for four-lane truck roadways on I-35 will occur through San Antonio, from San Marcos through Austin to near Round Rock, in Waco, and a short segment in Ft. Worth. Other freeways with LOS C in 2022 include segments of I-10 in Houston and short freeway segments in the Dallas/Ft. Worth metroplex.

7.3.2.3 Findings from the Crash Analysis

The analysis of New Jersey Turnpike Authority crash data comparing crashes on inner roadway car-only lanes with outer roadway mixed-flow lanes indicated that truck-free freeway facilities would have a better safety record than mixed traffic facilities. The results of the analysis showed that the outer roadway experiences more crashes, both when raw numbers are used and when exposure is included into the analysis. The results also show that trucks are over-involved in crashes given the exposure on these sections. Even though the outcome of this section suggests that separating truck traffic from passenger cars for freeway facilities improves safety, further work is needed to understand the contributing factors leading to truck-related crashes in the outer lanes.

For the purposes of this report, TTI removed 75 percent of the truck-related crashes from routes with truck roadways, using the statewide crash costs to calculate reduction in societal cost as a result of crash reduction. For the three case studies in Chapter 6, the cost savings averaged $700,000 per mile due to crash reductions.

7.3.2.4 Findings from Cost Evaluation Issues

The other primary cost elements investigated in this research besides safety were initial construction cost, delay cost, and fuel cost. Tables 47, 48, and 49 in Chapter 6 summarize the resulting benefit/cost ratios for a wide variety of truck and non-truck volume, terrain, and percent entering and exiting the truck facility at interchanges. In almost all cases, the outcomes exceed the pre-established threshold B/C of 2.0, indicating that building truck roadways would have an overall positive impact in almost all cases. These results do not reflect what might happen if tolls are required on these facilities.

7.3.2.5 Findings from Stakeholders

The following viewpoints come from motorists, TxDOT consultants, motor carriers, and enforcement. The largest constituent group is the public at large, most of whom are motorists. TxDOT commissioned a series of three public meetings within and adjacent to the proposed TTC-35 Study Area during 2004 and 2005 to solicit input from the public. Table 50 summarizes the results, indicating the percent of comments addressing trucks and the percentage of positive, neutral, and negative comments. The percentage of comments pertaining to trucks was in the 5 to 11 percent range. The number of negative comments for the TTC in general was consistently just under half of the total, whereas the number of positive comments was less than a third in all cases. The percentages are based upon an overall total number of 3942 comments.

Table 50. Summary of Public Meetings on TTC-35.

Dates	No. of Mtgs.	% Truck Comments	Comments		
			Positive	Neutral	Negative
Apr 7-Jan 15, 2004	26	5	31%	23%	46%
Oct 19-Nov 18, 2004	44	10	27%	24%	49%
Feb 7-Mar 31, 2005 [a]	47	11	17%	38%	45%

[a] Numbers for the 2005 meetings are preliminary and are subject to change.

The Texas Motor Transport Association considers the concept of barrier-separated truck roadways a good idea. Both car drivers and truck drivers see the concept of truck roads as a means of separating them from each other and therefore agree that it as a good thing. However, there are also some issues to be resolved in the current planning of the TTC to make it more closely reflect what would most benefit all users. The first big issue pertains to paying tolls for the use of truck roadways, especially since motor carriers already pay high taxes. Truckers are more likely to use toll roads if non-toll alternatives are very congested or if other impediments to reasonable speeds exist. Shippers place many demands on carriers to deliver shipments within a concise time window, so if non-toll roads do not allow timely deliveries, truckers will probably increase their use of toll roads. Incentives such as higher speed limits on the TTC bring negative side effects such as lower fuel mileage and higher insurance rates. The lower crash rates assumed elsewhere in this document will undoubtedly be compromised if truckers opt for higher speeds. The view of TMTA on increased weights, which the TTC might allow, is that carriers must still reduce the load for travel off the TTC, requiring additional processing and consequent delays and possibly new equipment. Finally, public perception will be negative if truck facilities are underutilized, especially when other motorists are in congested traffic and they see lanes that are not being adequately utilized.

The Department of Public Safety Commercial Vehicle Enforcement unit believes that separating trucks from passenger vehicles is a good idea. DPS prefers stationary sites where truck flows are heavy and especially if bypass routes are limited. Therefore, the TTC should be a good candidate for fixed facilities. DPS expects that the use of ITS will increase on the TTC, using components such as transponders and weigh-in-motion systems. DPS hopes to see an increase in CVISN integration along with the various processes pertaining to IFTA, vehicle registration, IRP, and so forth.

Much of the discussion with TxDOT's TTC consultants focused on the TTC-35 since it is the most congested corridor and will be the first corridor to be built. The Statewide Analysis Model outputs generally produced similar results in truck growth as this research. However, the TTI approach used historical data to predict future growth and the TTC consultants used SAM to predict future growth. The TTI methodology did not attempt to address truck diversion from one corridor to another, so the results may not fully represent all the changes which could occur. For example, shifts of truck traffic from the I-35 corridor to the proposed I-69 corridor are not shown by the TTI results. The SAM output indicates some truck diversion to the proposed I-69 corridor under some conditions such as heavy congestion along I-35. Besides the modeling (engineering) component, the overall analysis conducted for the TTC relies on revenues and costs since the project will involve private investment. A primary goal of the TTC is to minimize public funding, so it is very important to maximize private investor interest and participation.

7.4 ACTION PLAN FOR TRUCK ROADWAYS

The action plan for truck roadways in Texas relies primarily on truck volumes. The safety implications of separating trucks from cars are not well understood at this time, but based on the crash analysis conducted in this research and if current factors (e.g., speed limits and geometric design factors) prevail on the TTC, the result should be a reduction in overall crash costs due to separating trucks from cars. If the speed limits for trucks increase to 85 mph as proposed, there needs to be further investigation of the safety implications, since safety will be a major factor in the overall cost implications.

Based on truck volume forecasts, no major improvements to the roadway network, and the benefit/cost results provided in Chapter 6, this research recommends considering the following segments of I-35 and I-10 for two-or-more-lane truck roadways by 2022. The following are approximate lengths of need:

- Mexico border area, although more focused modeling is required (length of need may not reach 10 miles);

- In San Antonio from just south of downtown to 15 miles north of I-410 (total length 25 miles): 80 percent of the length will need four lanes and will operate mostly at LOS C and D with a short segment at LOS E, 20 percent of the length will require six lanes and will operate at LOS C and D;

- From San Marcos to Georgetown (total length 60 miles): 80 percent requires four lanes operating at LOS C or D and 20 percent needs six lanes at LOS D and E through Austin; and

- On I-10 in Houston from just west of downtown eastward to Decker Driver (S.H. 330) on the east side of Houston (total length 25 miles): 50 percent requires six lanes at LOS D and E and 50 percent requires four lanes at LOS C and D.

Likewise, research findings indicate the following approximate need for I-35, I-10, and other freeways for two-or-more-lane truck roadways by 2032:

- Mexico border area, although more focused modeling is required (length of need may not reach 10 miles);

- In San Antonio from just south of downtown then northward to Hillsboro (total length 230 miles): 60 percent requires four lanes at LOS C, D, and E, 25 percent will require six lanes at LOS D and E, and 15 percent will require eight lanes at LOS F;

- On I-10 in Houston from the I-610 west loop eastward to S.H. 61 on the east side of Houston (50 miles total): 50 percent requires four lanes at LOS C and E, 20 percent requires six lanes at LOS C and D, and 30 percent requires eight lanes at LOS D to F.

- Segments of other freeways in Houston, Dallas/Ft. Worth, and El Paso do not appear to meet the minimum length requirement.

As noted elsewhere in this report, there may be additional needs (e.g., the proposed I-69 freeway) for truck roadways which result from traffic diversion. This research used a historical growth approach and did not estimate how much truck traffic might divert to other corridors. In addition to the list of corridors and segments, there may be needs that are not as easily predicted using the typical growth and modeling techniques. They include major truck traffic generators such as:

- major seaports,

- large warehousing or distribution centers, and

- intermodal hubs.

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APPENDIX A

Cost Estimate for Two-Lane Truck Roadway

Table 51. Two-Lane Truck Roadway Cost Estimate.

DESCRIPTION				
Two-lane width plus paved shoulders, total paved width 44 ft (2 13-ft lanes, 12-ft rt shldr, 6-ft lt shldr)	Units	Multiplier	Cost/unit	Ext (side A)
14-inch continuously reinforced concrete pavement	25813.33		$38.00	$980,907
1-inch asphalt stabilized base	25813.33	1419.733	$40.00	$56,789
6-inch cement treated base	25813.33		$6.00	$154,880
6-inch lime treated subgrade	25813.33		$2.00	$51,627
Lime	116160	0.003	$100.00	$34,848
CTB (Furnish and install)	5280		$25.00	$132,000
Embankment (cu yd) (half the TxDOT est)	16035.56		$5.00	$80,178
Prep ROW (53 stations/mi)	53		$10,000.00	$530,000
Lighting (high mast)				$210,000
Signing				$15,000
Striping				$125,000
Storm drain				$1,000,000
Barricades and traffic handling (for 18 mo.)		18	$12,500.00	$225,000
Bridge (sq. ft.)	6600		$60.00	$396,000
CTMS				$225,000
Retaining wall (sq. ft.)	16800		$40.00	$672,000
W.F. terminal anchor system				$50,000
Landscaping (1% of estimate)				$49,392
Mobilization (10% of estimate)				$493,923
TOTAL PER MILE (EA DIRECTION)				$5,482,544
Estimated cost for opposite direction truckway				$5,482,544
Total cost per mile				**$10,965,087**

