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16. Abstract
The number of trucks on many highways in Texas and across the nation has increased to the point that special or unique roadway design treatments may be warranted. Increases in truck traffic have resulted from increases in time-sensitive freight (e.g., just-in-time deliveries), the North American Free Trade Agreement (NAFTA), and until recently a robust economy. As particular corridors have become increasingly dominated by truck traffic, or in locations where truck traffic might reasonably be segregated, questions have arisen regarding accommodations and treatments that may be appropriate for those corridors to address issues caused by truck traffic. This research investigated the sensitivity of current Texas design practice to the unique operating characteristics of large commercial vehicles and determined threshold conditions under which design should reflect these larger vehicles. Findings of this study indicate that serious consideration needs to be given trucks when the average annual daily truck traffic (AADTT) reaches 5000 trucks per day during the design period. When the design AADTT reaches 25,000 trucks per day, there may be justification for considering separated truck roadways with a minimum of two lanes in each direction. This research recommends that the Texas Department of Transportation (TxDOT) consider changes in the following design parameters in its TxDOT *Roadway Design Manual* (and/or other appropriate documents): stopping sight distance, intersection and channelization, lane width, shoulder width and composition, sideslopes and drainage features, traffic barrier, passive signs, and acceleration lanes.

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TRUCK ACCOMMODATION DESIGN GUIDANCE: POLICY MAKER WORKSHOP

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CHAPTER 1. INTRODUCTION TO TRUCK ACCOMMODATION

1.1 INTRODUCTION

The number of trucks on many highways in Texas and across the nation has increased to the point that special or unique roadway design treatments may be warranted. Increases in truck traffic have resulted from a robust domestic economy, increases in time-sensitive freight (e.g., just-in-time deliveries), and the North American Free Trade Agreement (NAFTA). As particular corridors have become increasingly dominated by truck traffic, or in locations where truck traffic might reasonably be segregated, questions have arisen regarding accommodations and treatments that may be appropriate for those corridors to address issues caused by truck traffic.

Three prominent scenarios of truck treatment or accommodation that seem to depend largely on the volume of trucks on the roadway are: 1) allow trucks to operate in mixed flow with no special design treatment, 2) allow trucks to operate in mixed traffic with some restrictions on trucks and/or cars to improve safety and/or operations, and 3) provide separate truck roadways. For at least the second and third scenarios, there need to be special design considerations given to accommodate trucks and make the roadway as safe as feasible. More information on the topics covered in this workshop document is available in Report 4364-1 *(1)*.

Large trucks operating together on the same lanes and separated from cars operating on their own lanes form two more homogeneous blends of vehicles with similar operating characteristics when compared to a single mixed traffic stream. Acceleration rates, stopping distances, weaving capabilities (lane changing, usually near merge or diverge locations), and roll stability are but a few of the operational characteristics that make trucks different. Driver knowledge and expectations are factors in this environment as well because many car drivers behave as if they expect trucks to operate like passenger cars. Even these operational features alone are not sufficient justification to build expensive truck roadways, but as overall congestion increases and the numbers of trucks increase, and as trucks are involved in incidents or crashes, the result is often much more catastrophic than if only cars are involved. Crash severity generally increases where trucks are involved, resulting in greater damage to smaller vehicles and their occupants and to roadway appurtenances. It is easy to understand why safety is the most prominent argument used to support the concept of separating trucks although lack of supporting safety documentation for full separation of trucks leaves uncertainty regarding the full safety implications. Another supporting reason for separating trucks is being able to design truck roadways with thicker pavement for heavier truckloads while designing car lanes with thinner pavement (or realistically for smaller or fewer trucks).

Separating trucks from other traffic can occur either spatially or by time of day. Spatial separation can be accomplished to some degree by designated routing or by placing trucks in their own lanes along the same routes with passenger vehicles. Certain commodities such as hazardous materials need the maximum practicable separation from other traffic and population centers, so some cities have designated non-radioactive hazardous material routes for the through movement of these vehicles. Truck lane restrictions may only apply to certain hours of the day or certain traffic conditions or both. In Texas, the I-10 lane restriction in Houston (discussed in more detail elsewhere) was limited to weekdays and daylight hours when traffic was heaviest. Cities often pass ordinances to establish truck routes to keep trucks on routes that best accommodate them geometrically and structurally, and minimize their impact by separation from highly populated areas. Cities with alternative or bypass routes sometimes restrict long-haul trucks from using interior, non-bypass routes, but enforcement of these bans is difficult.

1.2 PROJECT OBJECTIVES

This project responds to the immediate need to more fully understand highway design features that are, or should be, influenced by trucks. The research addresses the topic for the state of Texas through a number of specific objectives. The primary objectives were as follows:

- develop a profile of the truck fleet using, and expected to use, Texas roadways;
- evaluate geometric design criteria currently used and determine whether the criteria adequately reflect truck characteristics;
- identify design-related practices used elsewhere that could best improve Texas design practice; and
- develop geometric guidelines for implementation.

1.3 STAKEHOLDER INPUT

Stakeholders in the considerations of truck design accommodation include the Texas Department of Transportation (TxDOT), the motor carrier industry, the various enforcement agencies, and particularly the Texas Department of Public Safety (DPS). Researchers contacted the various stakeholders to solicit input, then summarized findings. This section summarizes two surveys and results of office visits to TxDOT districts and division personnel. Texas Transportation Institute (TTI) researchers conducted one survey and the Research and Technology Implementation (RTI) office conducted the other one.

The RTI survey report *(2)* is divided by: 1) actions currently being taken to mitigate the impacts of increasing truck traffic levels on the Texas highway system, and 2) actions suggested by survey respondents to mitigate truck impacts. It is further subdivided into the following categories: geometric design, pavement design and construction, pavement maintenance, bridges and structures, work zone safety, traffic control devices, traffic management, and truck parking facilities. While the primary emphasis for Research Project 0-4364 is geometric design, other categories are also important and are included below.

The following list of geometric design initiatives is an indication of what the districts are already doing, or planning to do, to accommodate trucks. Several district responses suggest a review of existing design standards to determine if they are still appropriate for current and projected future truck traffic volumes.

- At least three districts are considering adopting the “Texas Super 2” geometric design guidelines. The “2” in the “Super 2” refers to a two-lane roadway, with one lane in each direction. TxDOT sponsored research that developed these guidelines for intermittent passing lanes to provide improved capacity and traffic safety on two-lane routes that do not carry enough traffic to warrant upgrading to a four-lane facility.

- Lane and shoulder widening projects (not necessarily Super 2).
- Increased sight distance and using larger turning radii at intersections.
- Providing passing and climbing lanes.
- Districts are considering different design standards for rehabilitation projects. Right-of-way restrictions, particularly in cities, make major changes difficult. If standards are increased too much, rehabilitation of existing facilities might not be possible. Bypasses around towns might be the only alternative; however, they are expensive, require a large amount of right-of-way, are unpopular in many areas, and take a long time to develop and construct.

From a traffic operations standpoint, one-third of all responses indicated a need for managed lanes along freeways, especially through urban and metropolitan areas. Responses were divided as to the best way to separate truck traffic from smaller vehicles. Suggestions include "preferred truck lanes," "designated truck lanes," "truck-only lanes," and "truck-excluded lanes." The Waco District indicated interest in conducting a pilot project along I-35. Passenger cars and light trucks would have at least one lane free of heavy trucks but would be allowed to use the "truck-preferred" lanes as necessary.

From a pavements standpoint, 11 of 24 districts reported increased use of reinforced concrete pavement for main lanes due to increased numbers of trucks. There is also increased use of concrete pavement at intersections and for rest stop parking areas. Pavement type selection includes life cycle cost analysis in at least three of these districts. However, lack of resources for funding the higher initial costs of superior-performing products continues to be the final determining factor in most cases. Perhaps one of the most significant actions taking place in response to increasing truck traffic is the ongoing development of Heavy-Duty Hot Mix Asphalt Pavement ("perpetual pavements") Specifications. The heavy-duty specifications are intended for use on roadways carrying an average of 5000 trucks per day (tpd). Pilot testing has recently concluded on five projects, and full-depth projects are now planned in the Waco, Laredo, and Fort Worth districts. Expected life of roads constructed with heavy-duty mixes is indefinite, with minor rehabilitation expected after 15 to 20 years.

Table 1 indicates the results of the 84 survey forms returned to the Texas DPS then to TTI for evaluation. There were four general questions and four specific questions about geometric design problems, followed by questions about vehicle trends. According to these results the major problems related to geometric design for commercial vehicles pertains to shoulders too narrow for emergency parking, insufficient parking space, and inadequate intersection design for trucks.

Table 1. DPS Survey Result Summary.

Survey Question	No. of Comments
Shoulders Too Narrow for Trucks	60
Insufficient Parking for Trucks	46
Inadequate Intersection Design for Trucks	39
Two-Lane Roadways Need Climbing Lanes	27
Short Distance between Entry/Exit Ramps	20
Sharp Turns or Curves Causing Rollover	19
Accel/Decel Lane Lengths Too Short	18
Specific Parking Problem Locations	14
Other Trends Affecting Opr. Characteristics	8
Trend in Longer Semi Trailers	7
Trend in Different Vehicle Types	4

Motor carriers or their representatives had the following comments to add regarding current geometric design for trucks.

- Some Texas Motor Transport Association (TMTA) members are concerned that TxDOT is converting some of its rest areas into DPS enforcement operations. If that happens, during periods of heavy traffic, truck queues might extend to the travel lanes and become a serious safety problem.

- Motor carriers are open to the idea of using toll roads, but they want to always have a non-toll alternative and not be forced to use the toll facility. Even when motor carriers use toll roads, they are still paying heavily for non-toll facilities so they feel like they are paying twice. Motor carriers support multiple options, so if a toll road saves enough time, a business decision can be made that it may be worth the additional cost. Motor carriers need to be represented in major highway decisions.

- There has been discussion of limiting truck operations during the peak periods. Truckers already avoid peak period delays as much as possible. However, shippers are forcing trucks to deliver at selected times, and trucks are obligated to meet shipper demands.

- Trucks need information that Intelligent Transportation Systems (ITS) can provide (e.g., changeable message signs) at least one hour in advance of urban areas in order for the information to be useful.

- One of the factors related to truck size that affects geometric design is trailer length. Some anticipate increased use of longer trailers, and in Texas, they can be as long as 59 ft. Only a few TMTA members need more cube space today due to low-density freight.

- Truckers sometimes have trouble negotiating freeway ramps and connector roadways where there are left-hand exits. Trucks typically travel in the right lanes, so left exits require moving across freeway lanes from right to left. This movement is more difficult in large trucks due to their size and car drivers not being willing to yield. Also, trucks have trouble negotiating some ramps in heavy traffic because of a tight turning radius.

- Merge areas and acceleration lanes are the most challenging design situations for truck drivers, according to one carrier. Drivers have perceived that very few acceleration lanes in Texas provide adequate space for a truck/trailer combination to accelerate and merge with the traffic stream. Other general examples of geometric problems are narrow intersections and turnaround lane curves.

- One truck driver stated that many entrance ramps merge with the main lanes at an undesirable angle, creating a blind spot for many truck drivers. The angle is sometimes too large for the driver to use rear-view mirrors but so small that he or she cannot look out the window and see past the "sleeper." There are some ramps that this driver avoids altogether if possible because of this problem.

- There were several comments from truck drivers pertaining to insufficient truck parking in public rest areas. TxDOT has an ongoing $70 million program to improve truck parking with the goal of providing truck parking areas spaced no farther apart than 60 to 90 miles along designated travel corridors carrying at least 5000 vehicles per day (vpd). TxDOT anticipates that these funds will be depleted in four years, beyond which there will be an additional need for $110 million (in 2002 dollars) to complete the program. Figures 1 and 2 clearly indicate some of these parking problems; both are along I-35 north of Austin. In Figure 1, both the geometrics and the space available are inadequate, while Figure 2 shows an area along a frontage road near a truck stop where truckers created their own parking area.

Figure 1. Rest Area along I-35.

Figure 2. Truck Parking Area along I-35 Frontage Road.

CHAPTER 2. MAJOR TEXAS TRUCK CORRIDORS

2.1 INTRODUCTION

For purposes of analysis of the Texas road network, the research team selected some road classes to be retained and some to be removed from the total network file. The goal in the selection process was to cover at least the National Highway System (NHS) network in Texas, but the selected network is actually more than that network. Road classes retained are Interstate, U.S. highways, and a subset of State highways. Figure 3 shows the resulting network.

The analysis in this study of truck-transported commodity movements relied upon the freight movement database, TRANSEARCH, provided by Reebie Associates through the state of Texas for 1998 *(2)*. The complete database contains freight movement of all transportation modes, but this analysis only considers the truck transport data. In 1998, trucks moved a total of 769 million tons of commodities on Texas highways. This includes 23.3 million tons of commodities moved between Texas and Mexico.

2.2 DOMESTIC AND INTERNATIONAL TRUCK FLOWS

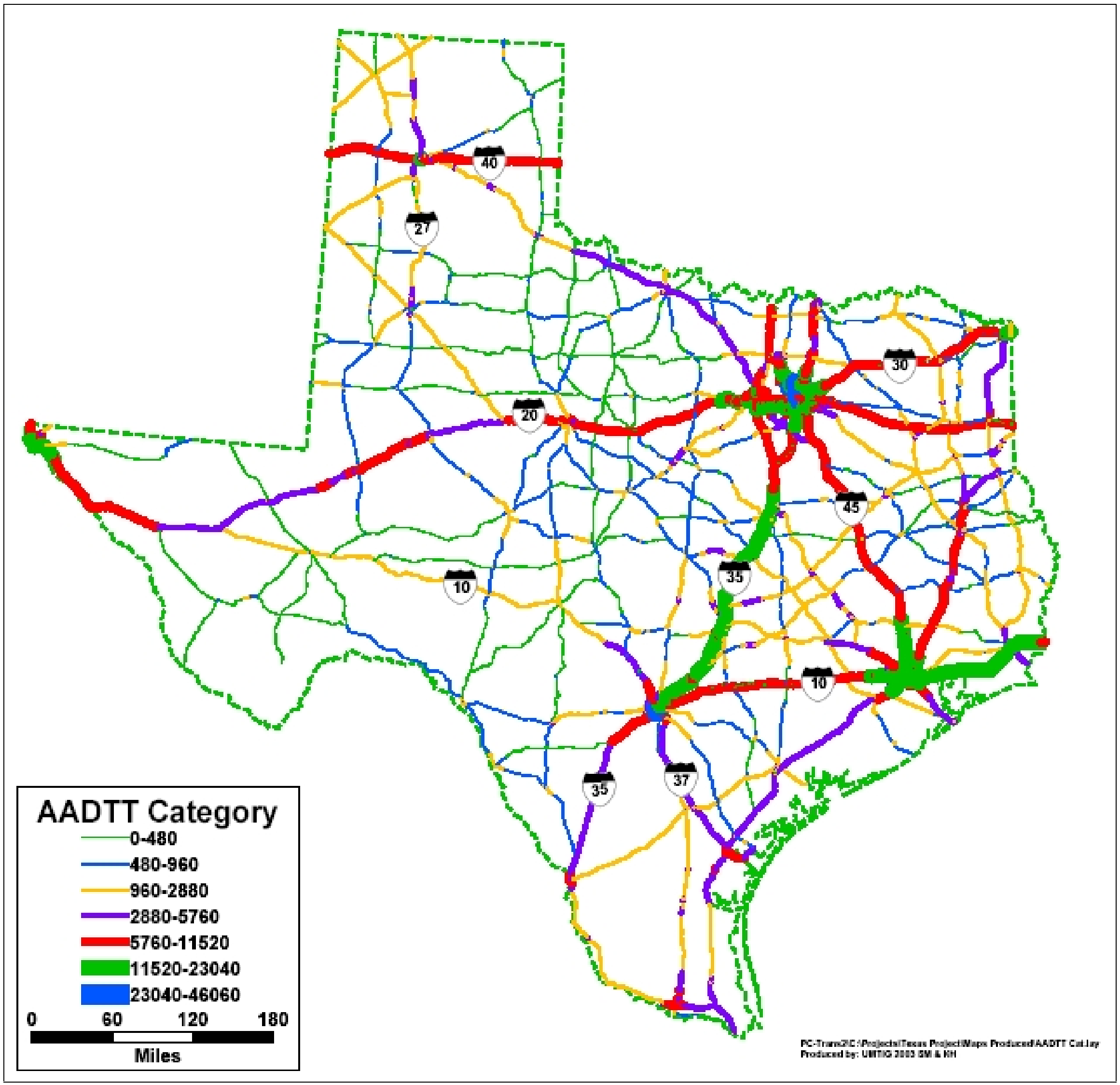
This section covers domestic truck flows by two categories: 1) by truck volume levels, and 2) by highway designation. It then provides information on U.S./Mexico truck flows.

2.2.1 Truck Flows by Volume Level

This section covers truck flows, beginning with statewide truck counts on the major truck corridors. Table 2 shows the average annual daily truck traffic (AADTT) categories developed for the purposes of this analysis. Researchers selected the categories to give a practical physical sense of different levels of truck traffic when functioning in an idealized BASIC FLOW manner. Calculating BASIC FLOW characteristics assumed that the AADTT is evenly split in each direction; travels in one lane in each direction; experiences no seasonality, day-of-week, or time-of-day variation; that all trucks travel at 60 mph (88 ft/sec); and that all trucks travel at constant time and spacing headways, varying only by AADTT level. The AADTT is defined as the total (two-way) truck traffic at a location on a roadway in a year's time, divided by 365.

Table 2. AADTT Categories.

CATEGORY NAME	AADTT RANGE
Very Low	0-480
Low	480-960
Medium	960-2880
Medium High	2880-5760
High	5760-11520
Very High	11520 plus



Source: UMTIG

Figure 3. Texas Highway AADTT Categories.

2.2.2. Truck Flows by Highway Type

Table 3 is a summary of route-miles and truck-miles traveled (TMT) for all State (ST), Interstate (IH), and US routes in Texas. From it come the following findings:

- Highways with high truck volumes (5760-11520) account for 6 percent of the route miles and 31 percent of the annual TMT.

- Highways with very high truck volumes (11520-23040+) account for 2 percent of the route miles and 18 percent of the annual TMT.

Also, by highway type, the following findings are useful:

- Interstate highways account for 11 percent of the route miles and 49 percent of the annual TMT.
- U.S. highways account for 40 percent of the route miles and 32 percent of the annual TMT.
- State highways account for 50 percent of the route miles and 20 percent of the annual TMT.

Figure 4 graphically depicts the truck-miles traveled by these same AADTT categories. Figure 4 shows sections of Texas Interstate, U.S., and State highways experiencing AADTT levels in each of the respective categories via line width and color.

Table 3. Route-Miles and Truck-Miles Traveled.

AADTT	Route Miles			Ann. Truck-Miles Traveled (Millions)		
Category	IH	US	State	IH	US	State
0-480	0.0	3635.2	8909.3	0.0	353.1	740.3
480-960	0.9	3505.5	3484.7	0.2	886.2	854.6
960-2880	443.9	3701.1	2441.6	381.3	2179.1	1364.0
2880-5760	656.8	983.8	300.1	992.5	1421.5	397.8
5760-11520	1560.8	295.1	101.8	4602.5	780.0	284.3
11520-23040	558.8	40.1	0.0	2940.0	220.1	0.0
23040-46060	12.8	0.0	0.0	115.0	0.0	0.0
Total	3234.1	12160.7	15237.5	9031.4	5840.0	3641.0

Source: UMTIG, Based on TxDOT input.

2.2.3 Truck Flows across the U.S./Mexico Border

There were significant increases in trucking activity to/from, along, and across the Texas/Mexico border through the 1990s. This has been accompanied with, and influenced by, investments in highway and border-crossing infrastructure, including major new bridge facilities catering to commercial vehicle movements at Brownsville, Los Indios, Pharr, Laredo, and El Paso. Plans are underway for building new commercial crossing facilities or upgrading existing facilities. Many of these developments have taken place in the last five or so years. Several have effected major changes in truck traffic characteristics and patterns along the border, and much more change can be expected. Of the 4.3 million truck movements across the entire southern border, Texas accounted for 67 percent, California for 24 percent, Arizona for 8 percent, and New Mexico for less than 1 percent. The 2001 movement was 5 percent less than that experienced in 2000 *(3)*.

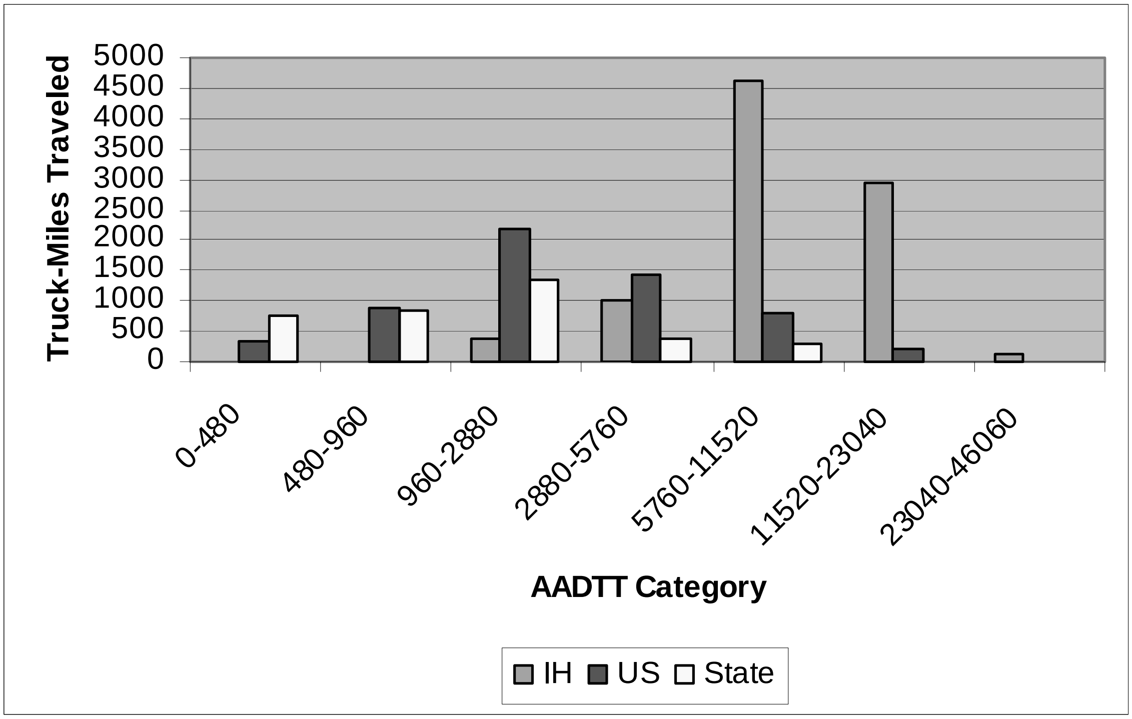


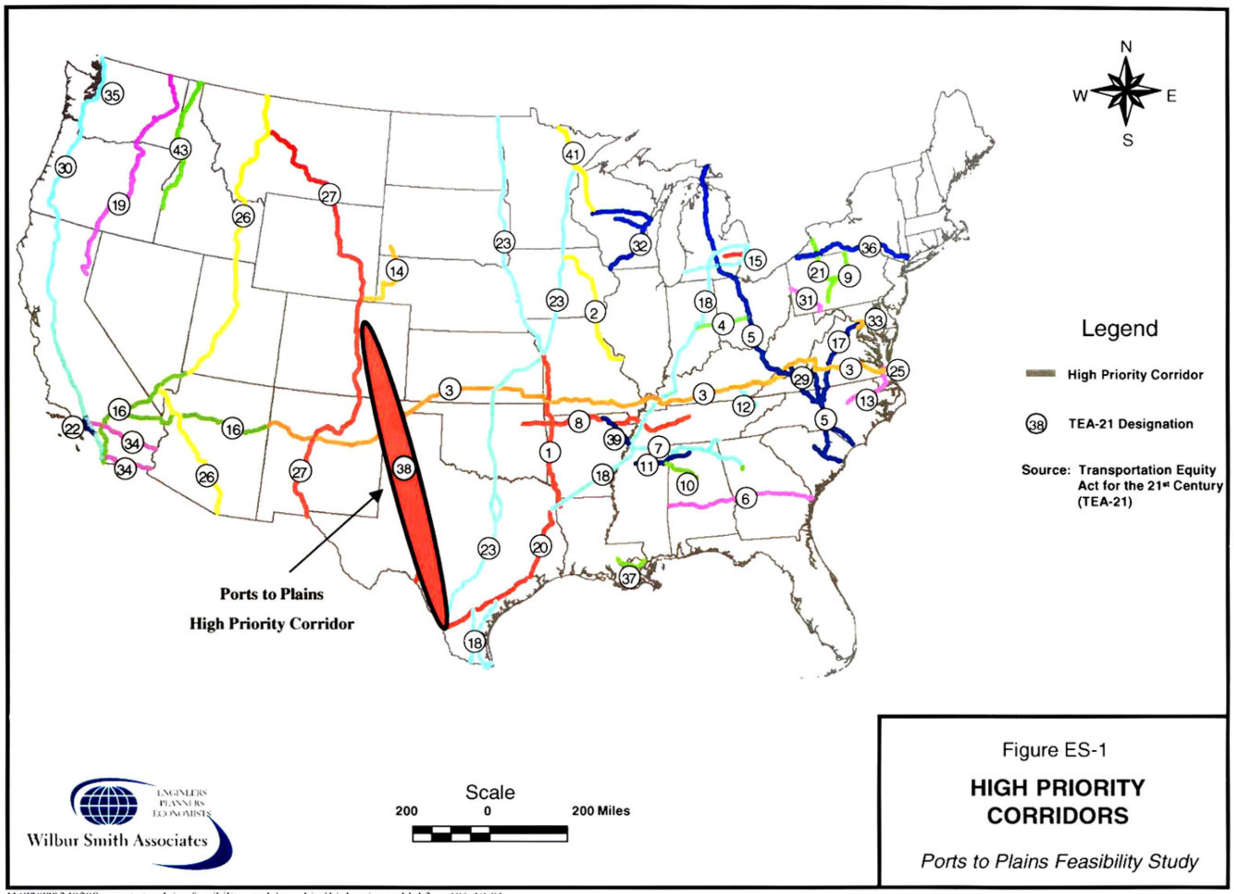
Figure 4. Truck-Miles Traveled by AADTT Category.

2.2.4 Truck Forecasts for Specific Corridors

There are six high-priority corridors designated in Transportation Equity Act of the 21st Century (TEA-21) that pass though Texas. These corridors are as follows:

- Corridor 3 (I-40 etc.),
- Corridor 18 (southeast and northeast Texas, part of proposed I-69),
- Corridor 20 (part of proposed I-69),
- Corridor 23 (I-35/29 Mid-Continent Corridor),
- Corridor 27 (to El Paso), and
- Corridor 38 (Ports-to-Plains).

Figure 5 illustrates these high-priority corridors *(4)*. This section summarizes truck forecast information presented in readily available studies for three of these proposed projects: the I-69, the I-35, and the Ports-to-Plains corridors.



H:\TE\TP\349390 – ports to plains feasibility study\graphics\high-pri-corr-blob2.ppt\06-18-01

Source: Ports to Plains Study

Figure 5. High-Priority Corridors.

As an example of information being disseminated from recent corridor studies, this discussion includes a brief synopsis of recommendations coming from the I-35 study. The purpose of the I-35 study "was to assess the need for improved local, intrastate, interstate, and international service on I-35 and to clearly define a general feasible improvement plan to address those needs." A recommended investment strategy for the corridor is outlined, the purpose of which is to guide future, potential improvements *(5)*. The recommended strategy is called the Trade Focus Strategy (Alternative 4). This strategy included special provisions to accommodate truck traffic between Dallas-Fort Worth and Laredo. The need for these recommended provisions arose from the study's forecasted truck traffic for the corridor. The strategy envisages provision of a NAFTA truckway (with larger truck sizes and weights) where their implementation could result in lane savings on I-35. Two truckway options were considered possible: 1) a separate facility, and 2) a truckway within the existing I-35 right-of-way *(5)*. The strategy assumes the truckway is located within the I-35 ROW for environmental and cost purposes. The alternative also assumes incorporating comprehensive ITS-CVO (commercial vehicle operations) facilities/services, and pre-clearance centers for customs activities.

The various consultants working on these corridor plans had to address the growth in truck traffic for the next 20 or so years. The TTI team summarized these growth rates to be able to predict needs for truck accommodation. For example, the I-35 corridor growth rate, based on Transportation Planning and Programming (TPP) estimates, was around 3 percent per year (compounded annually). However, the Waco District predicted a higher value at around 5.0 percent per year based on historical information for the corridor. The Ports-to-Plains study *(4)* estimated a lower value for the corridor that would connect Denver, Colorado, with the Mexican border at Del Rio/Eagle Pass/Laredo. Their estimates for various segments of the corridor were predominantly in the 1.5 to 2.0 percent range, with the exception of near the border where it was nearer 4.0 percent per year. In summary, future growth in truck traffic will probably be in the range of 3.0 to 5.0 percent per year.

CHAPTER 3. TRUCK ACCOMMODATION STRATEGIES

3.1 INTRODUCTION

Trucks have slower braking and acceleration rates than passenger cars, which increases frustration to drivers in congested situations. Additionally, the lack of maneuverability of trucks relative to passenger cars contributes to crashes *(6, 7)*. Due to the large size and weight of trucks, truck crashes generally result in more severe injuries or fatalities than crashes that do not involve trucks. Truck crashes also receive greater publicity *(6)*. This chapter investigates some of the ways to accommodate trucks, including some real world examples. The major initiatives covered in this chapter include the New Jersey Turnpike, the proposed Trans-Texas Corridor, and some truck accommodation projects in California.

3.2 EVALUATION OF STRATEGIES

Strategies or treatments for trucks that extend for long distances along the mainline can be categorized into: 1) *lane restrictions*, and 2) *truck-preferred or truck-only facilities*, although the information found in the literature search and reported in this chapter uses varying terminology. There will be other terms used to be consistent with literature sources to describe these categories of treatments. A distinction on the second category is that in one case non-trucks are allowed to use the facility, but sources are not always clear to what degree non-trucks are "encouraged" to use or not to use such facilities. This chapter treats *bypass facilities* separately from the two extended length treatments noted above; they typically serve a short-distance need for trucks to improve safety and operations near interchanges.

One of the critical issues that must be addressed, especially in exclusive truck facilities, is public perception. "Truck-only" facilities have not been successful except in rare instances for reasons of cost, public perception, and because only a very small percentage of the total freeway mileage in the U.S. has the truck volumes to justify the need. The public must be able to observe reasonably full utilization of a facility that it believes it subsidizes, but is restricted from using. Underutilized high occupancy vehicle (HOV) facilities have experienced a similar response over the past few years. Currently operating truck-preferred facilities demonstrate considerable merit because passenger vehicle drivers have a choice. If the truck facility is more congested than the car facility, then auto drivers choose the car facility, and if the truck facility is less congested, passenger vehicle operators can go there. The size and maneuverability of cars allows them to move to the roadway with less impedance, thereby balancing the flow. Even though truck drivers prefer exclusive facilities (only large commercial vehicles), they tolerate cars.