APPENDIX B

Level of Service Graphical Results

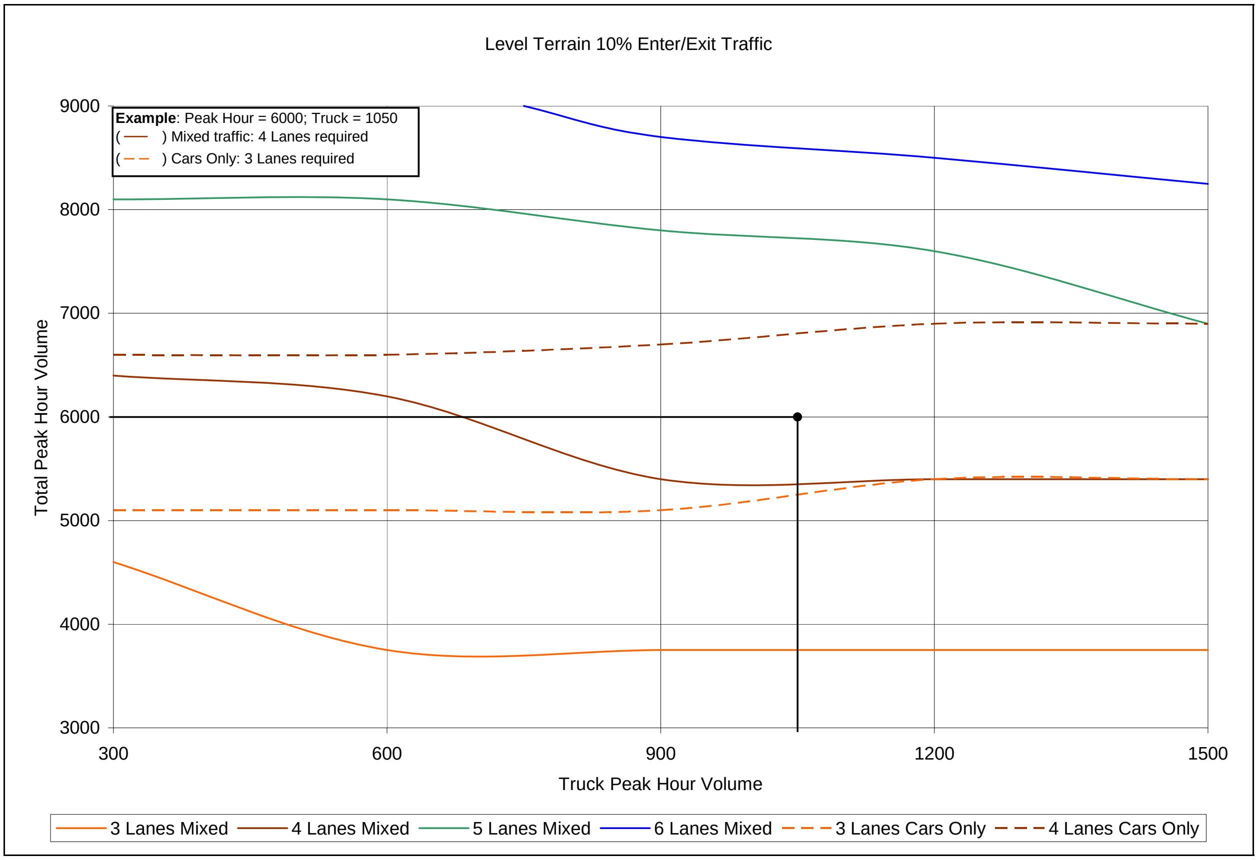

Figure 33. Freeway Design Based on LOS for Flat Grades, 10% Enter/Exit.

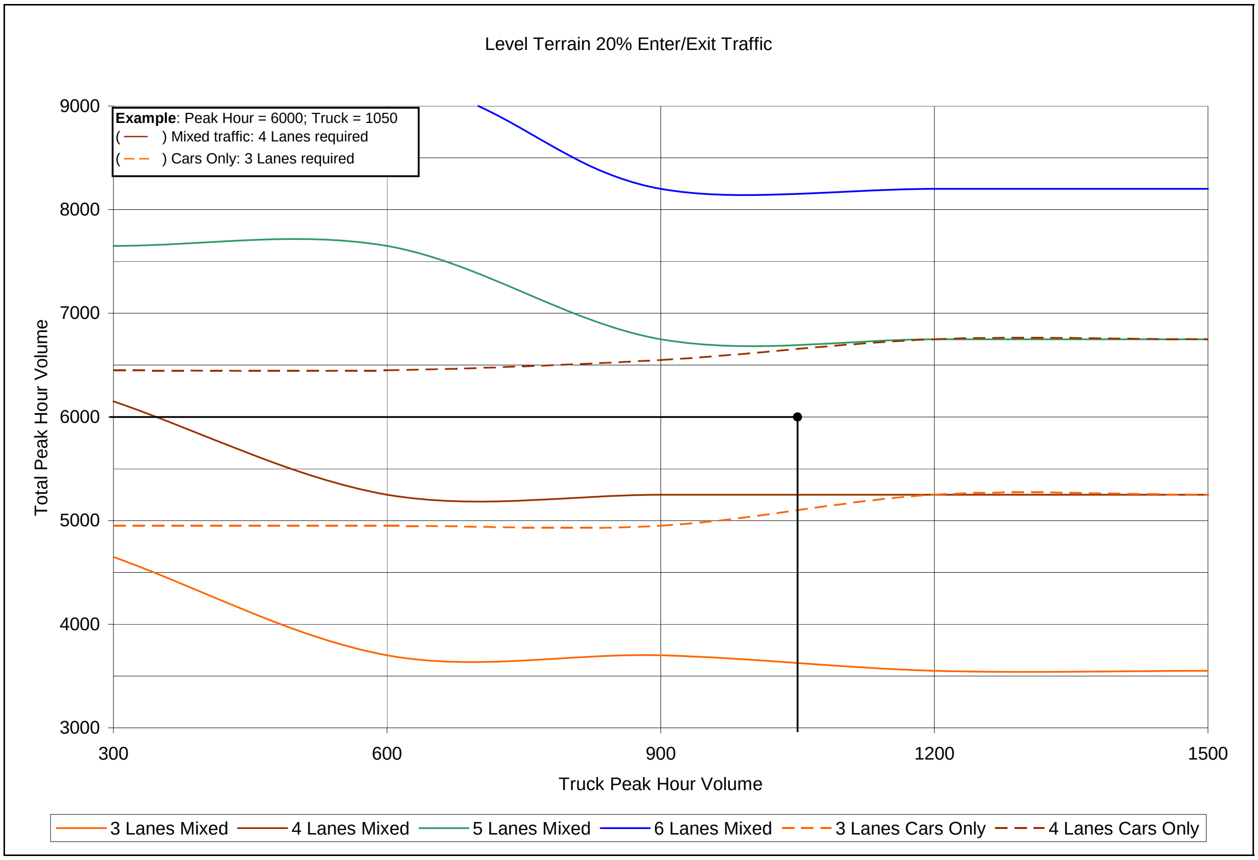

Figure 34. Freeway Design Based on LOS for Flat Grades, 20% Enter/Exit.

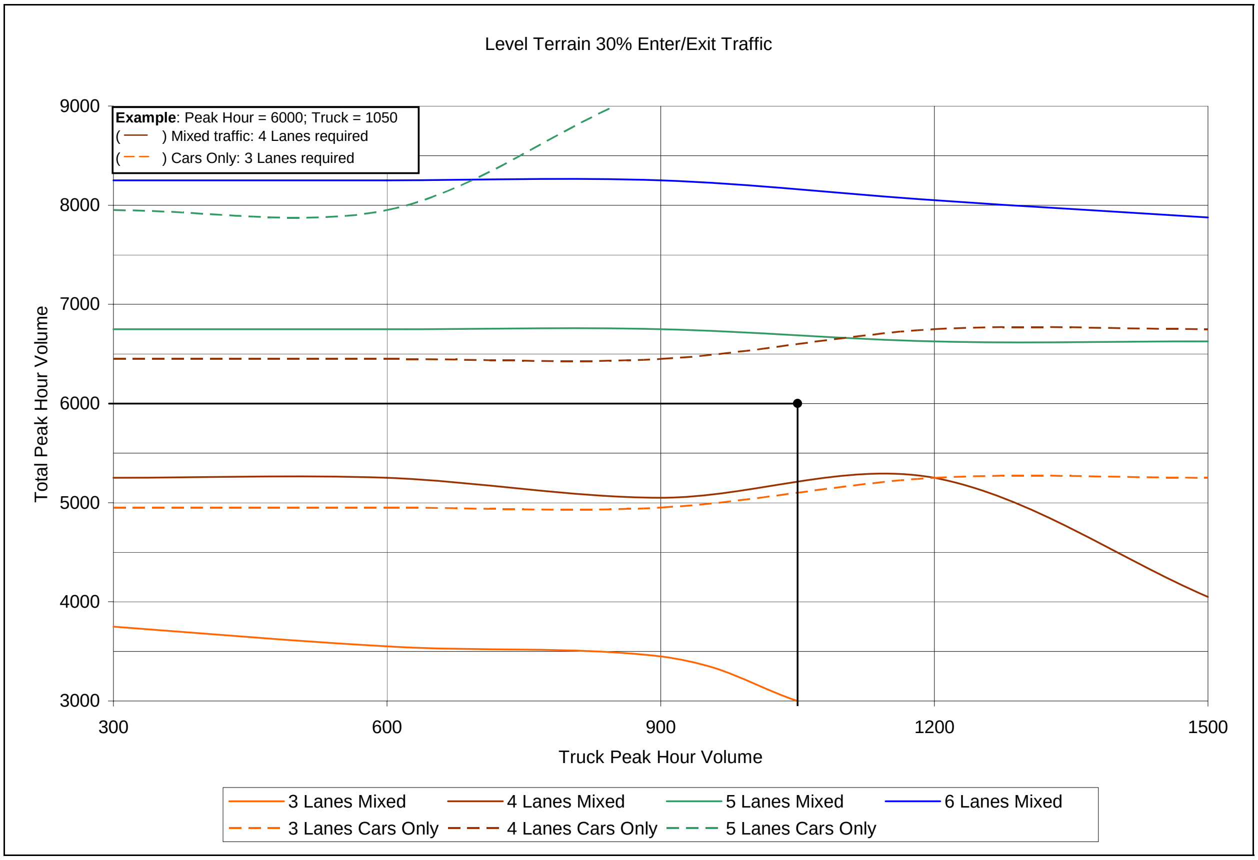

Figure 35. Freeway Design Based on LOS for Flat Grades, 30% Enter/Exit.