3.2.1 Lane Restrictions for Trucks

Lane designations or lane restrictions are a management strategy that limits certain types of vehicles to specified lanes. 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 May 1997, the 75th Texas Legislature passed legislation that permits a local municipality to request lane restrictions on certain highways within the municipality's jurisdiction. The request for a lane restriction must be approved by the Texas Department of Transportation. Specific criteria must be met prior to TxDOT approval of a municipality's request. For example, the highway must be a state-maintained controlled-access facility with at least three through-lanes in each direction, and an engineering study must be conducted by TxDOT to determine the feasibility of the proposed lane restrictions. The current process includes conducting a traffic study, removing/installing the appropriate traffic control devices, and periodically reviewing the lane restrictions to ensure against any negative impacts that may result from the lane restrictions *(8)*.

Some of the specific findings or observations coming from past studies of truck lane designations include the following:

- A 1989 study by Garber and Joshua *(9)* that examined large truck crashes on Interstate highways in Virginia for the period from 1983 to 1985 concluded that safety could be enhanced by reducing interaction between large trucks and smaller vehicles.

- A 1990 study by Zavoina, Urbanik, and Hinshaw that examined the effects of truck restrictions on rural Interstates in Texas *(10)* on six-lane, rural Interstate highway sections concluded that even though truck lane restrictions should theoretically improve capacity and safety, the research evidence did not support this assumption.

- Mannering, Koehne, and Araucto *(11)* conducted a study in the Puget Sound region that considered lane restrictions and found that in nearly every instance where a comprehensive examination of a lane restriction implementation occurred, there were negligible changes in operations and safety. The authors recommended that truck lane restrictions not be implemented in the Puget Sound area.

- A study conducted in the Netherlands found that the designation of a truck lane restriction is feasible only when truck traffic density is in the range of 600 to 1000 trucks per hour (tph). Densities lower than this range would result in inefficient lane usage, whereas higher truck traffic densities would result in bottlenecks *(12)*.

- One area of particular concern when implementing truck restrictions on urban freeways is the creation of a "barrier effect" in weaving areas. An indication of the barrier effect is an over-involvement of trucks in weaving area crashes, rear-end collisions, and side collisions *(13, 14)*.

- Trowbridge et al. *(15)* discovered considerable resistance by the general public to any strategy that was perceived as a special benefit to truck traffic. However, the general public favored truck lane restrictions. Both the Organisation for Economic Co-operation and Development (OECD) study *(12)* and public input on the Capital Beltway truck lane restrictions supported the notion of lane restrictions. Public opinion on the beltway study was so favorable that lane restrictions were maintained even though there was no indication of improved traffic operations or a reduction of crashes *(16, 17)*.

- In September 2000, a truck lane restriction demonstration project began on the I-10 East Freeway in Houston. TTI monitored and evaluated the compliance, enforcement, crash records, freeway operations, and public perception. The project, deemed successful, found that compliance rates averaged between 70 and 90 percent. Vehicle crashes along the freeway main lanes dropped by 68 percent during the 36-week monitoring period, while the operations impact was insignificant *(18)*. Increased enforcement during the period of the lane restriction should not be ignored as part of the reason for the reduction in crashes.

General findings from the literature pertaining to lane restrictions include *(19)*:

- Trucks should not be restricted to a single lane and trucks should only be restricted on roadways with three or more lanes by direction.
- Trucks should either be restricted from the left lane or to the right two lanes.
- Trucks should not be restricted such that use of entrance and exit ramps is difficult.
- Perceptions of automobile drivers are positive, while perceptions of truck drivers are generally negative.
- Lane restrictions generally improve traffic operations by reducing potential auto-truck conflicts and by eliminating slower-moving vehicles from certain lanes, but safety improvements are not as obvious.

3.2.2 Truck Roadways

In cases where the numbers of trucks, high truck-involved crash rates, or other factors necessitate more than lane restrictions, truck-preferred or truck-only facilities offer a solution to mitigate the effects of increasing truck traffic, including exclusive truck lanes. Provision of truck roadways typically creates dual facilities that incorporate an inner and outer roadway in each direction that is physically separated.

Some specific findings from the literature pertaining to truck roadways are as follows:

- A Samuel study for the Reason Public Policy Institute proposed self-financing toll truckways consisting of one or two lanes in each direction built in the existing right-of-way. Trucks using the truckways would be rebated federal and state fuel taxes for the mileage traveled on the truckways. Federal truck size and weight regulations would also be eased for truckway users *(20)*. Even with heavy truck size and weight incentives, the use of single lanes with apparently no opportunities for overtaking slower trucks is perceived as a critical flaw of this analysis.

- The S.R. 60 Truck Facility Project in California would have raised $1.2 billion of the total construction cost of $4.3 billion. The remaining $3.1 billion would have to be raised through other federal, state, or local sources. Based on historical data, this funding gap would be larger than public funding agencies would be willing to cover. The gap is also too risky for significant private investment in project construction. Therefore, the financial consultant concluded that the project was not financially feasible *(21)*.

- Trowbridge et al. investigated the benefits and costs of using reserved capacity lanes as exclusive truck lanes in the Seattle area. The net effect would be a modest overall increase in cost due to pavement deterioration and the consequent increased maintenance. In the reserved capacity feasibility study, responses from the general public indicated considerable resistance to any strategy that was perceived as a special benefit to truck traffic *(15)*.

- Hoel and Vidunas *(22)* examined the economics of exclusive vehicle facilities defined by the 1990 Exclusive Vehicle Facilities (EVFS) model developed by Janson and Rathi *(23)*. Although no single factor is dominant; the ones that contribute to the feasibility of exclusive lanes include: traffic volume, vehicle mix percentage, crash rate, and maintenance and construction costs.

- The OECD report on truck roads verified that exclusive truck facilities would be unpopular with the general public. Also, this same study noted that speed variations can increase both emissions and fuel consumption by 25 to 40 percent, while traffic congestion can increase emissions and fuel consumption by 50 to 100 percent *(12)*.

- A special conference on the environment in 1989 called by the European Conference of Ministers of Transport found that a 10 percent reduction in traffic congestion for trucks would result in a significant decrease in environmental pollution, while a 10 percent decrease in traffic congestion for automobiles would be inconsequential *(24)*.

The best example in the U.S. of a truck freeway alongside a car freeway is the New Jersey Turnpike, where the inner roadway is reserved for light vehicles only, and the outer roadway is a truck-preferred scenario, but is open to passenger vehicles as well. The separated facilities, which are also referred to as dual-dual segments, were implemented to relieve congestion. The turnpike has a 32-mi segment that consists of interior (passenger car) lanes and exterior (truck/bus/car) lanes within the same right-of-way *(25)*.

3.2.3 New Jersey Turnpike

The New Jersey Turnpike, the first controlled-access toll road to span the entire state, was opened in stages as sections were completed. The first section from Interchange 1 (Deepwater) to Interchange 7 (Bordentown) opened on November 15, 1951. The turnpike has been lengthened and widened over the years since its construction; five major improvement projects have both improved safety and increased capacity. Today, the dual-dual roadway extends from Interchange 8A to Interchange 14, a distance of 32 mi *(26)*. The inner roadway of the dual-dual system is for cars only, and the outer roadway is for cars, trucks, and buses. Reasons for building the dual-dual roadway were twofold: 1) traffic management had a goal of automating traffic control, and 2) to allow flexibility in closing parts of the roadway for maintenance activities or crashes. Figure 6 shows the general layout of the inner and outer roadways, although some sections have more separation between the inner and outer "barrels." As Figure 7 shows, the inner and outer roadways have their own access ramps to/from each interchange. This figure also shows the overhead signs that guide motorists when an incident or major congestion occurs on one or the other roadway.

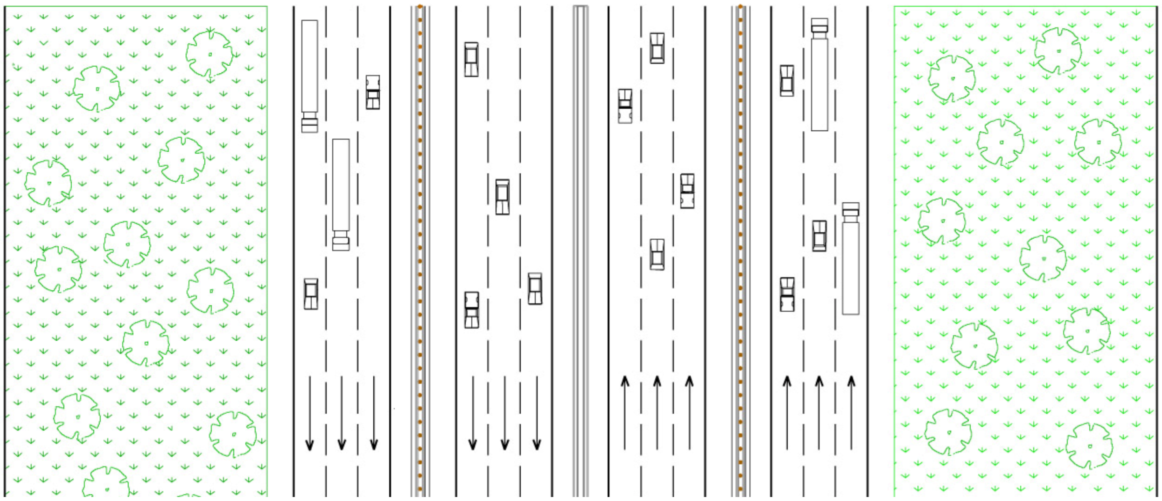


Figure 6. Typical Cross-Section of Dual-Dual Roadway.

Figure 7. Individual Ramp Access for the Inner and Outer Roadways.

Report 4364-1 contains detailed information about the traffic volume, and specifically the truck volume operating on the New Jersey Turnpike. The volume of Class 3+ (three or more axle trucks and buses) vehicles using the truck roadway (outer lanes) is in the range of 21,000 to 28,000 vehicles per day.

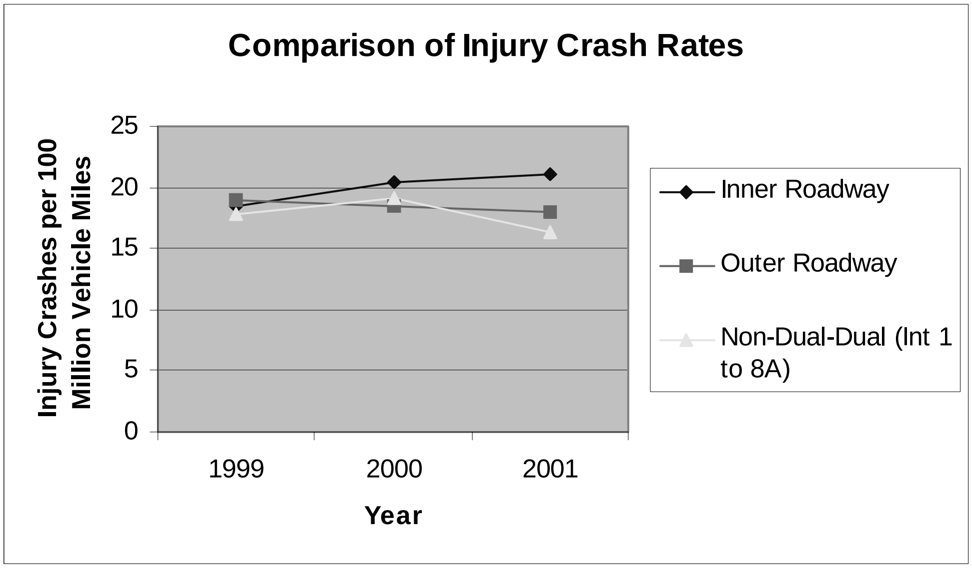
Figures 8 and 9 show injury and total crash rates on the turnpike for 1999, 2000, and 2001. On a comparative basis, one might expect the non-dual sections and perhaps the outer roadways to have higher crash rates than the inner (car-only) roadways. This comparison indicates that crash rates on the inner roadway are not always lower than those of the outer roadway. Obviously, the crash rates are not the only variable of interest. Car crashes with other cars are usually less severe than truck crashes with cars. Other factors besides separation that might influence crash rates include construction or design standards, lane restrictions for commercial vehicles, enforcement level, incident response, use of ITS, and strategic locations of service plazas.

Examples of design standards used by the New Jersey Turnpike Authority (NJTA) are 12-ft travel lanes throughout on both the inner and outer roadways (allowing exceptions in construction areas) and 12-ft paved shoulders on the right side of the travel way on newer sections of the turnpike. The turnpike's 42-inch high concrete barrier provides a more positive barrier than shorter cross-sections to contain commercial vehicles while not increasing the risk for passenger vehicles impacting the barrier. The authority is now building all median barriers that separate opposing directions of traffic according to this standard. The barrier is not just taller than the standard 32-inch barrier; it is also built to be stronger. It is 12 inches thick at the top instead of the standard 6-inch thickness, it is more heavily reinforced, and it is anchored more securely at the bottom.

Full-scale testing of this barrier by the Texas Transportation Institute in 1983, which yielded acceptable results, helped lead to its acceptance for use by the turnpike authority *(27)*. According to NJTA personnel, this barrier has performed extremely well in accomplishing the primary objective of containing all vehicles, including large combination vehicles. NJTA operations personnel receive notification each time a commercial vehicle strikes the barrier and blocks traffic lanes, and turnpike personnel respond to the more serious crashes.

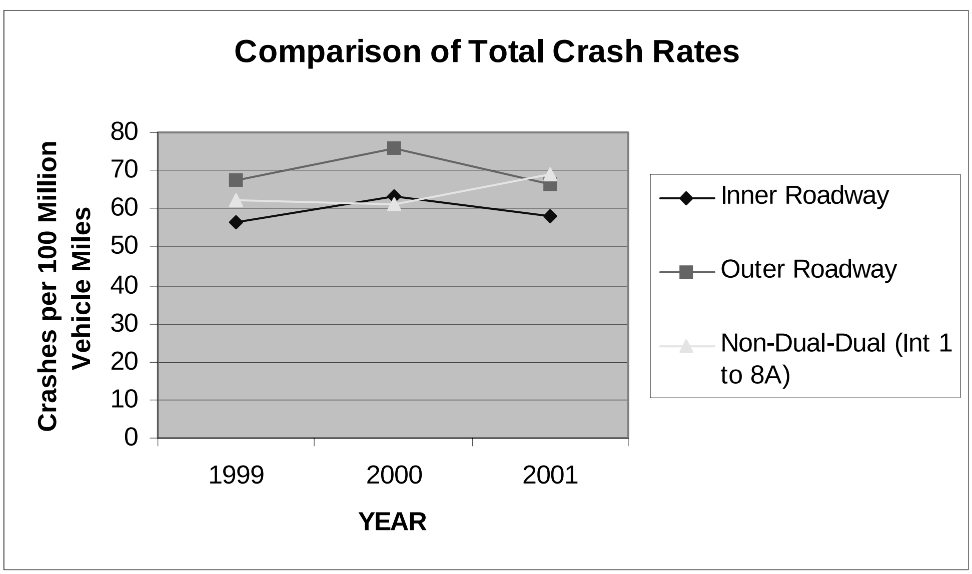
NJTA was one of the first agencies to impose lane restrictions for trucks in the 1960s. The restriction does not allow trucks in the left lane of roadways that have three or more lanes by direction. This restriction thus covers much of the turnpike; however, the outer roadway has only two lanes between Interchange 8A and Interchange 9. On the dual-dual portion of the turnpike from Interchange 9 to Interchange 14, buses are allowed in the left lane of the outer roadway. When an incident or maintenance work forces closure of the outer roadway, lane restrictions are still imposed on the inner roadway.

For enforcement, the New Jersey Turnpike employs more state police per lane-mile than other jurisdictions in the New Jersey Troop. According to NJTA personnel, these troopers also make more motor vehicle stops, investigate more crashes, and pick up more disabled vehicles than officers in other jurisdictions. Undoubtedly, this effectiveness in the enforcement arena serves a major role in preventing crashes and enforcing safety regulations.



Source of Data: New Jersey Turnpike Authority

Figure 8. Turnpike Injury Crash Rates for 1999, 2000, and 2001.



Source of Data: New Jersey Turnpike Authority

Figure 9. Turnpike Total Crash Rates for 1999, 2000, and 2001.

To ensure continued success with enforcement efforts, NJTA traffic engineers and enforcement personnel meet monthly. In these meetings, engineers identify problem areas where they believe additional enforcement will be effective in reducing crash rates and/or compliance with laws. NJTA engineers believe this good working relationship is essential in maintaining the safest possible environment for motorists.

The turnpike authority oversees incident management through its contacts with the state police and contracted towing and emergency response services. It is critical that an adequate number of wreckers, ambulances, and fire fighting equipment and personnel are always available to meet any potential emergency on the turnpike. A hazardous materials specialist is also on call for quick response when needed. Expeditious clean-up of incidents and reopening of lanes reduces the number of secondary crashes that occur as high-speed and unsuspecting motorists approach the end of a stopped queue of vehicles.

For intelligent transportation systems applications, the NJTA has variable message signs, drum signs, neon signs, and highway advisory radio (HAR) in addition to fixed signs. If installed today, the turnpike authority would probably choose the more flexible matrix format due to the larger numbers of messages that can be programmed into the sign system. Drum signs are effective in diverting traffic between inner and outer roadways such as shown in Figure 7.

The turnpike's 12 service plazas offer locations that are strategically placed to provide motorists with convenient places to eat, refuel and other vehicle services, and relax. Closely related is the need for truck parking to provide adequate rest and minimize fatigue as well as meet hours-of-service requirements.

The additional construction cost of a dual-dual roadway comes primarily from the cost of the additional right-of-way, the metal beam guardrail, additional pavement (including shoulders), additional length of overhead structures, increased sign costs, and increased interchange costs due to additional ramps. The approximate construction cost of a dual-dual roadway with 12 lanes is $25 to $30 million per mile excluding interchanges. Some of the most recent interchanges in urban and suburban areas cost the turnpike authority over $100 million, including toll plazas and related appurtenances. One fairly recent interchange in a rural area with 11 toll lanes and new inside ramps (using existing outside ramps) cost $45 million. An improvement project completed in the early 1990s, which widened a 6-mi segment of non-dualized freeway to a dualized freeway with 10 lanes (2-3-3-2 configuration) and some interchange improvements, cost the authority $300 million.

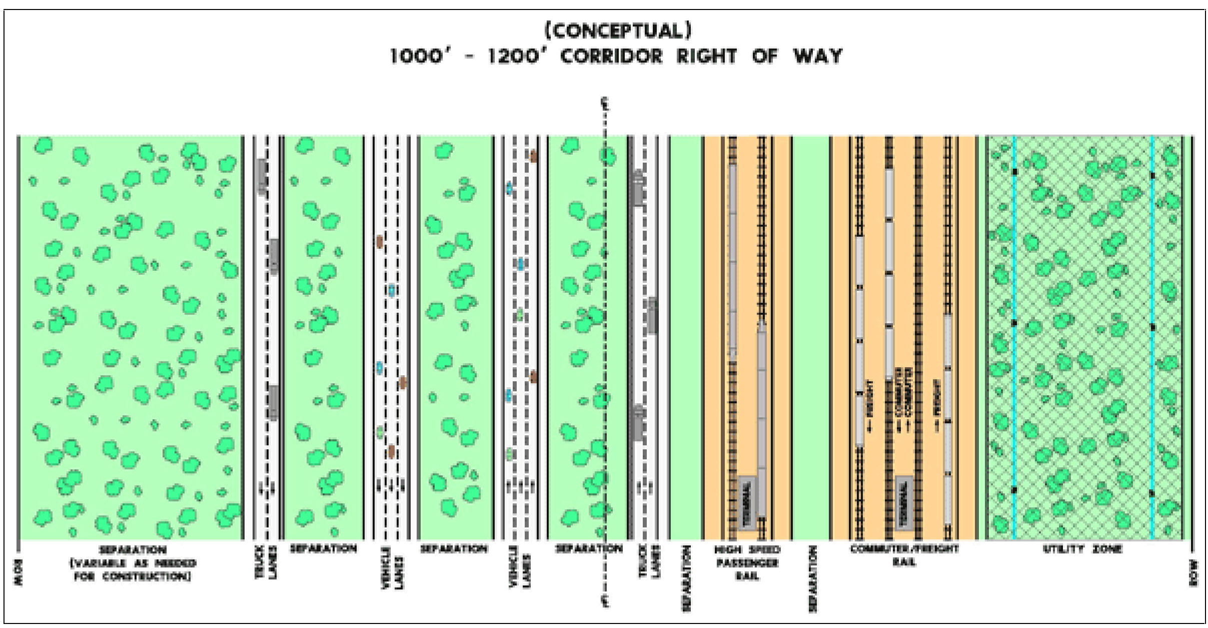
Rough estimates of non-dualized freeway in New Jersey indicate a cost of approximately $10 million per mile, excluding environmental challenges, which must be addressed. For example, noise barrier is required now, whereas it was not required as much in recent years. In one example, the cost of noise barrier construction and relocation of houses cost $28 million on a 15-mi segment of freeway. For comparison, the current cost of rural freeway in Texas is about $930,000 per lane-mile.

3.2.4 Proposed Trans Texas Corridor

One of the most revolutionary ideas for transportation in Texas and the largest engineering project ever proposed is the Trans Texas Corridor. It is a concept that will connect Texas and other states with a 4000-mi 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 (three in each direction), one for high-speed freight and one for conventional commuter and freight trains. There will also be a 200-ft-wide dedicated utility zone *(28)*. Figure 10 represents the general layout of these facilities.

The truck lanes and separate truck roadways would have the following geometric and structural features:

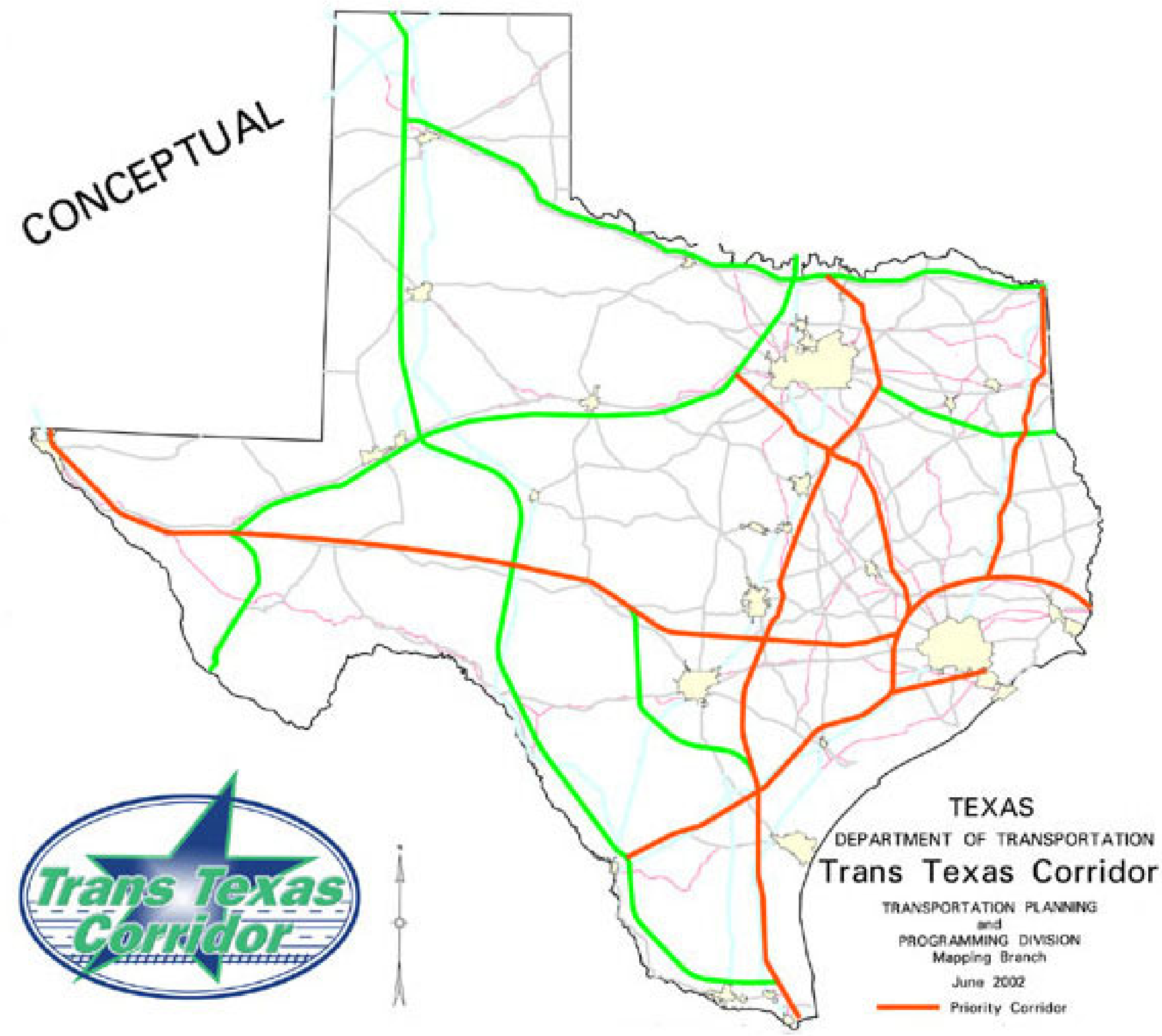
- 13-ft lane width (versus 12 ft for the passenger lanes),
- 12-ft outside shoulder width (versus 10 ft),
- 4-ft inside shoulder width (versus 10 ft),
- 80 mph operating speed on tollways, and
- Significant load-carrying capacity on truck lane pavements only.



Source: Reference *(28)*

Figure 10. Concept Plan View of the Proposed Trans Texas Corridor.

Figure 11 shows that there are four corridors that have been identified as priority segments; they will parallel I-35, I-37, and I-69 (proposed) from Denison to the Rio Grande Valley, I-69 (proposed) from Texarkana to Houston, and I-10 from El Paso to Orange. The corridor will connect to major cities while not sending traffic directly through them, and it will be designed to take advantage of ITS. It will be 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, the plan calls for building separate passenger lanes to segregate cars and trucks on their own roadways *(28)*.



Source: Reference *(28)*

Figure 11. Map of the Proposed Trans Texas Corridor.

3.3 THRESHOLDS FOR TRUCK ACCOMMODATION

To determine the need for specific truck treatments, designers rely upon recently developed computer models, experience from other states, and engineering judgement. This discussion is not intended as an endorsement of any of these treatments or evaluation methods; they are simply presented as a point of beginning to determine possible application in Texas. One of the latest computer models is by Battelle; it updated the values used by a previous model and also evaluated the program code and determined that its continued use was appropriate *(29)*. Designers can use the program to 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 program allows the user to input site-specific information for 57 variables grouped into three categories: a) traffic characteristics; b) cost of construction, maintenance, and right-of-way; and c) crash costs (including lane blockage and time-to-clear data), crash rates by vehicle type, and value of time. Based on either user inputs or default values, the program calculates net present worth, benefit/cost ratio, and other facility performance measures. The Battelle updated model lists and describes the possible options shown below.

- *Case 0:* Base scenario or do-nothing (used for comparing with other scenarios).
- *Case 1:* No change in number of lanes but redesignate functions.
- *Case 2:* Add mixed lanes (no lane use restrictions).
- *Case 3:* Add non-barrier lanes, designate at least one lane to trucks (no mixed lanes).
- *Case 4:* Add non-barrier lanes, designate at least one lane to trucks (allows both heavy and mixed lanes).
- *Case 5:* Add barrier-separated exclusive truck lane(s) (ETL) for trucks (no mixed lanes).

Table 4 summarizes the proposed thresholds developed by Battelle based on annual average daily traffic (AADT), annual average daily truck traffic, level of service, truck-involved crash rates, daily traffic delays, and proximity to freight origin-destination points.

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 it should be noted that 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 gross vehicle weight (GVW). To summarize, the two traffic volume criteria for exclusive truck facilities are as follows:

Table 4. Suggested ETL Evaluation 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 (volume/capacity ratio ≥ 1)	To rank potential locations that satisfy traffic criteria
Truck-involved fatal crash rate	≥ national average (2.3 per 100 million vehicle-miles traveled, 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 *(29)*

- The Douglas criterion for traffic volume is an AADT of at least 120,000 vpd and 20,000 (large) tpd where there are at least four lanes in each direction and the traffic demand occurs over at least a 10-mi length or has a large truck traffic generator at one terminus *(19)*.

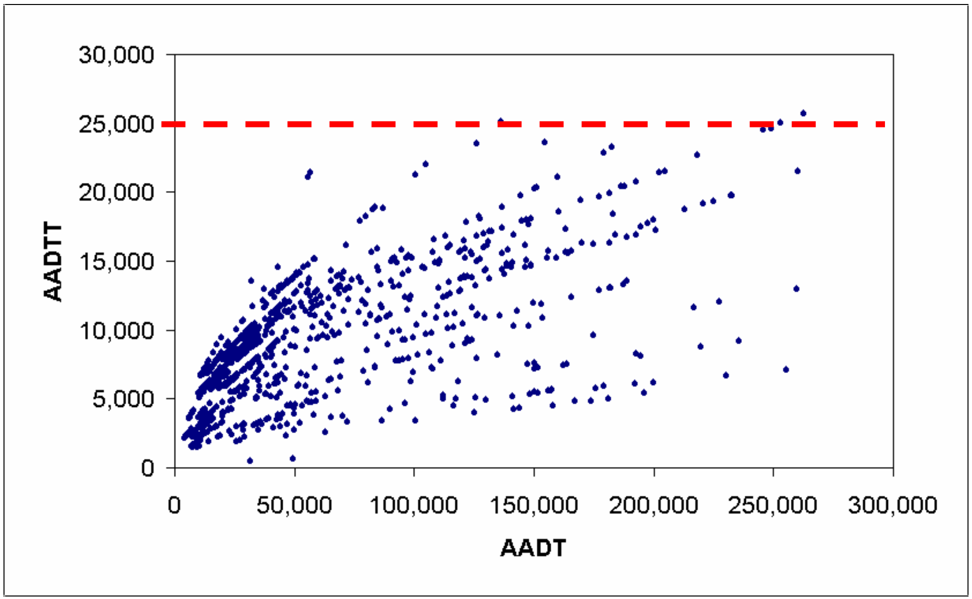
- The Battelle criterion for traffic volume is an AADT of at least 100,000 vpd and 25 percent trucks on a facility with four or more lanes in each direction.

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). Figures 12 and 13 utilize TxDOT data for all trucks above 10,000 lb GVW. The influence of the smaller two-axle trucks varies, with greater influence in and near urban areas. Converting the available TxDOT data to eliminate the smaller trucks varies by location, so an across-the-board conversion would not be appropriate. Based on TxDOT data, the number of Class 3 plus 4 vehicles seems to be most highly correlated with urban areas versus rural areas and time of day. There are more of these smaller trucks (and buses) in and near urban areas and during daylight hours.