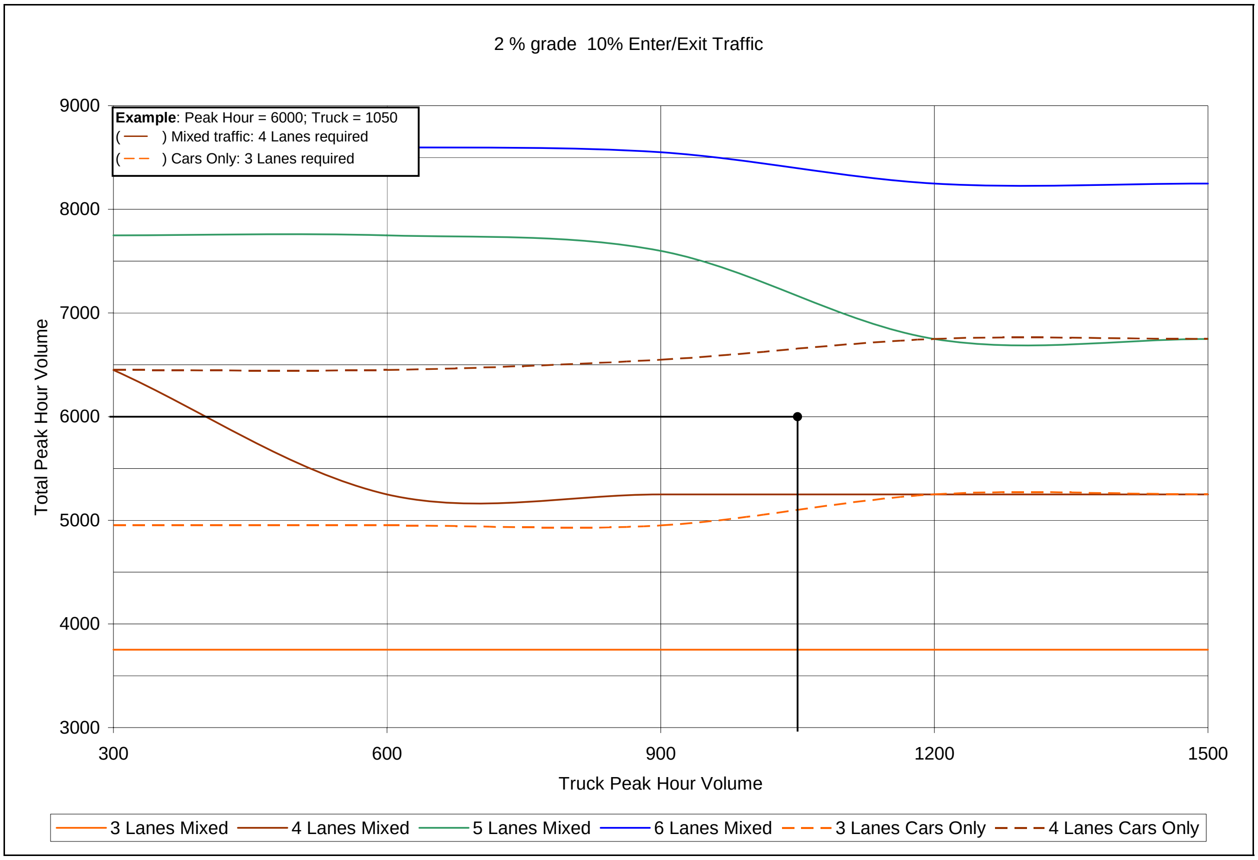

Figure 36. Freeway Design Based on LOS for 2% Grades, 10% Enter/Exit.

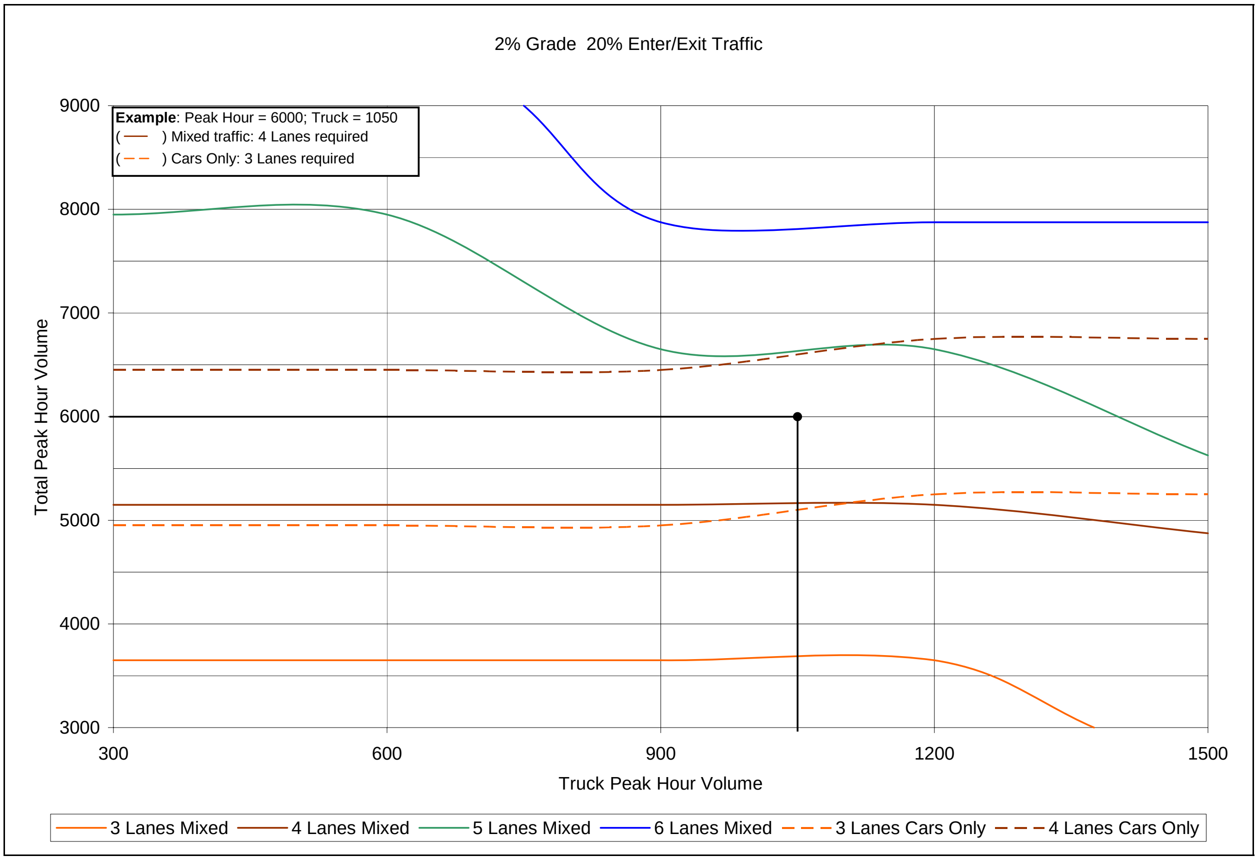

Figure 37. Freeway Design Based on LOS for 2% Grades, 20% Enter/Exit.