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 level-of-service (LOS) is a useful measure of quality of traffic flow where all the traffic and roadway characteristics are known or can be accurately predicted.

3.3.1 Texas Truck Volumes

Figure 12 indicates the relationship between AADTT (total two-way annual trucks divided by 365) and AADT (total two-way annual traffic divided by 365) for Texas Interstate highways where most of the truck treatments will be warranted since Interstate highways serve the largest portion of the high truck demand, followed by U.S. highways.



Source: TxDOT

Figure 12. Correlation between AADT and AADTT (IH Road Class).

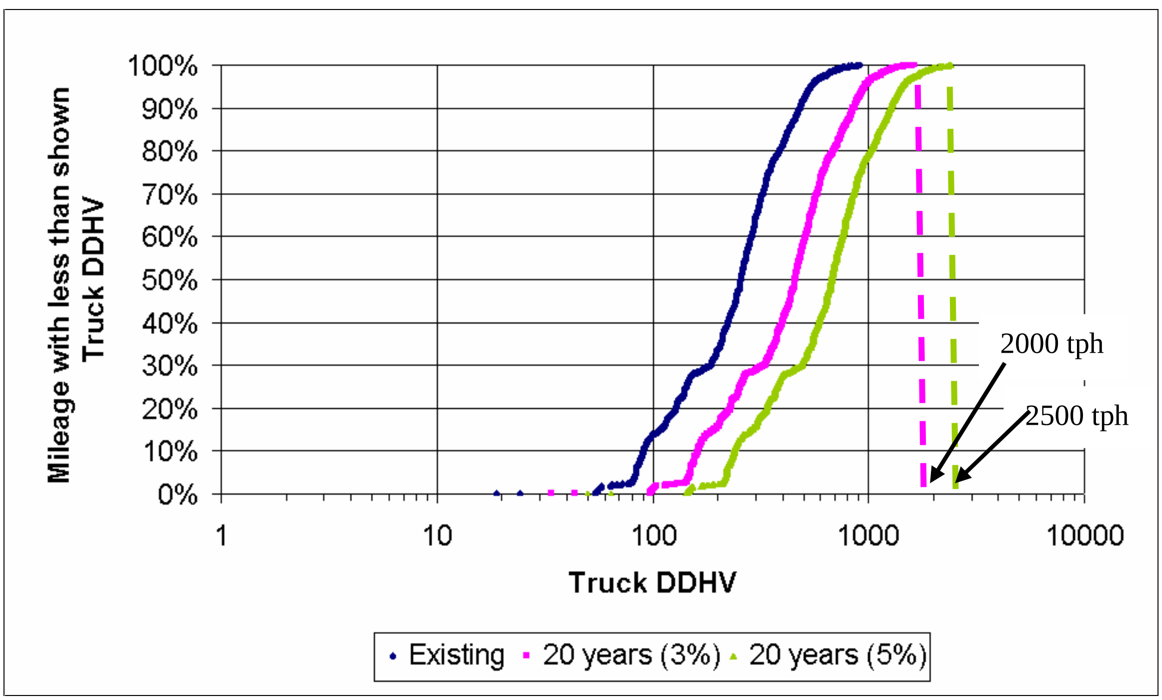


Figure 13. Cumulative Frequency Distribution for Peak-Hour Truck Traffic on Interstate Highways (3235 miles).

TTI's operational analysis on S.R. 60 in California used a combination of CORSIM runs and the Highway Capacity Software (HCS) to determine the capacity of a separate truck roadway and LOS based on predicted truck flows. The results indicated that the capacity of a two-lane truck facility was approximately 1600 trucks per lane per hour in flat terrain and 800 trucks per lane per hour in rolling terrain *(21)*. The TTI analysis also utilized factors for specific grades based on the characteristics of each. By comparison, the passenger car capacity (LOS E) for basic freeway segments in the 2000 *Highway Capacity Manual* (HCM) at free-flow speeds at or greater than 70 mph is 2400 passenger cars per hour per lane *(30)*.

Translating from AADTT to hourly truck flows requires knowledge of large truck peaking characteristics. This analysis uses typical vehicle classification data from Texas sites to determine threshold information. Appendix G in Report 4364-1 *(1)* contains graphics based on directional hourly traffic demand for seven selected relatively high-volume sites (minimum of 5000 tpd) segregated by Class 5 and above (large trucks) and other vehicles. For this analysis, a "typical" peak hourly bi-directional truck demand can be taken as about 6 percent of the AADTT, but the authors recommend further evaluation. Report 4364-1 has a discussion of hourly directional splits as well for each of these sites, along with hourly percentages.

Design for mixed traffic on a given facility where traffic volume is more precisely known typically uses the 30th highest hour in the year. The design value for truck facilities must also consider the appropriate design period (e.g., 20 years) for determining the desired demand volume of trucks. Therefore, the analysis should apply appropriate truck growth factors, likely in the range of 3 to 5 percent growth per year.

For purposes of this study, the focus is on larger trucks, but Class 3 and 4 vehicles may also need to utilize truck roadways or be segregated in truck lanes if lane restrictions are imposed. From a capacity standpoint, Class 3 and 4 vehicles should probably be included, although it is also anticipated that a limited number of trucks may still need to use mixed flow lanes. This discussion assumes that all Class 3 and up vehicles need to be accommodated.

Pursuing this analysis further and considering the terrain that might be encountered in the various large urban areas that serve the highest truck volume indicates that some of central Texas (e.g., the "hill country") would qualify as "rolling terrain" and the lower value of 800 trucks per lane per hour would apply. However, a large proportion of Texas freeways would be considered flat terrain where the capacity would be 1600 trucks per lane per hour. This higher capacity would apply to most freeways in and around large urban areas such as Houston, Dallas, Ft. Worth, El Paso, and portions of other urban areas.

Again, separate truck roadways should not have less than two continuous lanes in each direction. Capacities of roadways with 100 percent trucks are 1600 trucks per lane per hour in flat terrain and 800 trucks per lane per hour in rolling terrain. (The author recommends further review of these values in future research.) Based upon these values, observed peaking characteristics of truck flows, and growth rates in the 3 percent to 5 percent per year range, researchers predict the maximum peak-hour truck flows in 20 years will be 2000 trucks per hour at 3 percent growth rate and 2500 trucks per hour at 5 percent growth rate (see Figure 13). This result indicates that a truck roadway with two lanes (by direction) in flat terrain will have a capacity of 3200 trucks per hour and can accommodate a growth rate of 5 percent (or higher) over a 20-year design period. Considered another way, this finding suggests that a separated truck roadway with two lanes in flat terrain would not reach its capacity even during peak hours (assuming trucks only) at the end of 20 years and even at a 5 percent growth rate. The perception of underutilization may become an issue, at least at first. In rolling terrain, the higher growth rate would require more than two lanes, given the values cited above.

3.3.2 Truck Accommodation Threshold Summary

First, the authors encourage widespread practice of *truck-friendly design* at all levels of truck activity, especially if future truck growth rates are expected to be high. In general terms, this concept means designing a "forgiving environment." For example, intersection design for undeveloped areas in or near urban areas should ask the question, "What if a large truck stop is proposed nearby?" Based on data presented in Report 4364-1, 85 percent of the truck-miles traveled in Texas occurs on roadways where the AADTT is at least 1000 trucks per day. Table 5 helps visualize breakpoints in truck activity.

Table 5. Summary of Route-Miles and Annual TMT.

AADTT	Route-Miles	Annual TMT
960 – 2880	22%	21%
2880 – 5760	6%	15%
5760 – 11,520	6%	31%
11,520 – 23,040	2%	18%
SUM	36%	85%

Source: Based on TxDOT data.

The second truck threshold for considering special truck treatments is 5000 trucks per day. At this level of truck activity, there needs to be more of the design features that explicitly reflect the operating characteristics of trucks. The third level or threshold is for truck roadways and must only be considered when the volume of trucks reaches reasonably full utilization of a minimum two-lane roadway. Based on the two literature sources cited in this chapter, Battelle *(29)* and Douglas *(19)*, and the current truck volumes being experienced in Texas compared to the California and New Jersey facilities, the truck volume that would justify building future separate truck roadways is 25,000 trucks per day. Table 6 summarizes the threshold values; the authors will consider them for design issues in the next chapter.

Table 6. Threshold Summary.

AADTT	Design Hour Volume	Truck Treatment
0 – 1000	0 – 60	Truck-friendly design
1000 – 5000	60 – 300	Some design for trucks (see Chapter 4)
5000 – 25,000	300 – 1500	All design for trucks (see Chapter 4)
Over 25,000	Over 1500	Two-lane truck roadway

According to data presented in Report 4364-1, 100 percent of the highway mileage in Texas will have a demand less than the capacity of a two-lane truck roadway in flat terrain in 20 years even at a high growth rate. This finding suggests that truck roadways built in the near future in flat terrain will operate well below capacity unless passenger vehicles are also allowed to use the truck roadways. In rolling terrain (e.g., the "hill country"), the capacity is approximately 800 trucks per lane per hour, resulting in a corresponding AADTT value of just over 53,000 trucks per day. On the basis of AADTT, Report 4364-1 predicts that 92 percent of the high-growth corridor mileage with two dedicated exclusive truck lanes in each direction will experience a demand at or lower than this value in 20 years.

The traffic volume criteria that would warrant a truck roadway should be related to the capacity of a separate two-or-more-lane (barrier separated) roadway. Since the analysis of future Texas truck volume suggests that none of the high-volume mileage in flat terrain would be sufficient to justify building the minimum two lanes, designers must look at two options. These two options appear to be: 1) allow only trucks and let the facility operate at a LOS much lower than its capacity during the early years of its use, or 2) allow passenger vehicles to share the "truck facility." The first option will probably result in negative public relations, but would be preferred by truck drivers. It might also attract trucks from other parallel corridors and experience an even higher than expected growth in trucks. Building such a facility is perhaps the only way to determine if truck roadways are really safer than maintaining mixed flows. The second option (allowing passenger cars) assures better utilization of the facility but is probably no safer for passenger car occupants than other mixed flows of large and small vehicles.

CHAPTER 4. DESIGNING FOR TRUCKS

4.1 INTRODUCTION

The TTI research team developed a set of guidelines for the accommodation of trucks in geometric design. The basic documents used in the development of these guidelines were the American Association of State Highway and Transportation Officials (AASHTO) Green Book *(31)* and the TxDOT *Roadway Design Manual* (TRDM) *(32)*. Recent research supplemented these two documents and provided guidance on whether current design is sensitive to the operating characteristics of large trucks. The primary definition of trucks used in the design process is Class 5 and above in the Texas 6 Vehicle Classification Scheme or Class 6 and above in the FHWA Vehicle Classification Scheme. The general methodology used was to check values in the Green Book, then determine if the TxDOT *Roadway Design Manual* adequately reflects those values.

TTI produced a preliminary list of design elements early in the project to use in developing guidelines; Table 7 shows the list of elements found in the TxDOT *Roadway Design Manual*. Most of these elements relate to geometric design, although some pertain to roadside hardware and to Intelligent Transportation Systems elements. To adequately design roadways for large trucks, one must first know the size and operational characteristics of the design vehicle population. Report 4364-1 provides information on these vehicle characteristics and a parallel research project sponsored by the National Cooperative Highway Research Program (NCHRP) *(33)*, which conducted a survey of current vehicle characteristics. Some of the data collection for this NCHRP study actually occurred in Texas, providing input to indicate whether truck operational characteristics are changing.

4.2 DESIGN ELEMENTS

Design elements in this chapter track the following categories: sight distance, horizontal alignment, and cross-section elements. Each of these categories has multiple sub-elements addressing more specific areas of design or operations. For this Policy Maker Workshop, the text only includes the elements that either do not fully reflect operating characteristics of trucks on freeways, or ones that cannot feasibly be changed to fully reflect the operational needs of trucks, or those that need further research. The shaded elements in Table 7 are the ones being recommended for change in TxDOT practice or that need additional research.

4.2.1 Sight Distance

Sight distance is the length of roadway ahead of the driver that is visible to the driver. The minimum amount of sight distance provided for drivers should be sufficient for a vehicle traveling at the design speed to stop before reaching a stationary object in its path. This *stopping sight distance* (SSD) is the basis for design for crest vertical curve length and minimum offsets to horizontal sight obstructions. Stopping sight distance must be available at every point on the roadway.

Table 7. Design Factors Potentially Affected by Truck Characteristics.

Design Category	Specific Focus Area [a]
Sight Distance	Stopping Sight Distance Decision Sight Distance Passing Sight Distance RR-Highway Grade X-ing Sight Distance Intersection Sight Distance
Horizontal Alignment	Curve Radius Superelevation Intersection and Channelization Pavement Widening
Vertical Alignment	Critical Length of Grade Downgrades
Cross-Section Elements	Lane Width Shoulder Width and Composition Sideslopes and Drainage Features Pavement Cross-Slope Breaks Vertical Clearance Traffic Barrier Passive Signs Curbs Acceleration Lanes

[a] Shading indicates focus areas recommended for change.

4.2.1.1 Stopping Sight Distance

The recommended stopping sight distances in the Green Book are based on passenger cars and do not explicitly consider trucks. As a general rule, large trucks need longer stopping distances from a given speed than cars. However, one factor that tends to compensate for longer truck stopping distances is the driver eye height advantage. In the Green Book, the eye height for passenger cars is 3.5 ft and that for trucks is 8.0 ft. Separate stopping sight distances for trucks and cars, therefore, are not generally used in highway design.

There is one situation noted in the Green Book to which designers should pay close attention because the truck driver eye height advantage may not apply. It is where horizontal sight obstructions occur on downgrades, and particularly on long downgrades where truck speeds may exceed car speeds. The Green Book states that it is desirable to provide stopping sight distance greater than tabulated or computed values for design.

Recommendation: The author recommends that a statement of caution regarding horizontal curves at the end of long downgrades be added to the TRDM for truck roadway design. Wording similar to that contained in the Green Book would be appropriate.

4.2.2 Horizontal Alignment

In the design of highway alignment, it is important to establish the proper relation between design speed and curvature. The two basic elements of horizontal curves are curve radius and superelevation.

4.2.2.1 Intersection and Channelization Geometrics

Selection of the appropriate design vehicle is critical in properly designing intersection and channelization geometrics. Districts use a software program such as AutoTurn or templates to establish turning characteristics of the design vehicle. For today's high-volume roadways, the most common large truck is a WB-65, a tractor-semitrailer combination vehicle with a 53-ft semitrailer (shown in Figure 14). Future truck roadways may allow larger vehicles, so the designer must continue to monitor trends in vehicle characteristics. It should be noted that NCHRP 15-21 recommends dropping the WB-50 design vehicle.

Recommendation: The author recommends adding the WB-65 design vehicle to the TRDM for truck facilities, along with accompanying text to support its selection for many design features. Also, there should be appropriate language cautioning designers that design tools like AutoTurn do not consider driver input and the variability introduced by drivers. Figure 15 illustrates the variability introduced by different drivers.

4.2.3 Cross-Section Elements

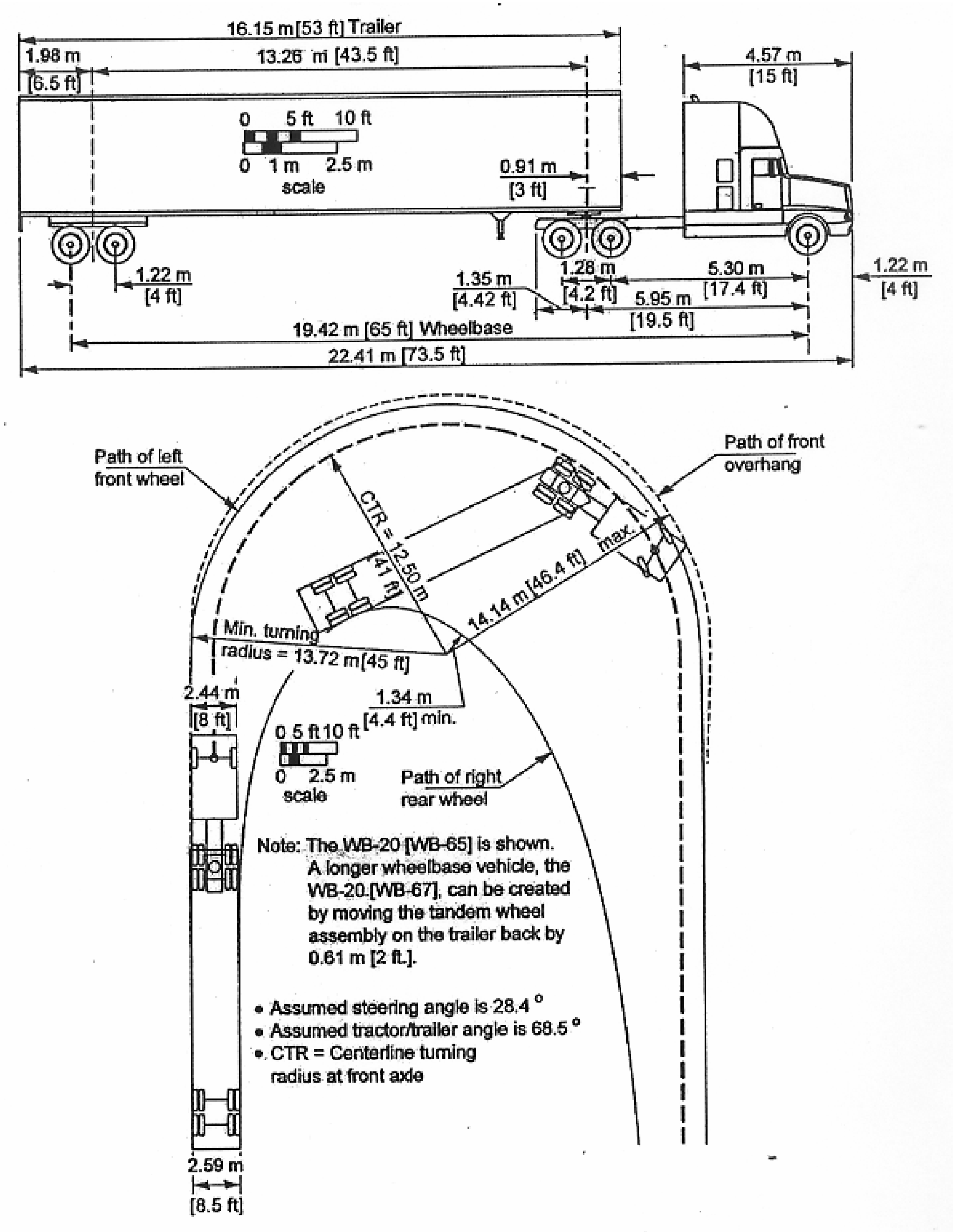
4.2.3.1 Lane Width

The lane width criteria in the AASHTO Green Book apparently have no reference to any explicit vehicle width specification. However, implicit in the criteria for 11- and 12-ft lanes is that these lane widths consider truck width. The Surface Transportation Assistance Act of 1982 mandated that states allow 8 ft-6 inch (102-inch) vehicle widths on a national network. Even with the widespread use of 102-inch trailers today, lane widths remain at 12 ft on freeways. Mason et al. *(34)* proposed the following formula for establishing the lane width where trucks are adjacent to existing travel lanes:

$$W = W_v + 4.5 \text{ ft}$$

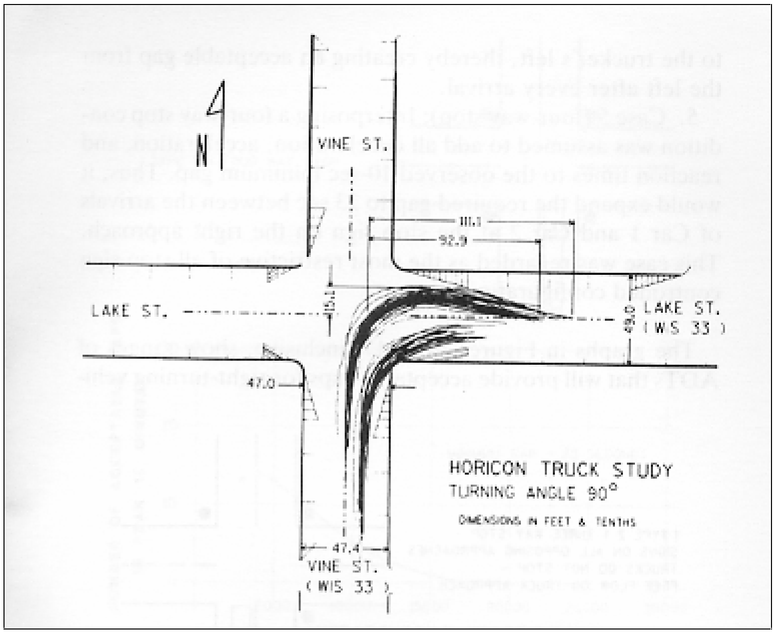
where:

W = Width of one lane, ft
W_v = Width of the vehicle, ft



Source: Reference 31.

Figure 14. Minimum Turning Path for WB-65 Design Vehicle.



Source: Reference (35).

Figure 15. Intersection Turning Paths of Trucks.

Given that the dominant vehicle width on truck roadways will be at least 8 ft-6 inches, the design engineer should use 13-ft lanes, which is the lane width resulting from the Mason et al. formula. Truck roadways may also need to accommodate occasional permitted overwidth loads rather than having them use a parallel mixed flow facility (see Figure 16). It should be noted that proposed lane widths for truck lanes on the Trans Texas Corridor are 13 ft. For mixed flow lanes, the 8 ft-6 inch vehicles still have ample width on 12-ft lanes, but consideration should be given to the probability of the roadway becoming an exclusive truck roadway.

Recommendation: The TRDM recommends using a minimum lane width of 12 ft for high-speed facilities such as all freeways and most rural arterials. The author recommends increasing the lane width from 12 ft to 13 ft for exclusive truck facilities and staying with 12-ft lanes where trucks remain in the mixed flow or are restricted to specific lanes.

Figure 16. Oversize Load on 12-ft Lane.

4.2.3.2 Shoulder Width and Composition

The AASHTO Green Book recommends that on high-speed, heavily traveled highways and highways with large numbers of trucks, shoulders should have a usable width of 10 ft and preferably 12 ft. Where roadside barriers, walls, or other vertical elements are present, it is desirable that the vertical elements be offset a minimum of 2 ft from the outer edge of the usable shoulder.

It is also important on high-volume truck routes that the shoulder be paved. To ensure that the shoulder has adequate structural strength and to simplify construction, it is desirable that the shoulder be designed with the same depth and composition as the mainlanes. Figure 17 shows a truck parked at the edge of a truck roadway.

<u>Recommendation</u>: The author recommends increasing the outside shoulder width to 12 ft along truck roadways and mixed flow roadways predicted to reach an AADTT of at least 5000 trucks per day during the design period. The design should also offset vertical elements (e.g., barrier) a minimum of 2 ft from the outer edge of the usable shoulder.

Figure 17. Truck Parking on Truck Roadway.

4.2.3.3 Traffic Barriers and Crash Cushions

Concrete barriers are effective safety devices; their purpose is to redirect a vehicle and prevent it from entering the path of oncoming traffic while keeping the vehicle upright. In order for this to occur, the barrier must stop the roll motion of the vehicle and allow it to "slide" along the top of the barrier until it rights itself.

NCHRP 22-12 *(36)* is underway at the University of Nebraska, with one of its goals being to develop guidelines or warrants for different test levels pertaining to barriers. Even before this study gets underway, it is understood that barriers for trucks must be at least 42 inches tall and must have sufficient steel to withstand a truck impact. The Texas 42-inch barrier has a constant slope face, which makes an angle of 10.8 degrees with respect to vertical and was originally tested and developed for use as a temporary concrete barrier. However, it has since been widely used as a permanent concrete median barrier. This 42-inch single-slope barrier has not been full-scale tested to the appropriate test standards *(37)*.

There have been at least three successful standard tests on 42-inch barriers; two were New Jersey safety-shape barriers, and one was a vertical wall. Based on this testing, the barrier shape/profile and height of the TxDOT 42-inch single-slope barrier is probably adequate. However, verification would require a strength analysis to prove that the current barrier design is adequately reinforced to accommodate standard impact loads.

Again, the 42-inch height is considered a minimum for containing tractor-trailers and, depending on the actual impact conditions, it is possible that the box trailer (but typically not the tractor) could overturn across the barrier. Even under these circumstances, the consequences may not be severe if there is a wide shoulder (e.g., 10 to

12 ft) to provide a buffer zone from the opposite direction traffic. A taller barrier (e.g., 54 inches) would provide even greater containment capacity.

Crash cushions are currently designed only for passenger vehicles and not for trucks, so further research is needed to determine truck needs. Design for trucks would require either a stiffer design or a longer overall crash cushion.

Recommendation: The author recommends an evaluation of the results of NCHRP 22-12 when completed to determine their application to Texas roadways in general and to truck roadways in particular. As a preliminary statement, the longitudinal barrier associated with truck roadways or where AADTT reaches 5000 trucks per day during the design period should always be 42 inches in height and structurally sufficient for trucks, meeting the proper barrier requirements.

4.2.3.4 Passive Signs

With the possibility of trucks following other trucks at fairly close spacings, there exists the potential of signs being visually blocked by a vehicle ahead. Designers must give consideration to sign placement to ensure adequate visibility for all motorists. The engineer might consider oversize signs, overhead signs, and sign redundancy to convey the appropriate information to truck drivers. An example of sign placement that seems to work well occurs on the dual-dual roadway of the New Jersey Turnpike. The NJTA places guide signs overhead on its dual-dual roadway system in advance of all interchanges over both the inner and outer roadways. As a minimum, guide signs for interchanges begin with a 2-mi advance sign placed between the inner and outer roadways, followed by a 1-mi sign, then a ¼-mi sign placed at the start of the ¼-mi deceleration lane.

Recommendation: For truck roadways, it is anticipated that diamond interchanges will be very common, so the author recommendsthe use of overhead signs instead of ground-mounted signs approaching diamond interchanges. There should be two advance signs in addition to the Exit Direction sign mounted in advance of the gore. The advance signs should be located upstream of the interchange at 1 mi and 2 mi in rural areas and at ½ mi and 1 mi in urban areas. Since the *Texas Manual on Uniform Traffic Control Devices (38)* already stipulates that signs for other interchange types be mounted primarily overhead, the only recommended change pertains to diamond interchanges. The author also recommends the use of overhead signs for mixed flow roadways where the number of trucks predicted during the design period exceeds 5000 tpd. Figure 18 is an example of a passive sign that would be critical to truck drivers.

Figure 18. Example of Passive Sign for Trucks.

4.2.3.5 Acceleration Lanes

Acceleration lanes are speed-change lanes that provide adequate distance for vehicles to accelerate to near highway speeds before entering the through lanes of a highway. The Green Book states that to assist truck acceleration, high-speed entrance ramps should desirably be located on descending grades and that longer acceleration lanes should be provided on elevated freeways where entrance ramps must necessarily incorporate upgrades. Findings of NCHRP Project 15-21 establish the minimum acceleration lengths for a 180 lb/hp truck. These minimum acceleration lengths are, on average, about 1.8 times greater than the minimum acceleration lengths given in the Green Book (and the TRDM).

Recommendation: The author recommends increasing acceleration lane lengths on roadways with AADTT predicted to reach at least 5000 tpd during the design period to reflect the requirements of today's trucks.

4.3 ITS AND ROADSIDE PARKING

This section encompasses elements such as Intelligent Transportation System treatments for trucks and roadside parking for commercial vehicles. The text that follows discusses a few of the more pertinent applications that have been documented in the literature or that research staff discovered through interviews.

4.3.1 Intelligent Transportation Systems

Some of the elements that qualify as Intelligent Transportation Systems for trucks can also serve passenger car needs. Included are variable message signs (VMS), automated traveler information systems (ATIS), in-vehicle devices, and transponders. Devices that detect the size, speed, and weight of trucks require special roadway sensors. For applications where truck drivers are unable to perceive potential hazards in design features, warning systems can be effective in measuring truck height, speed, and weight and determining if the truck is too large or traveling too fast for the conditions ahead. Examples of roadway geometric features that may present problems are limited overhead clearance, sharp curves on freeway connectors or on the mainline, and long downgrades. Curves are more hazardous for large trucks than passenger cars due to the higher propensity of rollover in large trucks. The discussion that follows begins with more general applications for all vehicles followed by some that apply specifically to trucks.

4.3.1.1 Smart Signs

Variable message signs should be considered to control traffic on each roadway where there is one roadway for cars and another for trucks as shown by Figure 19. These signs can facilitate diverting traffic from one roadway to another if an incident occurs. The need for traffic monitoring systems needs to be assessed versus relying on 911 cell phone calls to detect problems such as incidents. These signs will also be useful in displaying information pertaining to traffic congestion or other problems downstream of the actual sign location. The initial planning for truck facilities, whether exclusive to trucks or not, should also include communication for video and data to urban traffic management centers such as in Austin, San Antonio, and Houston.

Figure 19. Variable Message Signs for Separate Roadways.

4.3.1.2 Truck Rollover Warning Systems

Although rollover crashes are not the most common type of crash involving large commercial vehicles, they are often catastrophic. The higher eye height advantage of truck drivers is not always sufficient to provide the driver an adequate view of roadway geometrics, so ITS elements can fulfill a need by supplementing other more typical roadway information. One of the ITS safety systems that has been successfully deployed in a few locations is rollover warning systems. Until recently, these systems were completely outside the vehicle and provided driver input through a roadside warning device. At least one device has also been introduced as an available option from one large truck manufacturer to be installed on the vehicle to provide an in-cab warning. The University of Michigan Transportation Research Institute (UMTRI) *(39)* recently evaluated this system.

Most recently, the Georgia Department of Transportation (DOT) contracted the installation of six truck rollover warning systems near Atlanta. The purpose of these warning systems is to reduce crashes on hazardous highway curves. The systems measure weight, height, and speed while a truck is traveling at highway speeds, and utilize this information to warn a driver of unsafe conditions *(40)*.

Figure 20 shows one application of a relatively high-end truck rollover system that was installed on the Capital Beltway near Washington D.C.; it utilized a speed warning system on a freeway ramp that had a history of truck rollovers. Figure 21 shows some of the components used. This system, installed at the northbound I-495 exit to Route 123 North in McLean, Virginia, utilized two weigh-in-motion (WIM) systems upstream of the curve to calculate the weight, speed, height, vehicle configuration, and deceleration to determine the need to activate the warning sign. Baker et al. concluded that adding vehicle weight as one of the measured parameters reduced the number of false alarms compared to the speed-based system by approximately 44 to 49 percent (depending on the accuracy of the WIM system selected) *(40)*.