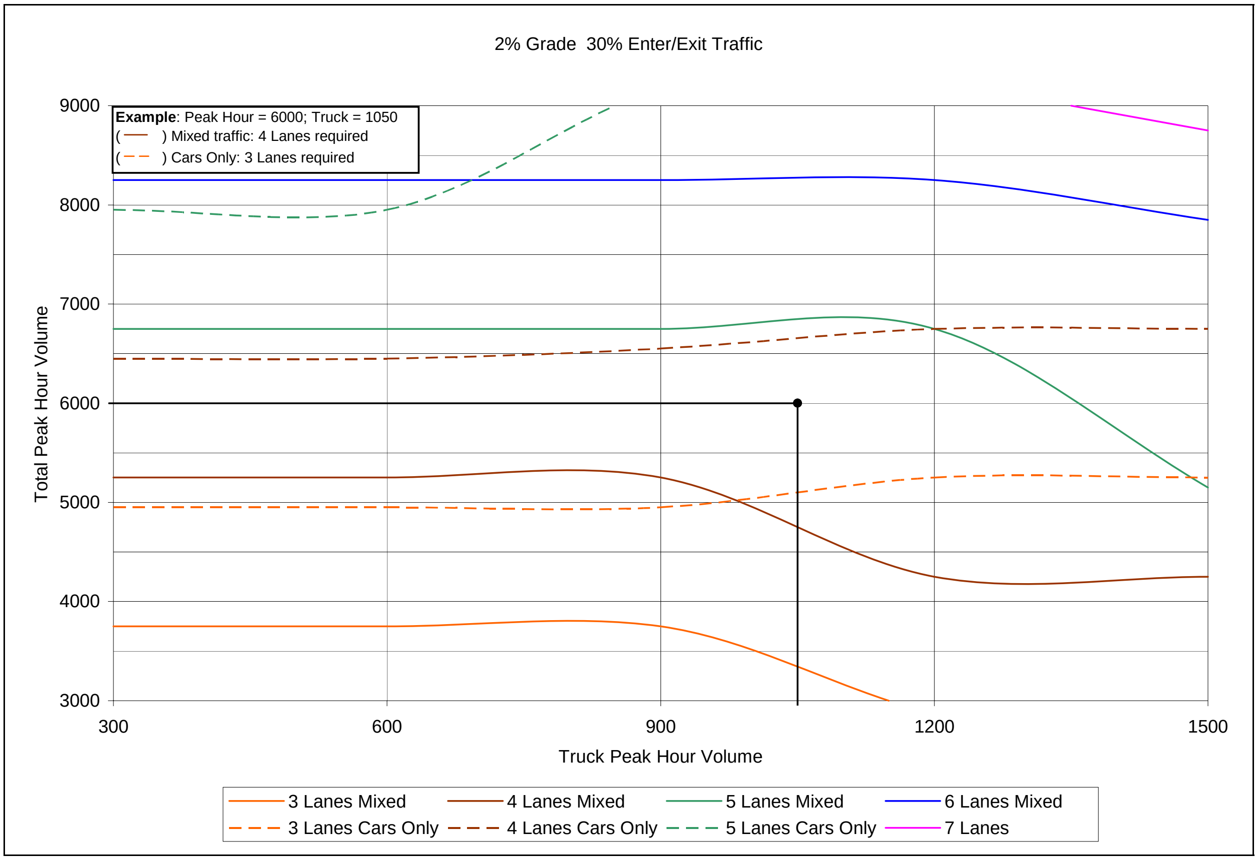

Figure 38. Freeway Design Based on LOS for 2% Grades, 30% Enter/Exit.

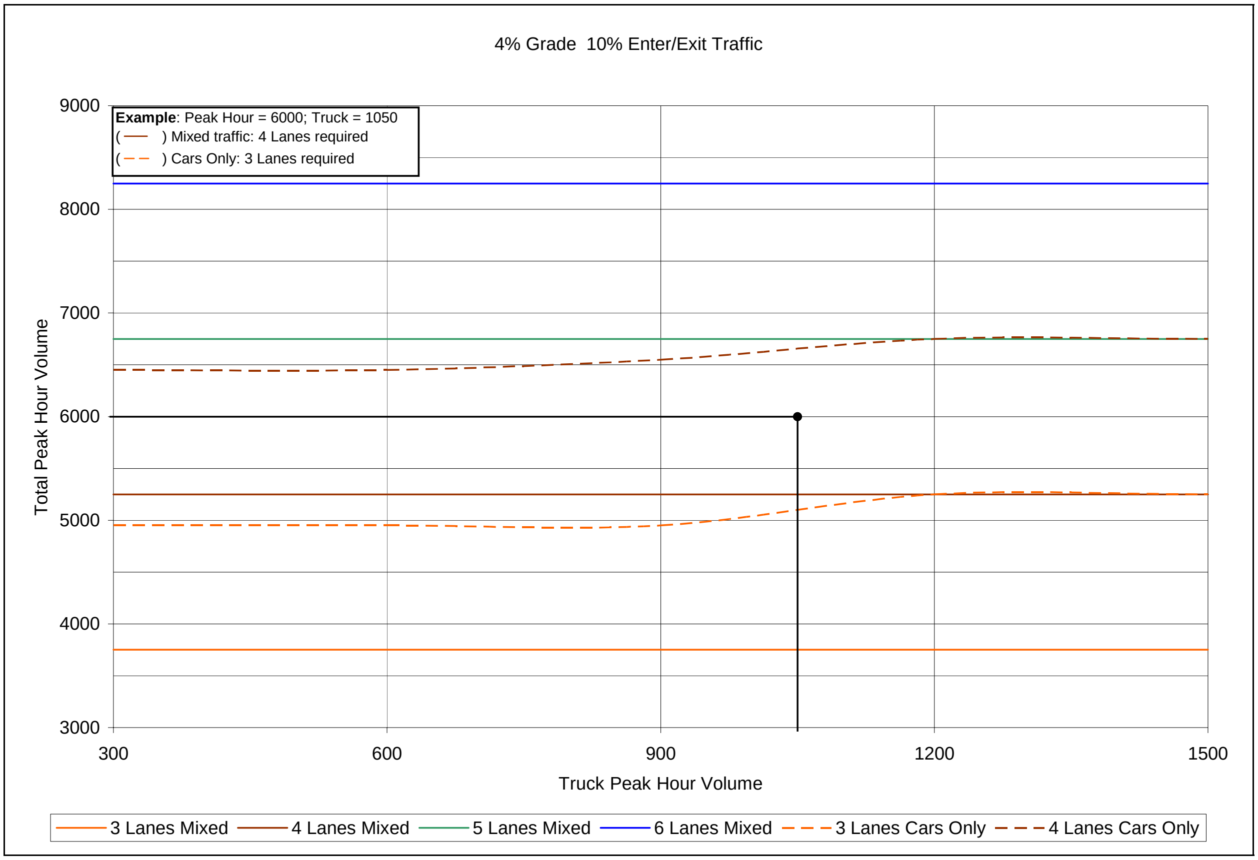

Figure 39. Freeway Design Based on LOS for 4% Grades, 10% Enter/Exit.

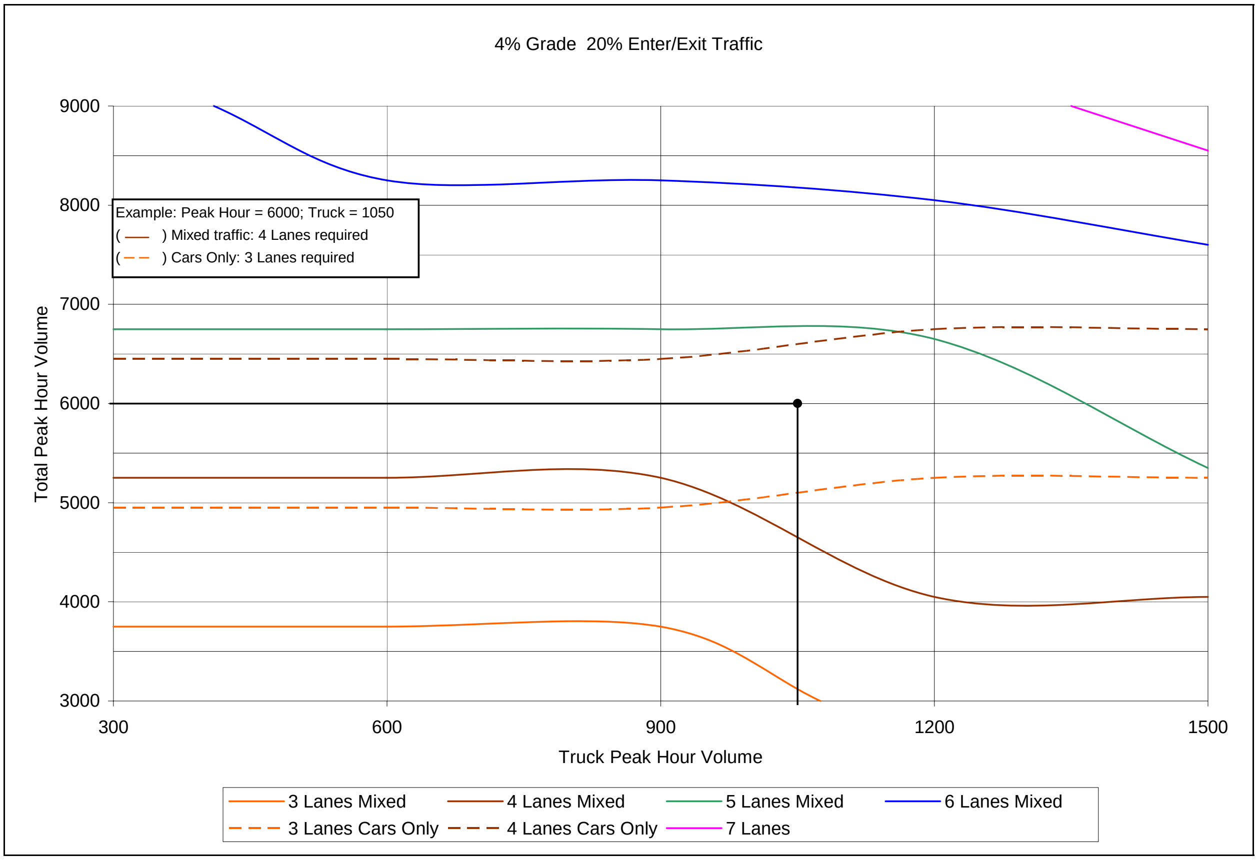

Figure 40. Freeway Design Based on LOS for 4% Grades, 20% Enter/Exit.