Middleton *(41)* tested the effects of active and passive signs on truck speeds on a Houston freeway connector (I-610 and U.S. 59 north) that had a history of truck crashes due primarily to two sharp curves and high approach speeds. At monitored locations downstream of the warning, the critical trucks (85th and 95th percentile groups) exhibited decreases of 2 to 3 mph. Study findings reinforce the need to calculate an accurate safe speed for every individual truck in order to reduce false alarms and improve driver compliance with the displayed safe speed. The Houston District has installed several of these speed warning devices for trucks since the first evaluation of the active warning system.

Figure 20. Active Warning System on the Capital Beltway.

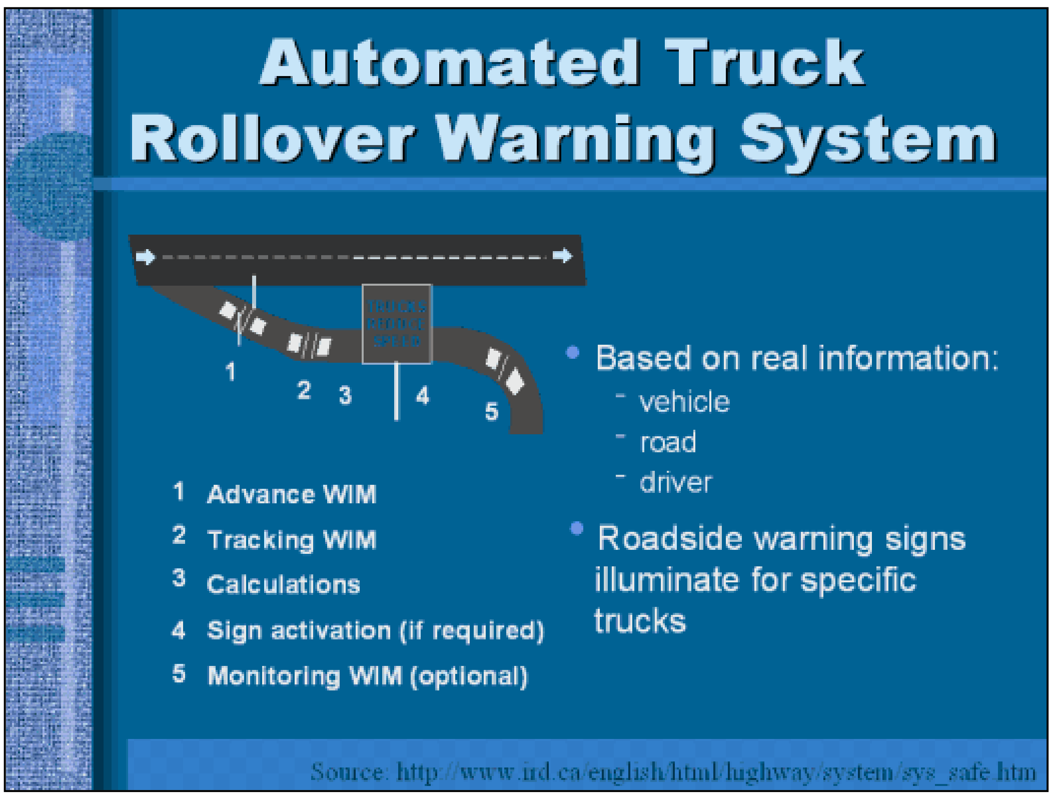
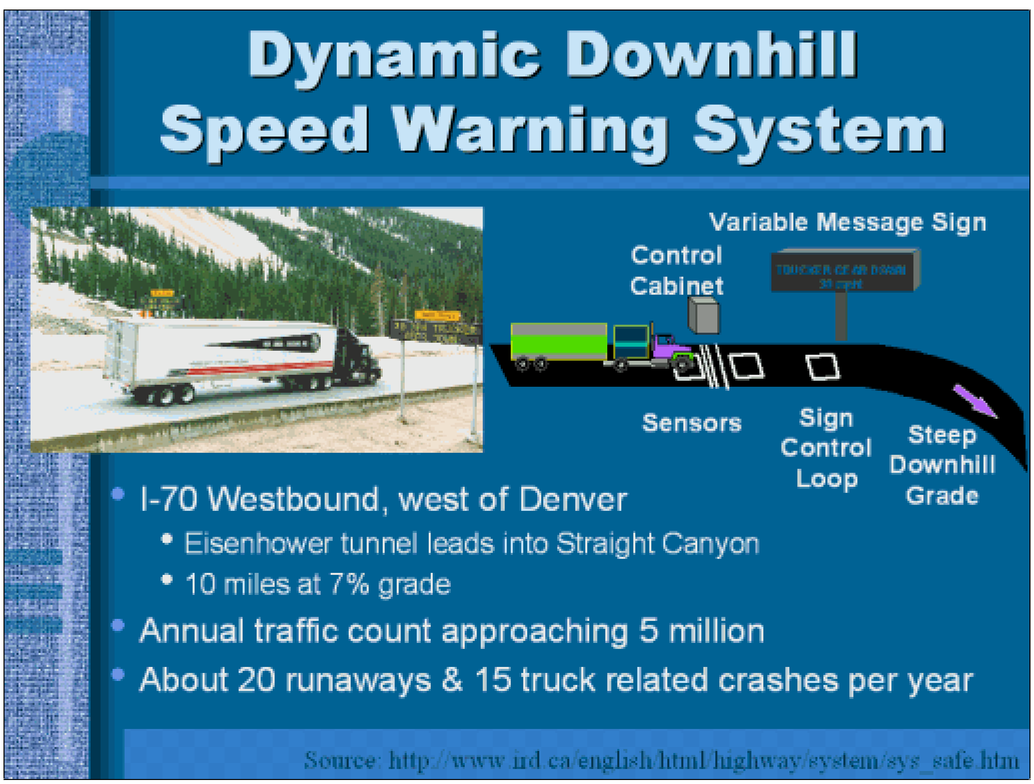


Figure 21. Components of Rollover Warning System.

4.3.1.3 I-70 Downhill Truck Warning System

For the period from 1989 to 1991, the six most heavily used downgrades in Colorado experienced 156 crashes, of which four were fatal, 58 were injury crashes, and there was much resulting property damage *(42)*. The Colorado Department of Transportation (CDOT) decided to supplement passive advisory signing and runaway truck ramps with an automated Downhill Speed Warning System. This truck warning system is located on I-70 in the westbound direction west of Denver about ¼ mi west of the Eisenhower tunnel. It precedes a 10-mi downgrade of 7 percent where truck drivers have not always made adequate preparation at the top of the long grade. Trucks, especially loaded ones, must approach a downgrade of this magnitude and length in a low gear to avoid overheating and subsequently losing brakes.

Figure 22 depicts the speed warning system and some of its components. This equipment includes a WIM system in the pavement, a VMS, a sign control loop, and a microprocessor that communicates with roadway sensors and the VMS. The WIM system determines the classification and weight of each truck, then the warning system processor determines the safe speed for that vehicle by its weight. The VMS displays the safe speed for each truck as it approaches the beginning of the downgrade.



Source: Reference *(42)*

Figure 22. Downhill Speed Warning System.

4.3.1.4 Overheight Vehicle Detection and Warning System

The Michigan Department of Transportation (MDOT) contracted with a consultant to evaluate the use of an overheight vehicle detection and warning system at a site in Oakland County at the western fringe of the metropolitan Detroit urban area. Three companies that offer such equipment are: Trigg Industries; ASTI Transportation Systems, Inc; and International Road Dynamics. Trigg Industries claims to have provided systems to 26 departments of transportation. Its system consists of a transmitter, a receiver, and warning indication components. The transmitter emits two infrared beams across the roadway, which allows the system to distinguish the height and direction of travel. Trigg claims that its system can detect heights at speeds between 1 and 100 mph and that weather conditions such as rain, fog, and snow do not interfere with its operation *(43)*.

As part of its contract with MDOT, the consultant prepared and sent out a survey form to determine additional information on the use of overheight detection and warning systems. In general, the agencies felt that the systems were advantageous. Favorable opinions were twice as frequent as unfavorable comments. Mississippi and North Carolina both had long-term experience (over 10 years) with such systems, with Mississippi reporting no additional hits following installation, but North Carolina still recording hits following installation.

The estimated cost of the active detection and warning system MDOT installed along I-96 near Detroit was $110,000, but its estimated three-year benefit ranged from $609,000 to $674,000. Actual benefits and costs elsewhere would be site-specific, but at this site the installation was economically feasible with a benefit/cost ratio of much greater than 1.0. Also, it provides better protection of a height obstruction than two less expensive alternatives – a passive warning sign and a “sacrificial structure” that is the same height as the obstruction and placed upstream of the obstruction. The consultant recommended to MDOT that it install the active detection and warning system *(43)*.

4.3.2 Commercial Vehicle Parking

Section 4027 of the Transportation Equity Act for the 21st Century required that a study be conducted to determine the location and quantity of parking facilities in 49 states (Hawaii excluded) at commercial truck stops and public rest areas that could be used by motor carriers to comply with federal hours-of-service rules. The two-step approach used by the FHWA first hired a contractor to clarify truck driver parking-related needs and decision-making. This step included a nationwide sample of truck drivers at commercial truck stops and travel plazas, resulting in a total of 2046 completed surveys. In the second step, the FHWA encouraged the formation of partnerships of public- and private-sector stakeholders to inventory current facilities serving the NHS and determine current and projected shortages. This second stage also developed plans for action to meet the identified needs *(44)*.

The consultant determined the peak-hour demand for commercial truck parking by developing a model to estimate the demand based on total truck-hours of travel and the time and duration of the stops. The model includes the effects of the federal hours-of-service rules on parking demand.

The inventory of public rest areas and private truck stops utilized information from state departments of transportation and a proprietary database developed by Interstate America to determine existing parking availability at public and private facilities, respectively. There are an estimated 315,850 parking spaces at all facilities combined that are serving the needs of Interstate highways and other NHS routes carrying more than 1000 trucks per day. Approximately 10 percent of these spaces are in public rest areas, while 90 percent are in commercial truck stops. Truck drivers value public rest areas primarily for their convenience and commercial truck stops for their amenities *(44)*.

Texas is first among the states with the highest demand for truck parking, followed by California, then mid-western states of Indiana, Illinois, and Ohio. The ratio of public parking versus truck stop parking was based on the national driver survey, which indicated that 23 percent of the demand is at public rest areas and 77 percent is at commercial truck stops. The year 2000 peak hour parking demand in Texas is 8305 spaces in public rest areas and 27,797 spaces in commercial truck stops, with a 20-year forecasted annual increase in parking demand of 2.7 percent.

A total of 105 public rest area facilities (654 spaces) in Texas provide 3 percent of the available parking, whereas 284 truck stops and travel plazas (23,525 spaces) provide 97 percent of the current supply along Interstate and NHS routes with more than 1000 trucks per day. The proportion of total parking supply provided by public rest areas needs to be increased substantially to meet the needs as expressed in the national driver survey *(44)*.

The analysis for overcrowding compared the demand and supply results by examining the ratio of estimated parking space demand (from the demand model) and parking space supply (from the supply survey). A value near 1.0 indicates supply approximately equal to demand, and a value significantly greater than 1.0 indicates a shortage. The demand/supply ratio for Texas for public spaces was a value of 12.70, which was the second worst ratio of all the states. However, for commercial space, the value was 1.18, indicating a shortage but not nearly as severe as that for public parking spaces. Current and future actions planned by TxDOT to improve the demand/supply ratio include expanding public facilities. Other actions planned or suggested by some states include: expanding or improving commercial truck stops, encouraging the formation of public-private partnerships, educating or informing drivers about available spaces, changing parking enforcement rules, and conducting additional studies *(44)*.

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APPENDIX

Presentation Materials

Project 0-4364 Objectives

- Develop profile of current Texas truck fleet
- Evaluate major truck corridors
- Identify critical design issues for trucks
  - Lane use restrictions
  - Separate truck facilities or lanes
  - Use of roadside barriers or physical separation
- Develop geometric guidelines for truck corridors
- Develop workshops for mid-level designers and policy-makers

Designer Workshop Outline

- Introduction
- Stakeholder input
- Texas truck corridors
- Truck accommodation strategies
- Design guidelines
- Wrap-up

Policy-Maker Workshop Outline

- Introduction
- Stakeholder input
- Texas truck corridors
- Truck accommodation strategies
- Designing for trucks
- Wrap-up

Methods to Separate Trucks

- Spatial and temporal separation
- Mixed traffic flows
- Lane restrictions
- Truck roadways
- Discussion

Texas Transportation Institute — *Transportation Operations Group* — 5

Reasons to Separate Trucks

- Safety: crash severity
- Vehicle operational characteristics
- Roadway characteristics
  - Geometric design
  - Pavement structure

Texas Transportation Institute — *Transportation Operations Group* — 6

Policy-Maker Workshop Outline

- Introduction
- ➡ Stakeholder input
- Texas truck corridors
- Truck accommodation strategies
- Designing for trucks
- Wrap-up

Texas Transportation Institute — *Transportation Operations Group* — 7

Stakeholder Input

- TxDOT
- Motor carriers
- Enforcement
- Motoring public

Texas Transportation Institute — *Transportation Operations Group* — 8

Truck Parking Needs

- Truck driver hours-of-service
- Existing 100 public rest areas for trucks
- TxDOT’s goal: 60-90 mi. spacings
- TxDOT has $70 million program
- Current funds are insufficient

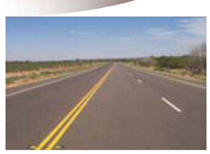
Texas Transportation Institute Transportation Operations Group 9

Examples of Truck Parking

Texas Transportation Institute Transportation Operations Group 10

Stakeholder Input: RTI Survey

- Improvements planned
  - Implementing “Super 2” design
  - Lane and shoulder widening
  - Increased “sight distance”
  - Intersection improvements
  - Passing and climbing lanes
  - Designated truck lanes
  - Heavy-duty asphalt pavement (>5000 tpd)



Texas Transportation Institute Transportation Operations Group 11

Stakeholder Input: Carriers

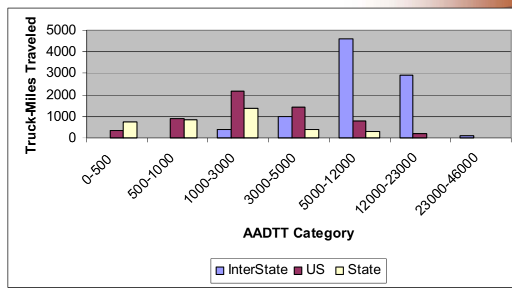
- Motor carriers vs. shippers
  - Pick-up and delivery schedules
  - Vehicle size issues
- Truck drivers need timely information
- Truckers want non-toll options
- Improvement needs:
  - Lengthen entry/exit ramps
  - More rest areas
- Maintain truck roadways as trucks only

Texas Transportation Institute Transportation Operations Group 12

Policy-Maker Workshop Outline

- Introduction
- Stakeholder input
- ➡ Texas truck corridors
- Truck accommodation strategies
- Designing for trucks
- Wrap-up

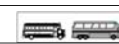
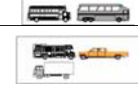
Truck-Miles Traveled by AADTT Category



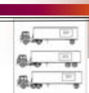
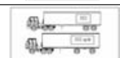
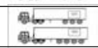
Truck-Miles Traveled by AADTT Category

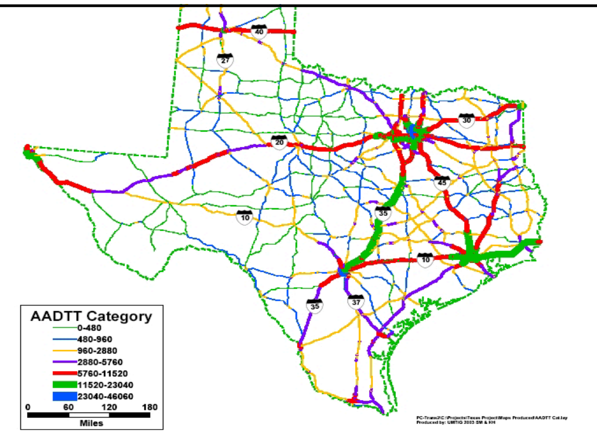
- Highways with truck volumes 0 to 1000 AADTT account for 64% of route mileage & 15% of TMT
- Highways with 1000 to 5000 AADTT account for 28% of route mileage & 36% of TMT
- Highways with over 5000 AADTT account for 8% of the route mileage & 49% of TMT

Vehicle Classification 3 - 7

FHWA Classification	Typical Vehicle Type
Class 3: 2 axles, 4-tire single units, pickup or van (with 1- or 2-axle trailers)	
Class 4: Buses	
Class 5: 2D – 2 axles, six tire single units (includes handicapped-equipped bus and mini school bus)	
Class 6: 3 axles, single unit	
Class 7: 4 or more axles, single unit	

Vehicle Classification 8 - 13

Class 8: 3 to 4 axles, single trailer	
Class 9: 5 axles, single trailer	
Class 10: 6 or more axles, single trailer	
Class 11: 5 or less axles, multi-trailers	
Class 12: 6 axles, multi-trailers	
Class 13: 7 or more axles, multi-trailers	



Texas Truck Corridors

- I-35
- I-10
- I-69
- Ports-to-Plains Corridor
- Trans Texas Corridor

I-35 Truckway Concept

- I-35 Trade Corridor Study (1999)
- Design speed: 75 – 150 mph
- Two conventional lanes
- Separate instrumented lane for trucks
- Interchange spacing: > 20 mi
- Increased use of technology

I-35 Truckway Concept

- Improved design features:
  - Heavier loads
  - Maximum grade of 3%
  - Longer acceleration/deceleration ramps
  - Wider pavement
  - Flatter turning radii at interchanges
  - Additional space at rest areas

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I-10 Study

- Eight states
- Criteria
  - Total daily truck volume
  - Volume/capacity ratios
  - Total overall vehicle volume
  - Number of trucks carrying high service freight
  - Number of trucks making deliveries within 100 miles

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I-69 Study

- ISTEA High Priority Corridor No. 18
- Indianapolis – Lower Rio Grande Valley (LRGV) extension
- LRGV components:
  - US 77 Brownsville – Victoria
  - US 281 McAllen – Victoria
  - Corpus Christi Northside Highway

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Ports-to-Plains Corridor

- Ports-to-Plains feasibility study
- Denver to Del Rio/Eagle Pass/Laredo
- Continuous 4-lane hwy not feasible
- Truck climbing lanes
- Use of increased technology
- Relief routes in corridor towns/cities

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Trans Texas Corridor

- 1,200-ft ROW
- Truck lanes:
  - 13-ft lane width
  - 12-ft outside shoulder width
  - 4-ft inside shoulder
  - 80 mph speed limit on toll road
  - Increased load carrying capacity

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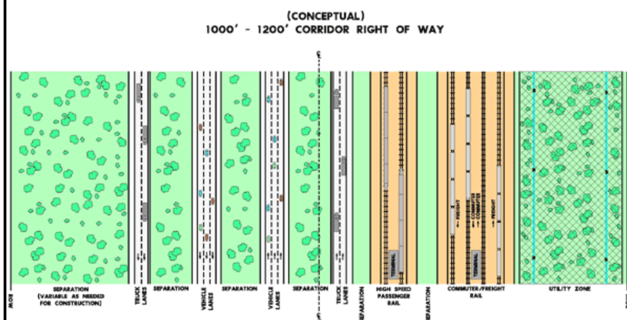
Trans Texas Corridor ROW



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Policy-Maker Workshop Outline

- Introduction
- Stakeholder input
- Texas truck corridors
- ➡ Truck accommodation strategies
- Designing for trucks
- Wrap-up

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Truck Accommodation Strategies

- Lane restrictions (LR)
- Truck-preferred or truck-only roadways

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Lane Restriction Research

- Research findings are mixed
  - 1989 study found that safety could improve
  - 1990 Texas study did not find improvements in capacity and safety
  - 2000 Texas study found crashes dropped by 68%
  - A Seattle area study recommended not implementing lane restrictions
  - LR can result in barrier effect in weaving areas
  - Public favors LR but does not favor special truck benefits

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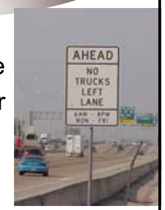
Lane Restriction Applications

- Only on roadways with 6 or more lanes
- Do not restrict trucks to a single lane
- Restrict trucks FROM the left lane or TO the right 2 (or more) lanes
- LR can be used to equalize pavement wear



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Existing and Proposed Truck Roadways

- New Jersey Turnpike ←
- I-5S North of Los Angeles
- SR-60 in Los Angeles
- I-710 in Los Angeles
- Trans Texas Corridor ←

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New Jersey Turnpike

- Dual-dual roadway (32 miles)
- Justification
  - To automate traffic control
  - Flexibility for maintenance and emergency management
- Separate access ramps

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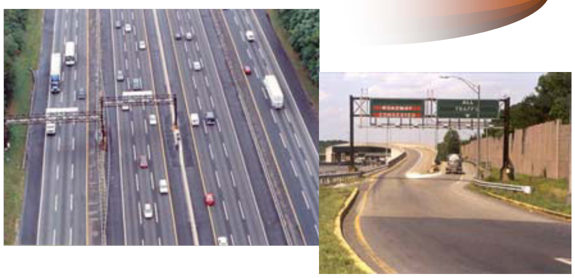
New Jersey Turnpike



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New Jersey Turnpike

- Two to three outer lanes (32 miles)
- AADT 137,000 to 215,000 vpd
- Truck AADTT: 21,300 to 28,000
- Truck percent: 11.7 to 14.9%
- 62% of cars use inner roadway
- Flat grades throughout

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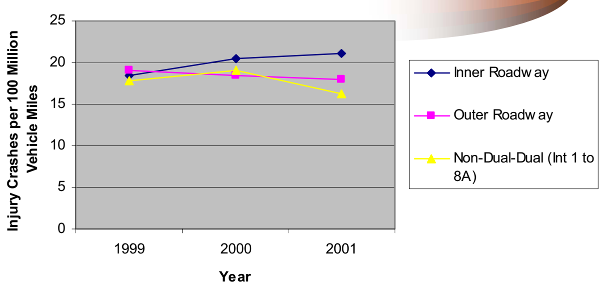
NJ Turnpike Injury Crash Rates



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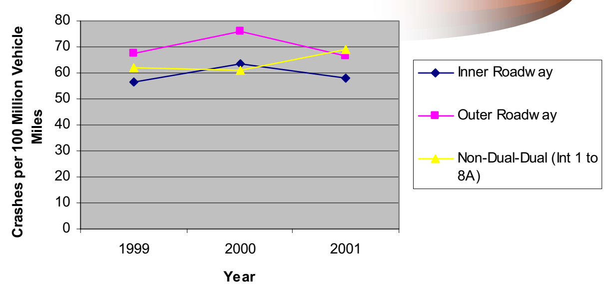
NJ Turnpike Total Crash Rates



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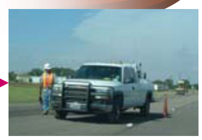
Thresholds for Truck Accommodation

- Battelle threshold criteria
  - 100,000 vpd
  - 25% trucks (Class 3+)
  - Truck-involved crash rates
  - Level of service "E" (capacity)
- Douglas threshold criteria
  - 20,000 trucks (Class 6+)
  - Minimum length 10 mi.

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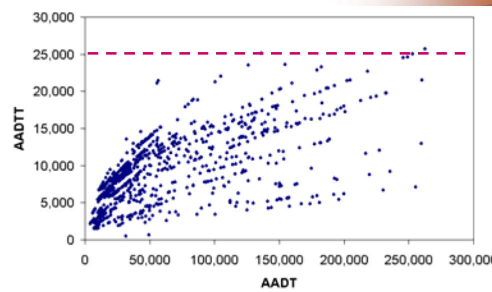
AADTT vs. AADT in Texas (IH)



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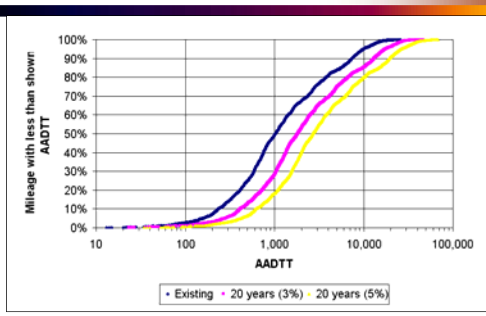
Predicted Growth in AADTT



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Truck Growth

- Build truck roads based upon predicted reasonably full utilization of minimum two lanes
- Roadway capacity is based upon terrain
- For flat terrain, the maximum AADTT for four lanes is 106,600 trucks per day
- For rolling terrain, the maximum AADTT for four lanes is 53,300 trucks per day
- Even on high-growth corridors in flat terrain in Texas, 100% of the highway mileage can handle this volume

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Free-Flow Truck Lanes

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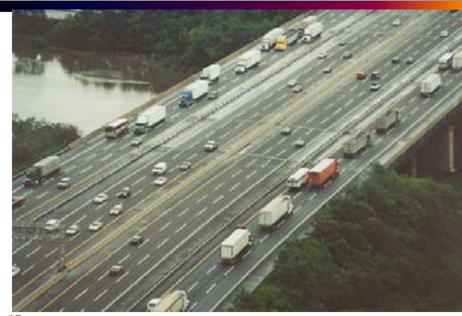
Truck Lanes Near Capacity



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Proposed Volume Thresholds

AADTT	Truck Treatment
0 – 1000	Truck-friendly design
1000 – 5000	Some design for trucks
5000 – 25,000	All design for trucks
Over 25,000	Two-lane truck roadway

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Geometric Design Issues

Sight distance
- Definition: “The length of roadway ahead of the driver that is visible”

Horizontal alignment
- Curve radius and “banking”
- Intersections
- Pavement widening

Vertical alignment
- Truck speeds on long grades
- Long downgrades

Cross-section elements
- Lane and shoulder widths
- Acceleration lanes
- Vertical clearance
- Traffic barriers
- Signs

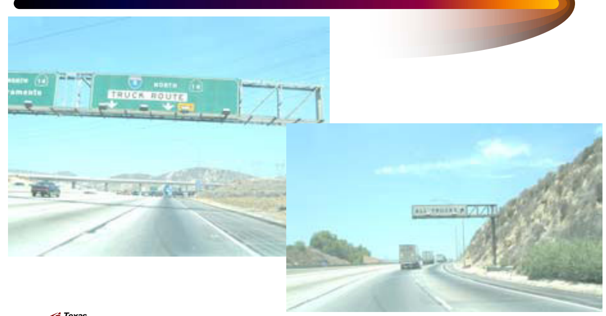
Changes Needed for Trucks

- Intersection Geometrics
  - Add Design Vehicle WB-65
- Lane Width
  - Widen from 12 ft to 13 ft
- Shoulder width
  - Widen from 10 ft to 12 ft on right side
  - Left shoulder depends on number of lanes

Changes Needed for Trucks

- Ongoing research will provide answers
  - Longitudinal barrier design
    - Minimum 42-inch height
    - Texas barrier needs strength test
  - Sideslopes
  - Drainage end treatments

Changes: Static Signs

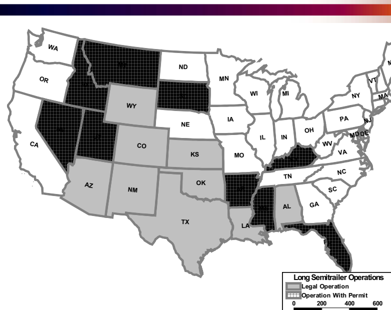


Changes: Static Signs

- Typical ground-mounted signs may be inadequate in high truck flows
- NJTA uses overhead guide signs at two miles, one mile, ¼ mile over both roadways
- Must consider truck driver eye-height

Monitor Vehicle Trends

States Allowing Long Semi Trailers



Technology Solutions

- Components
  - Weigh-in-motion
  - Active message signs
  - Changeable message signs
- Warning systems
- On-board systems
  - Automated Vehicle Location (AVL)
  - Automated Vehicle Identification (AVI)
  - On-board computers
  - Weight sensors

Weigh-in-Motion

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Weigh-in-Motion

- Useful in rollover warning applications
- Enforcement application
  - Overweight sorting system
- Types of WIM
  - Piezoelectric
  - Bending plate
  - Load cell

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Changeable Message Signs

- Divert traffic from one roadway to another
- Integral warning system component

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Rollover Warning System

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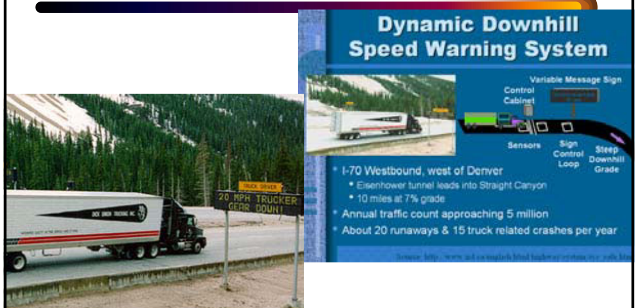
Downhill Warning System



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Policy-Maker Workshop Outline

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Wrap-Up

- Design Element Summary
- Discussion

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Design Element Summary

Design Element	Design Year AADTT		
	1000 to 5000	5001 to 25,000	Over 25,000
Stopping Sight Distance	* a	* a	* a
Decision Sight Distance	NC	NC	NC
Passing Sight Distance	NA	NA	NA
RR-Hwy Sight Distance	NA	NA	NA
Intersection Sight Dist.	NC	NC	NC

a Only a wording change in TRDM.

NA: Not applicable to high-volume, controlled-access roadways for trucks.

NC: No change from current design practice.

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Design Element Summary

Design Element	Design Year AADTT		
	1000 to 5000	5001 to 25,000	Over 25,000
Curve R and Superelev.	NC	NC	NC
Int. and Channelization	NC	*	*
Pavement Widening	NC [a]	NC [a]	NC [a]
Critical Length of Grade	NC	NC	NC
Downgrades	NC	NC	NC

[a] For design speeds over 60 mph.

NC: No change from current design practice.

* Special design considerations for trucks.

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Design Element Summary

Design Element	Design Year AADTT		
	1000 to 5000	5001 to 25,000	Over 25,000
Lane Width	NC	NC	*
Shldr. Width and Comp.	NC	*	*
Sideslopes & Drainage	NC [b]	NC [b]	NC [b]
Pavement X-Slope Breaks	NC	NC	NC
Vertical Clearance	NC	NC	NC

NC: No change from current design practice.

* Special design considerations for trucks.

[b] Apply findings of NCHRP 22-12 as appropriate to Texas Roadways.

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Design Element Summary

Design Element	Design Year AADTT (DHV)		
	1000 to 5000	5001 to 25,000	Over 25,000
Traffic Barrier	NC	* [b]	* [b]
Passive Signs	NC	* [c]	* [c]
Curbs	NC	NC	NC
Acceleration Lanes	NC	*	*

NC: No change from current design practice.

[b] Apply findings of NCHRP 22-12 as appropriate to Texas Roadways.

[c] For diamond interchanges use overhead signs instead of ground-mounted at ½ mi and 1 mi in urban areas and 1 mi and 2 mi in rural areas.

* Special design considerations for trucks.

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