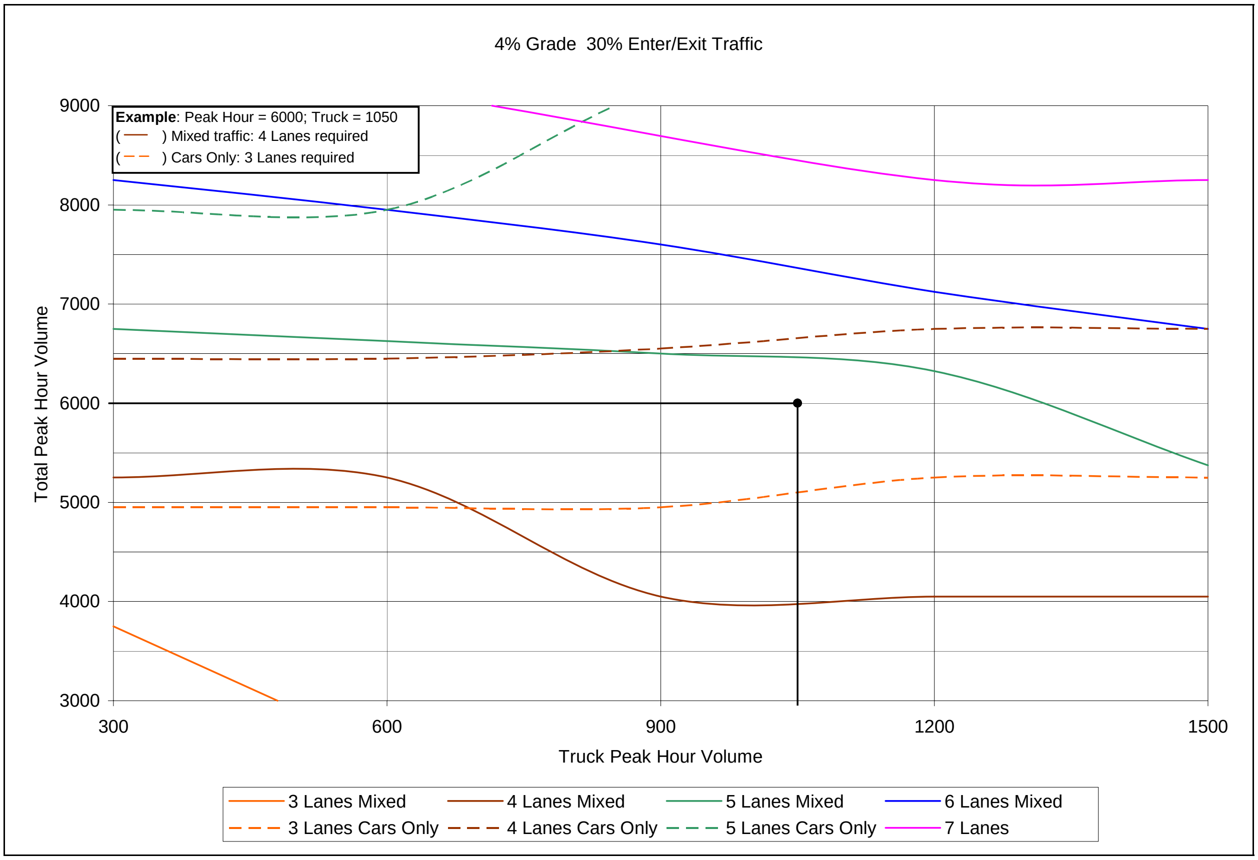

Figure 41. Freeway Design Based on LOS for 4% Grades, 30% Enter/Exit.

APPENDIX C

Delay and Fuel Cost Results

Table 52. Delay and Fuel Cost Results.

Grade	% Enter	Total Hourly Volume	Facility Type	Truck Hourly Volume 300	600	900	1200	1500
0	10	3000	Time $	$33.74	$56.84	$52.94	$84.32	$198.63
			Fuel $	$22.01	$13.05	$5.67	($5.27)	($66.76)
			Total $	**$55.74**	**$69.89**	**$58.61**	**$79.05**	**$131.87**
		4500	Time $	$64.69	$114.22	$92.28	$103.24	$143.51
			Fuel $	($13.95)	$21.63	$16.63	$13.06	$36.81
			Total $	**$50.73**	**$135.85**	**$108.91**	**$116.30**	**$180.31**
		6000	Time $	$81.53	$123.93	$113.10	$147.26	$219.80
			Fuel $	($21.12)	$37.15	($4.06)	($12.14)	$22.49
			Total $	**$60.41**	**$161.07**	**$109.04**	**$135.12**	**$242.29**
		7500	Time $	$128.34	$138.21	$187.44	$220.26	$258.32
			Fuel $	($13.68)	($9.84)	$4.36	$31.02	$26.89
			Total $	**$114.65**	**$128.37**	**$191.79**	**$251.28**	**$285.21**
		9000	Time $	$16.72	$129.40	$114.39	$225.68	$312.33
			Fuel $	($51.82)	($26.61)	($50.60)	($41.01)	($28.62)
			Total $	**($35.10)**	**$102.78**	**$63.78**	**$184.67**	**$283.71**

Grade	% Enter	Total Hourly Volume	Facility Type	Truck Hourly Volume 300	600	900	1200	1500
0	20	3000	Time $	$33.91	$55.22	$64.35	$79.64	$116.47
			Fuel $	$20.74	$10.02	$42.96	($3.03)	$5.11
			Total $	**$54.65**	**$65.24**	**$107.30**	**$76.62**	**$121.58**
		4500	Time $	$103.60	$125.24	$133.88	$122.12	$126.92
			Fuel $	$28.36	$12.17	$11.28	$21.43	($1.93)
			Total $	**$131.96**	**$137.41**	**$145.17**	**$143.55**	**$124.99**
		6000	Time $	$75.05	$119.87	$258.31	$218.94	$410.61
			Fuel $	$8.58	($20.87)	($0.43)	$51.29	$53.89
			Total $	**$83.64**	**$99.00**	**$257.88**	**$270.23**	**$464.50**
		7500	Time $	$109.06	$150.76	$262.42	$261.94	$333.59
			Fuel $	($2.86)	$31.21	($3.85)	$55.42	$63.47
			Total $	**$106.19**	**$181.97**	**$258.57**	**$317.36**	**$397.06**
		9000	Time $	($65.07)	$34.52	$66.39	$153.51	$463.46
			Fuel $	($82.37)	($48.96)	($51.07)	$63.52	$82.58
			Total $	**($147.44)**	**($14.44)**	**$15.32**	**$217.03**	**$546.04**

Table 52. Delay and Fuel Cost Results (Continued).

				Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**Facility Type**	**300**	**600**	**900**	**1200**	**1500**
0	**30**	**3000**	Time $	$39.97	$99.96	$206.99	$105.01	$121.54
			Fuel $	$27.37	$8.57	($0.67)	($5.85)	($0.31)
			Total $	**$67.33**	**$108.53**	**$206.31**	**$99.16**	**$121.22**
		4500	Time $	$76.59	$141.60	$218.91	$214.88	$189.15
			Fuel $	$33.23	$17.69	$24.01	$1.05	($5.99)
			Total $	**$109.82**	**$159.29**	**$242.91**	**$215.92**	**$183.15**
		6000	Time $	$57.85	$133.79	$179.80	$432.02	$401.59
			Fuel $	($14.90)	($19.55)	$10.23	$69.34	$38.07
			Total $	**$42.95**	**$114.24**	**$190.03**	**$501.36**	**$439.66**
		7500	Time $	$92.55	$113.27	$282.75	$588.69	$775.49
			Fuel $	($16.82)	($49.73)	($5.40)	$47.55	$38.99
			Total $	**$75.73**	**$63.54**	**$277.35**	**$636.24**	**$814.48**
		9000	Time $	$90.50	$218.85	$240.79	$464.75	$533.92
			Fuel $	($24.59)	($46.27)	($13.59)	$54.86	$45.10
			Total $	**$65.91**	**$172.58**	**$227.19**	**$519.61**	**$579.02**

				Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**Facility Type**	**300**	**600**	**900**	**1200**	**1500**
2	**10**	**3000**	Time $	$35.60	$76.40	$65.72	$74.56	$527.76
			Fuel $	$28.20	$16.31	$6.10	($27.55)	($70.73)
			Total $	**$63.80**	**$92.70**	**$71.83**	**$47.01**	**$457.02**
		4500	Time $	$106.15	$112.31	$106.27	$138.69	$87.35
			Fuel $	$44.05	$28.37	$35.26	$5.95	($32.70)
			Total $	**$150.20**	**$140.68**	**$141.53**	**$144.64**	**$54.65**
		6000	Time $	$71.92	$132.40	$134.08	$144.18	$145.02
			Fuel $	$37.28	($9.58)	($1.38)	$42.44	$20.71
			Total $	**$109.20**	**$122.83**	**$132.70**	**$186.62**	**$165.73**
		7500	Time $	$187.67	$188.26	$224.14	$162.33	$220.84
			Fuel $	$55.02	$53.13	$27.43	($12.87)	$33.92
			Total $	**$242.69**	**$241.39**	**$251.58**	**$149.46**	**$254.76**
		9000	Time $	($82.76)	$19.63	$131.98	$89.29	$247.74
			Fuel $	($41.51)	($56.30)	($44.47)	($27.54)	$39.90
			Total $	**($124.26)**	**($36.67)**	**$87.50**	**$61.76**	**$287.63**

Table 52. Delay and Fuel Cost Results (Continued).

				Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**Facility Type**	**300**	**600**	**900**	**1200**	**1500**
2	**20**	**3000**	Time $	$40.71	$139.69	$97.29	$300.25	$96.73
			Fuel $	$25.84	$11.29	$15.24	($18.92)	$13.27
			Total $	**$66.55**	**$150.98**	**$112.53**	**$281.33**	**$109.99**
		4500	Time $	$61.06	$152.12	$220.15	$286.73	$172.38
			Fuel $	$34.56	$15.10	$51.11	$11.67	($33.75)
			Total $	**$95.62**	**$167.23**	**$271.26**	**$298.40**	**$138.63**
		6000	Time $	$96.19	$137.45	$224.24	$226.38	$130.73
			Fuel $	($14.70)	($14.59)	$59.32	$49.25	($8.17)
			Total $	**$81.50**	**$122.86**	**$283.56**	**$275.63**	**$122.57**
		7500	Time $	$176.08	$328.78	$266.60	$249.17	$316.29
			Fuel $	$43.80	$4.93	($1.39)	$68.45	$41.18
			Total $	**$219.87**	**$333.72**	**$265.20**	**$317.63**	**$357.48**
		9000	Time $	$105.39	$81.20	$138.88	$243.17	$321.80
			Fuel $	($56.26)	($37.49)	($44.12)	($37.96)	$86.74
			Total $	**$49.13**	**$43.70**	**$94.76**	**$205.21**	**$408.54**

				Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**Facility Type**	**300**	**600**	**900**	**1200**	**1500**
2	**30**	**3000**	Time $	$48.88	$117.94	$171.46	$75.56	$77.34
			Fuel $	$31.60	$23.64	$1.10	($4.91)	$4.38
			Total $	**$80.48**	**$141.58**	**$172.56**	**$70.64**	**$81.72**
		4500	Time $	$74.10	$141.95	$215.23	$86.85	$52.90
			Fuel $	$40.70	$66.45	$50.51	$14.31	($5.21)
			Total $	**$114.80**	**$208.40**	**$265.73**	**$101.15**	**$47.69**
		6000	Time $	$116.50	$179.24	$254.99	$238.17	$122.55
			Fuel $	($10.26)	($10.66)	$72.40	$46.75	($1.46)
			Total $	**$106.24**	**$168.58**	**$327.39**	**$284.92**	**$121.09**
		7500	Time $	$1.29	$155.76	$315.56	$435.76	$478.75
			Fuel $	($6.30)	$15.37	$24.26	$127.50	$115.93
			Total $	**($5.01)**	**$171.13**	**$339.82**	**$563.27**	**$594.68**
		9000	Time $	$78.45	$200.82	$248.70	$252.78	$217.37
			Fuel $	($13.65)	($13.50)	($35.86)	($26.57)	($42.04)
			Total $	**$64.79**	**$187.32**	**$212.84**	**$226.21**	**$175.33**

Table 52. Delay and Fuel Cost Results (Continued).

				Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**Facility Type**	**300**	**600**	**900**	**1200**	**1500**
4	**10**	**3000**	Time $	$52.04	$124.70	$167.04	$68.72	($20.13)
			Fuel $	$5.68	($33.18)	($84.26)	($10.20)	$45.20
			Total $	**$57.72**	**$91.52**	**$82.78**	**$58.52**	**$25.07**
		4500	Time $	$106.15	$149.29	$180.67	$265.62	$187.70
			Fuel $	$42.10	$0.89	($55.32)	($89.58)	($81.17)
			Total $	**$148.25**	**$150.17**	**$125.35**	**$176.04**	**$106.53**
		6000	Time $	$98.93	$135.28	$137.75	$154.92	$102.39
			Fuel $	($9.89)	$9.26	($13.29)	$4.23	($24.37)
			Total $	**$89.05**	**$144.54**	**$124.46**	**$159.15**	**$78.02**
		7500	Time $	$117.82	$114.85	$181.54	$136.35	$230.08
			Fuel $	$30.19	$8.90	$11.19	($40.77)	$192.89
			Total $	**$148.01**	**$123.75**	**$192.74**	**$95.58**	**$422.97**
		9000	Time $	($29.93)	$149.76	$99.40	$150.66	$190.62
			Fuel $	($39.49)	($50.52)	$9.28	($27.53)	$236.91
			Total $	**($69.42)**	**$99.24**	**$108.68**	**$123.13**	**$427.53**

				Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**Facility Type**	**300**	**600**	**900**	**1200**	**1500**
4	**20**	**3000**	Time $	$58.58	$140.53	$161.02	$26.50	$96.73
			Fuel $	$107.61	$74.62	$26.04	($4.41)	$13.49
			Total $	**$166.19**	**$215.15**	**$187.06**	**$22.09**	**$110.21**
		4500	Time $	$91.29	$181.79	$216.94	$73.94	($53.12)
			Fuel $	$124.17	$92.33	$24.93	$39.05	$99.39
			Total $	**$215.46**	**$274.12**	**$241.88**	**$112.99**	**$46.26**
		6000	Time $	$91.60	$188.93	$175.31	$91.35	($27.91)
			Fuel $	($21.14)	$3.84	($46.09)	($66.42)	$111.23
			Total $	**$70.46**	**$192.77**	**$129.22**	**$24.93**	**$83.32**
		7500	Time $	$113.99	$171.61	$244.66	$146.36	$57.38
			Fuel $	($5.50)	($44.59)	$100.94	$58.65	$80.23
			Total $	**$108.48**	**$127.02**	**$345.60**	**$205.01**	**$137.61**
		9000	Time $	$79.61	$143.87	$151.40	$194.75	$53.50
			Fuel $	$155.84	$192.00	$173.09	$117.32	$231.35
			Total $	**$235.46**	**$335.86**	**$324.48**	**$312.07**	**$284.85**

Table 52. Delay and Fuel Cost Results (Continued).

				Truck Hourly Volume				
Grade	**% Enter**	**Total Hourly Volume**	**Facility Type**	**300**	**600**	**900**	**1200**	**1500**
4	**30**	**3000**	Time $	$74.52	$92.78	$119.45	$79.25	($37.93)
			Fuel $	$76.85	$9.79	($5.48)	$8.04	$47.79
			Total $	**$151.38**	**$102.57**	**$113.97**	**$87.28**	**$9.87**
		4500	Time $	$89.05	$156.20	$126.26	$104.64	($41.74)
			Fuel $	$36.65	$40.48	$13.42	$42.56	$46.25
			Total $	**$125.70**	**$196.67**	**$139.68**	**$147.19**	**$4.51**
		6000	Time $	$92.46	$198.95	$325.99	$249.19	($6.65)
			Fuel $	($8.03)	$135.75	$81.63	$3.18	$149.16
			Total $	**$84.43**	**$334.70**	**$407.62**	**$252.37**	**$142.52**
		7500	Time $	$51.33	$207.96	$258.99	$190.18	$47.05
			Fuel $	$281.29	$250.57	$165.98	$76.49	$180.32
			Total $	**$332.62**	**$458.52**	**$424.97**	**$266.67**	**$227.37**
		9000	Time $	$100.12	$169.87	$124.55	$86.65	$240.22
			Fuel $	$102.86	$73.84	($53.82)	$134.77	$192.01
			Total $	**$202.98**	**$243.71**	**$70.73**	**$221.42**	**$432.23**

APPENDIX D

Crash Detail for Three Case Studies

Table 53. Houston I-10 Crashes of Type: INCAPACITATING.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	4	0	5	1	0	6
2000	4	0	5	1	0	3
2001	7	0	9	1	2	3
SEVERITY	**15**	**0**	**19**	**3**	**2**	**12**

Table 54. Houston I-10 Crashes of Type: NONINCAPACIT.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	15	0	0	18	8	21
2000	12	0	0	17	4	10
2001	19	0	0	22	6	16
SEVERITY	**46**	**0**	**0**	**57**	**18**	**47**

Table 55. Houston I-10 Crashes of Type: POSSIBLE INJURY.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	57	0	0	0	108	67
2000	46	0	0	0	80	48
2001	54	0	0	0	105	62
SEVERITY	**157**	**0**	**0**	**0**	**293**	**177**

Table 56. Houston I-10 Crashes of Type: FATAL.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	1	1	1	0	0	2
2000	1	1	0	0	0	6
2001	2	2	0	1	2	2
SEVERITY	**4**	**4**	**1**	**1**	**2**	**10**

Table 57. Houston I-10 Crashes of Type: NON-INJURY.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	37	0	0	0	0	75
2000	24	0	0	0	0	51
2001	43	0	0	0	0	87
SEVERITY	**104**	**0**	**0**	**0**	**0**	**213**
CONTSEC1	**326**	**4**	**20**	**61**	**315**	**459**

Table 58. Huntsville I-45 Section 1 Crashes of Type: INCAPACITATING.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
2000	1	0	1	1	1	0

Table 59. Huntsville I-45 Section 1 Crashes of Type: NONINCAPACIT.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	1	0	0	1	0	1
2000	1	0	0	2	0	0
SEVERITY	**2**	**0**	**0**	**3**	**0**	**1**

Table 60. Huntsville I-45 Section 1 Crashes of Type: POSSIBLE INJURY.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	5	0	0	0	7	4
2000	2	0	0	0	2	2
2001	4	0	0	0	5	5
SEVERITY	**11**	**0**	**0**	**0**	**14**	**11**

Table 61. Huntsville I-45 Section 1 Crashes of Type: FATAL.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	1	1	0	0	0	1
2000	1	1	0	0	2	1
SEVERITY	**2**	**2**	**0**	**0**	**2**	**2**

Table 62. Huntsville I-45 Section 1 Crashes of Type: NON-INJURY.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	3	0	0	0	0	6
2000	3	0	0	0	0	5
2001	4	0	0	0	0	8
SEVERITY	**10**	**0**	**0**	**0**	**0**	**19**
CONTSEC1	**26**	**2**	**1**	**4**	**17**	**33**

Table 63. Huntsville I-45 Section 2 Crashes of Type: INCAPACITATING.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
2000	1	0	1	0	3	0

Table 64. Huntsville I-45 Section 2 Crashes of Type: NONINCAPACIT.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	7	0	0	10	3	8
2000	7	0	0	7	4	4
2001	3	0	0	4	1	1
SEVERITY	**17**	**0**	**0**	**21**	**8**	**13**

Table 65. Huntsville I-45 Section 2 Crashes of Type: POSSIBLE INJURY.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	7	0	0	0	16	5
2000	8	0	0	0	16	5
2001	8	0	0	0	11	10
SEVERITY	**23**	**0**	**0**	**0**	**43**	**20**

Table 66. Huntsville I-45 Section 2 Crashes of Type: FATAL.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	1	2	0	0	0	1
2001	1	1	1	0	0	1
SEVERITY	**2**	**3**	**1**	**0**	**0**	**2**

Table 67. Huntsville I-45 Section 2 Crashes of Type: NON-INJURY.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	11	0	0	0	0	18
2000	4	0	0	0	0	9
2001	8	0	0	0	0	14
SEVERITY	**23**	**0**	**0**	**0**	**0**	**41**
CONTSEC1	**66**	**3**	**2**	**21**	**54**	**76**
	737	**11**	**43**	**164**	**626**	**1000**

Table 68. Laredo I-35 Crashes of Type: INCAPACITATING.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	5	0	5	0	1	5
2000	7	0	10	1	11	7
2001	3	0	4	0	1	0
SEVERITY	**15**	**0**	**19**	**1**	**13**	**12**

Table 69. Laredo I-35 Crashes of Type: NONINCAPACIT.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	22	0	0	30	8	22
2000	20	0	0	26	2	26
2001	17	0	0	21	6	19
SEVERITY	**59**	**0**	**0**	**77**	**16**	**67**

Table 70. Laredo I-35 Crashes of Type: POSSIBLE INJURY.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	58	0	0	0	83	66
2000	43	0	0	0	57	44
2001	48	0	0	0	71	64
SEVERITY	**149**	**0**	**0**	**0**	**211**	**174**

Table 71. Laredo I-35 Crashes of Type: FATAL.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
2001	2	2	1	0	0	1

Table 72. Laredo I-35 Crashes of Type: NON-INJURY.

ACC_YR	CRASHES	FATAL	INCINJ	NONINC	POSSINJ	NONINJ
1999	42	0	0	0	0	83
2000	31	0	0	0	0	56
2001	21	0	0	0	0	39
SEVERITY	**94**	**0**	**0**	**0**	**0**	**178**
CONTSEC1	**319**	**2**	**20**	**78**	**240**	**432**

APPENDIX E

Use of CORSIM to Evaluate Truck Roadways

Simulating Texas Trucks in CORSIM

Within CORSIM, a submodel known as FRESIM contains all freeway simulation details; another submodel known as NETSIM handles surface street operations. Interface nodes between FRESIM and NETSIM create a CORSIM network, which then contains all desired surface and freeway roadway features, vehicles, and controls. Since truck roadways are conceptualized as freeway facilities within this research investigation, we will only present the details for using FRESIM to simulate truck roadways. However, we will use the all-inclusive term CORSIM to refer to the model and all of its components.

Several calibration changes must be made within an input file to ensure that CORSIM creates the most appropriate representation of truck types and characteristics for Texas conditions. By default, CORSIM features four generic truck types for freeway operations simulation. Table 73 presents these types, their default percentages in the traffic stream, and their general classification (refer to Table 8 in Chapter 3, Truck Classification Schemes, for more detail). Within CORSIM, all trucks feature a headway factor of 120, a "jerk value" of 7.0 ft/s^2, an emergency deceleration of 15.0 ft/s^2 and a maximum deceleration under normal conditions of 8.0 ft/s^2. The headway factor indicates that truck drivers generally allow greater spacing between vehicles than automobile drivers and the jerk and acceleration values govern the acceleration and braking performance limits of heavy vehicles. These values were found to be reasonably consistent with truck performance data described earlier in this report.

The "Performance Index" value shown for each CORSIM truck type shown in Table 73 affects the fuel consumption and emissions outputs from the model. Such differentiation is necessary so that larger and more heavily loaded trucks are correctly shown to be more demanding consumers of fuel and produce more emissions than smaller trucks.

Table 73. CORSIM Default Truck Types for Freeway Simulation.

CORSIM Truck Type	Length (Feet)	Performance Index	Performance Description	Texas 6 Classification	Percent of Truck Population
FRESIM 3	35	3	Single Unit	Class 5, 6	31
FRESIM 4	53	4	Semi-Trailer – Medium Load	Class 7, 8, 9, 10	36
FRESIM 5	53	5	Semi-Trailer – Full Load	Class 7, 8, 9, 10	24
FRESIM 6	64	6	Double-Bottom Trailer	Class 11, 12, 13	9

As indicated by Table 73, CORSIM has a limited number of truck types available for inclusion in the model. In addition, it uses one "truck type" to differentiate between trucks of the same type with different load levels, or weights. While at first appearing rather constrained, especially since the Texas 6 truck classification scheme features nine different truck types and the FHWA truck classification scheme includes eight different truck types, the number of truck types available in CORSIM is appropriate for the simulation of Texas' truck distribution (see Table 74 for more detail). By combining the truck population found in Texas into broad

Table 74. Truck Type Distribution for Rural Texas Conditions.

Truck Class	ATR Station 13D (40% Weight) (Daily Volume)	ATR Station 198 (60% Weight) (Daily Volume)	Final Distribution (Percent)
5	345	546	8.2
6	48	53	0.9
7	6	6	0.1
8	180	62	1.9
9	3169	5817	83.5
10	49	20	0.6
11	135	285	3.9
12	36	60	0.9
13	0	1	0.0

categories for single unit, semi-trailer, and double-bottom trucks and using the default load distribution for semi-trailers represented by CORSIM truck types FRESIM 4 and FRESIM 5, the distribution of trucks in Texas represented in CORSIM becomes that shown in Table 75. The new lengths shown for each truck type are weighted averages based on each truck length within the Texas 6 classification scheme and its relative proportion within the appropriate CORSIM truck type.

Table 75. CORSIM Distribution/Representation of Texas Rural Truck Population.

CORSIM Truck Type	Length (Feet)	Performance Index	Performance Description	Texas 6 Classification	Percent of Truck Population
FRESIM 3	35	3	Single Unit	Class 5, 6	9
FRESIM 4	68	4	Semi-Trailer – Medium Load	Class 7, 8, 9, 10	52
FRESIM 5	68	5	Semi-Trailer – Full Load	Class 7, 8, 9, 10	34
FRESIM 6	73	6	Double-Bottom Trailer	Class 11, 12, 13	5

Coding the Model

The data from Table 75 is incorporated into CORSIM by editing network properties. Once the user has created a TRAFED (CORSIM input file graphical editor) file and is within CORSIM's TRAFED editor, simply click on **Network** from the main menu bar and then select **Properties** from the pull-down menu. Once within the Properties pop-up window, select the tab for **Vehicle Types**; the window should look exactly like the one shown in **Error! Reference source not found.** 42. At the top of this window the user will see a pull-down box titled **Select a Vehicle Type to Edit**. By clicking the pull-down arrow the user is able to edit FRESIM vehicle Types 3, 4, 5, and 6 (i.e., the FRESIM truck types) to contain the values shown in Table 75. Upon completing each FRESIM vehicle (truck) type edit, the window should look like the window images shown in Figure 43. Red highlighting circles have been added to the images to show where values have been changed from the CORSIM default values.

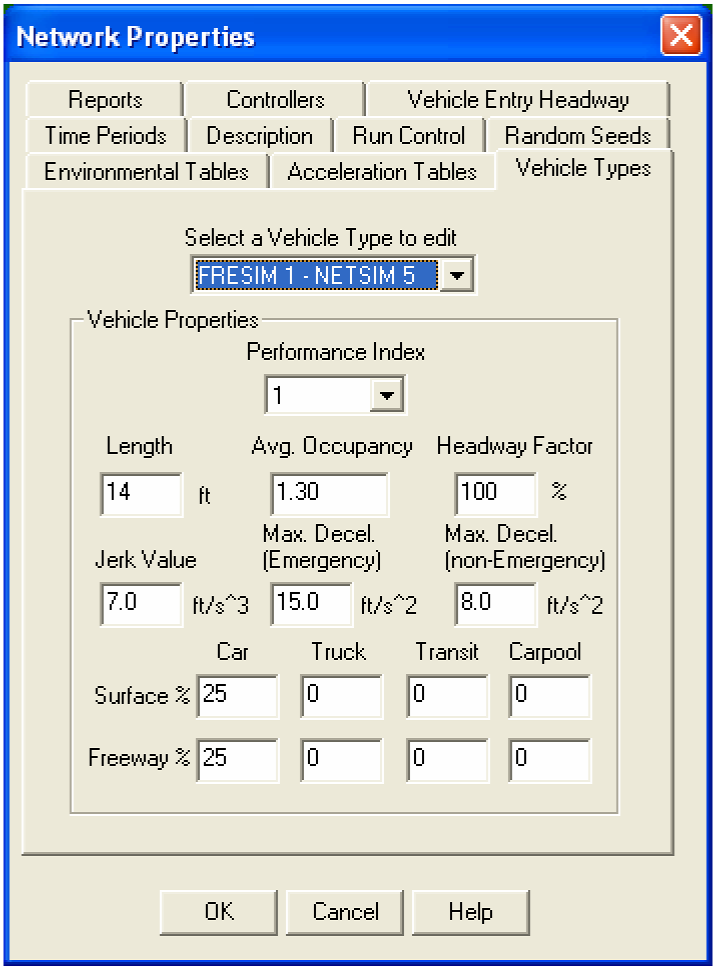

Figure 42. CORSIM Network Properties/Vehicle Types Window.

Once the truck population for Texas has been entered into CORSIM, the model can be coded for the unique situation being analyzed. Once the links have been correctly coded into CORSIM for the freeway mainlane sections and any ramps included within the geometric boundaries of the analysis, volume input details are coded. When specifying input volumes, ensure that the correct truck percentage of traffic is coded. For truck roadways as considered in this research, the truck percentage would be 100 percent. Figure 44 shows an example of a CORSIM entry node volume input window for a 100 percent truck allocation. When using the Texas truck percentage in CORSIM for a mixed flow facility, simply indicating the known percent trucks for that freeway segment's entry nodes and ramps will cause CORSIM to create trucks of the right type, in the right proportion (using the vehicle type data entered from Figure 43) and of the correct proportion in the overall traffic stream.

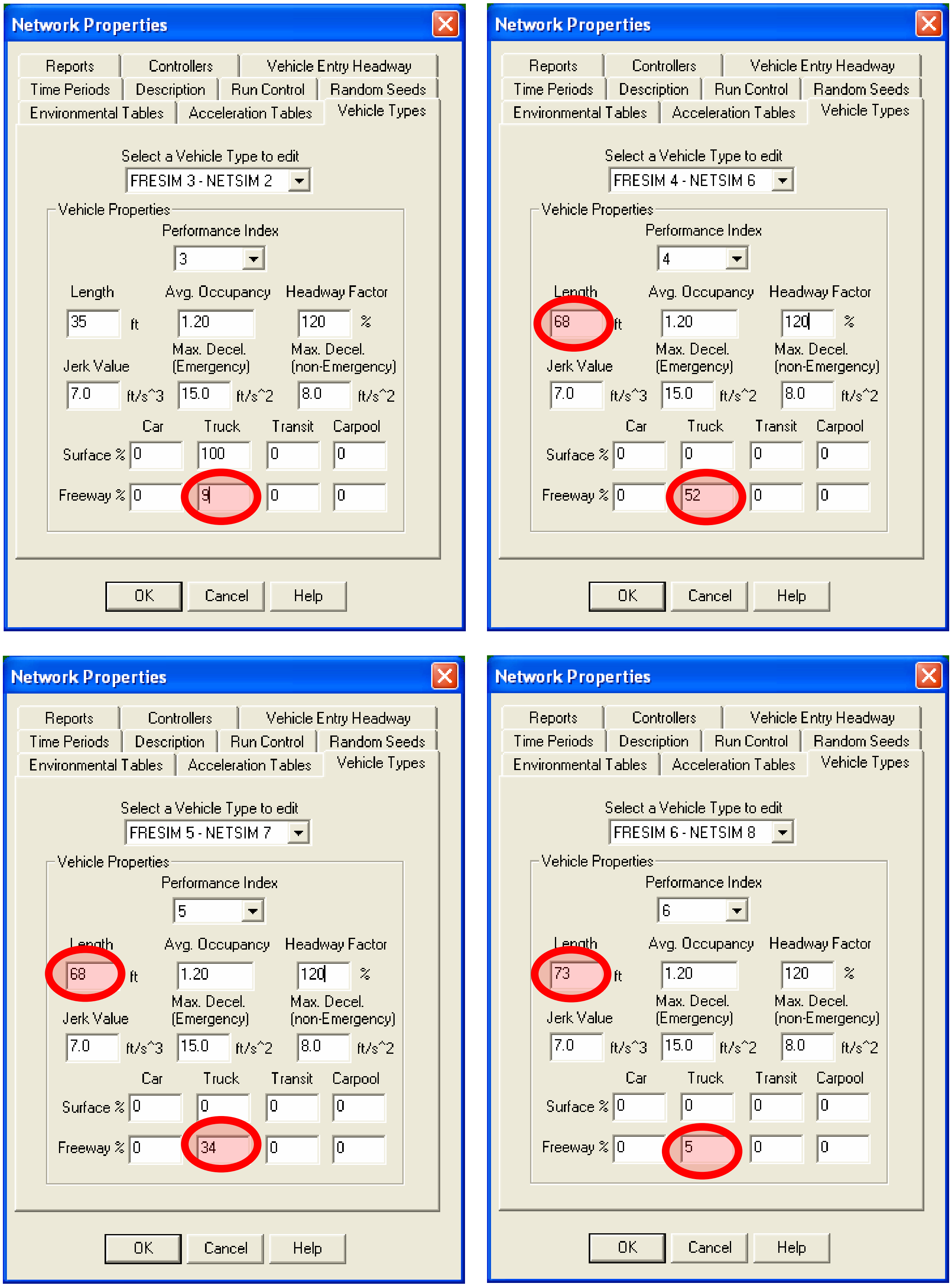

Figure 43. CORSIM Vehicle Types Edited for Texas Truck Population.

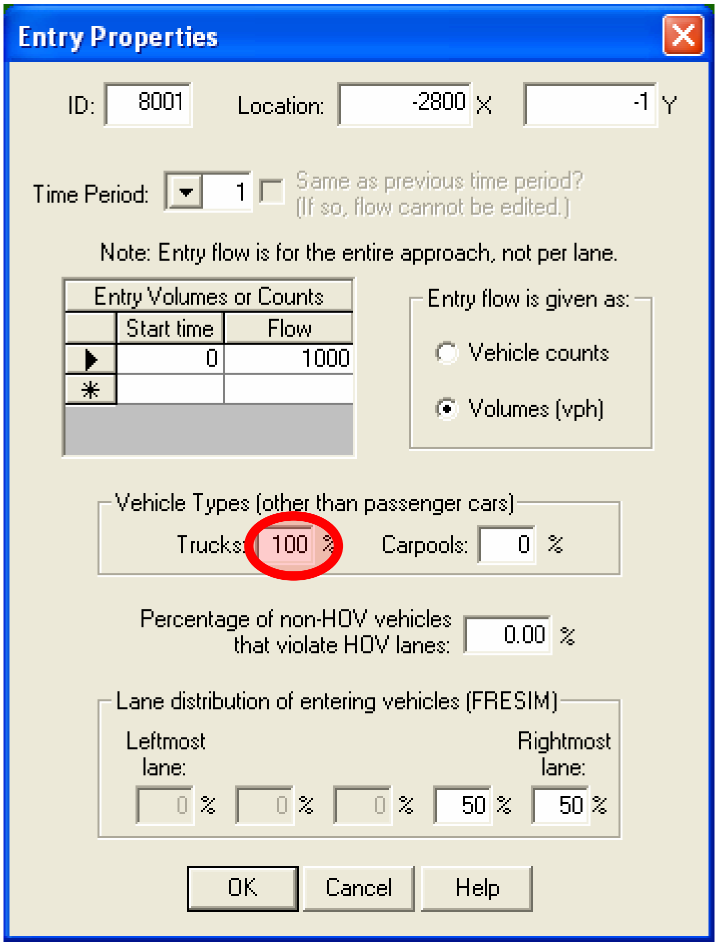

Figure 44. CORSIM Volume Data Entry Window.

If one of the truck treatment alternatives being investigated is truck lane restrictions, CORSIM includes a feature that allows you to either bias trucks to certain lanes of the freeway or to fully restrict trucks so that they only use certain lanes. To use this feature, simply double-click on a freeway link where you wish to add the restriction. A freeway link pop-up window will appear that allows you to edit the geometric properties of the link. Upon viewing this window, click on the **Trucks** tab (see Figure 45). The user has the option of letting trucks use all lanes, biasing trucks to a select number of left- or rightmost lanes on the freeway, or restricting trucks to a select number of left- or rightmost lanes on the freeway. In a common situation associated with truck lane restrictions, where trucks are not allowed to use the leftmost lane of the freeway, you would simply code the freeway links to restrict trucks to the rightmost two (2) through lanes (assuming a three-lane freeway).

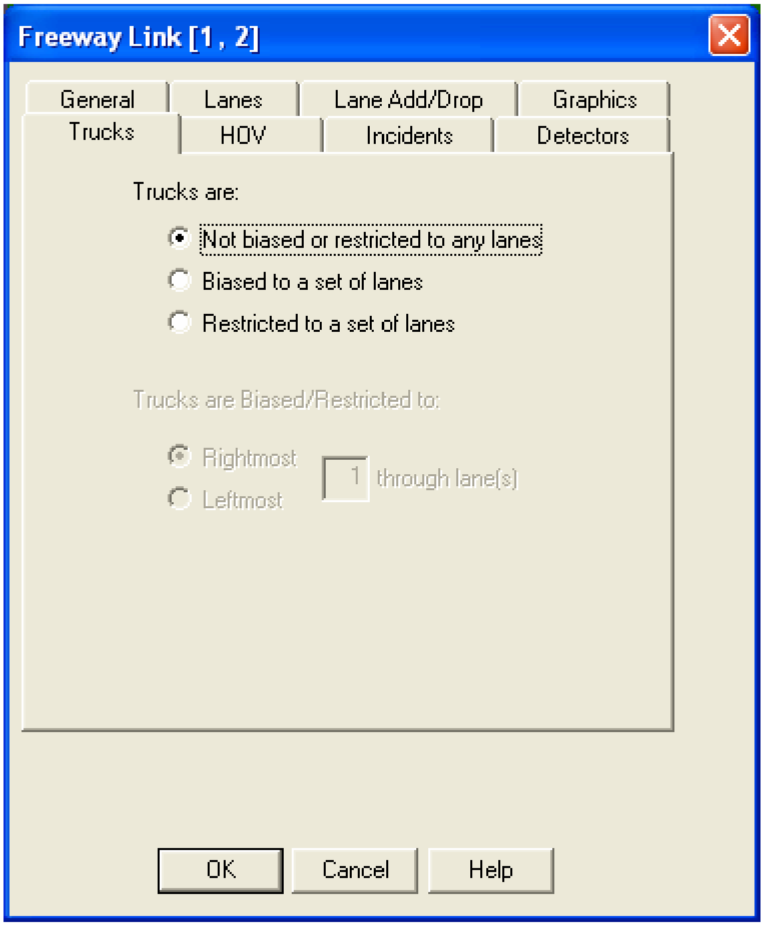

Figure 45. CORSIM (FRESIM) Truck Restriction Settings.

Creating a number of CORSIM input files for truck roadway simulation analysis requires creating a new TRAFED input file and re-entering the truck type distribution data shown in Figure 43. There is no way within CORSIM to alter the vehicle type distributions and save those setting for later use.