SAFETY AND OPERATIONAL ASPECTS OF EXCLUSIVE TRUCK FACILITIES

By

Dan Middleton
Research Engineer
Texas Transportation Institute
College Station, TX, USA
E-mail: d-middleton@tamu.edu

and

Dominique Lord
Assistant Professor
Texas A&M University
College Station, TX, USA
E-mail: d-lord@ttimail.tamu.edu

Summary/Abstract: Each year more than 40,000 people die as a result of highway crashes, and 1 in 8 of those fatalities involve commercial motor vehicles. USDOT has set an ambitious goal of a 50 percent reduction in truck-related facilities by the end of this decade. Meeting that goal will involve finding ways of improving the performance of all elements of the system – the driver, the roadway, and the vehicle. This research deals with the roadway aspect, by investigating the safety and operational aspects of exclusive truck facilities. Determining the need for truck facilities established criteria such as the vehicular volumes, safety elements, and financial feasibility. This paper only deals with the first two. The research approach developed level of service relationships using the simulation software VISSIM. The safety investigation consisted of an evaluation of crashes on the New Jersey Turnpike comparing car-only lanes with mixed flows of trucks and cars. Results of the safety investigation indicate that the crash rate in the outer lanes (mixed flow of cars and trucks) is almost double that in the inner lanes (cars only), given the same exposure. Although inconclusive, this outcome may indicate that truck traffic had an influence on crashes. Results of the operational analysis indicate that the capacity of a two-lane exclusive truck roadway under ideal conditions approaches 1,500 trucks (defined as 3-or more axle vehicles) per lane per hour.

INTRODUCTION

Truck travel in the United States has increased by 216 percent since 1970, as measured in vehicle-miles traveled *(1)*, whereas the population has increased by only 33 percent *(2)* and overall vehicle travel (total VMT) has increased by 137 percent over the same period *(3)*. Forecasts of future freight flows indicate that this growth trend will continue. The volume of domestic freight is projected to grow by 87 percent between 1998 and 2020, whereas the volume of international freight is projected to increase by 107 percent during the same period *(4).* Several trends are affecting this growth in truck traffic, and they include changes in the global economy, consumer demand, and logistics practices. It is anticipated that the growth in the numbers of trucks will bring a commensurate increase in the number and severity of vehicle crashes, all other factors equal. Nationwide statistics indicate that total crash rates for large trucks are lower than for passenger vehicles, but fatal rates are higher. In 2000, large trucks were involved in 212 total crashes per 100 million vehicle-miles (MVM) and 2.2 fatal crashes per 100 MVM, whereas passenger vehicles were involved in 245 total crashes per 100 MVM and 1.3 fatal crashes per 100 MVM *(5).*

The various challenges presented by commercial vehicles provided the impetus for the Texas Department of Transportation (TxDOT) sponsoring a research project to investigate strategies for separating trucks from passenger cars. The increasing presence of large trucks also prompted a monumental project described in more detail below called the Trans Texas Corridor (TTC), which proposes to utilize exclusive truck facilities.

Existing Truck Facilities in the U.S.

An NCHRP Synthesis *(6)* acknowledged two examples of dedicated roads for trucks which have already been built – Edgewater Road in New York and the South Boston Bypass in Massachusetts. These two examples were not built to high-speed controlled access freeway standards, which is the focus of this paper and the research it represents. By contrast, the New Jersey Turnpike is a freeway which has a 35-mile segment that consists of interior (passenger car) lanes and exterior (truck/bus/car) lanes within the same right-of-way. The inner and outer roadways are physically separated by barriers; the inner roadway is reserved for light vehicles or cars only, while the outer roadway is open to all vehicles *(7).* Use of the turnpike's crash history is not the total answer to safety on exclusive truck facilities, but it does compare mixed flows with homogeneous flows in a side-by-side comparison. The California Department of Transportation (Caltrans) has utilized truck bypass lanes at high-volume interchanges around Los Angeles and a 2.42-mi truck roadway north of the Los Angeles area since the 1970s.

Planned Exclusive Truck Facilities in the U.S.

California, Texas, and Virginia are planning to build exclusive truck facilities in the near future. In California, SR-60 and I-710 are freeways which serve extremely heavy truck traffic and which are being considered for exclusive truck facilities *(8, 9, 10).* Virginia Department of Transportation (VDOT) is planning on widening I-81 across the entire state *(11)*. The winning team proposed to widen I-81 from four to eight lanes throughout Virginia and separate trucks from passenger vehicles in two-lane divisions for each direction of travel *(12)*. The proposed plan would redesign interchanges with other interstates and other major truck exits to allow for separation between cars and trucks at exits *(13).* In Texas, the TTC is a proposed multi-use, statewide network of transportation routes in Texas that will incorporate existing and new highways, freight and passenger railways, and utility rights-of-way. The TTC will connect Texas and other states with a 4000-mile network of corridors with right-of-way widths up to 1200 ft and separated exclusive truck roadways *(14).*

Given that plans are well underway to build exclusive truck facilities in at least three states, there is an imminent need to identify the factors that contribute to the success of such facilities, primarily in terms of safety and operations. Two key deficiencies exist in contemplating exclusive truck facilities: 1) no pure truck freeway facilities exist in the U.S. so safety aspects are unknown, and 2) there is no methodology to easily evaluate the operational aspects of large networks of roadways with 100 percent trucks. The *Highway Capacity Manual* (HCM) *(15)* corrects for the number of trucks using a passenger car equivalency concept, but it only goes as high as 25 percent trucks. Therefore, developing truck networks which exclusively serve trucks requires a new methodology.

SAFETY ASPECTS OF TRUCK FACILITIES

Recent studies that have evaluated the safety effects of truck traffic levels on freeway facilities have been quite sparse *(16, 17, 18).* In addition, these studies have not provided clear understanding on how different truck traffic levels affect the number of crashes. As a result, there is a need to assess whether or not more homogeneous flows of traffic by vehicle type are safer than the current mixed flow scenario.

To accomplish the objective of the study, researchers conducted an exploratory analysis of crash data on a selected number of freeway sections located on the New Jersey Turnpike for the year 2002. These sections operate as a dual-dual freeway facility: divided inner and outer lanes. Under normal circumstances, the inner lanes have only passenger cars, so the outer lanes serve commercial vehicles (trucks and buses) plus passenger cars. The selected sections offer a good opportunity to compare the crash experience between passenger car-only and mixed traffic rural freeway facilities. This dual-dual freeway with exclusive passenger car lanes is the only type of facility of its kind and length in North America.

Analysis of Crash Data

This analysis used two study sections located on the northern part of the turnpike. The first study section is situated between interchanges 10 (MP 88.1) and 11 (MP 90.6) for a total length of 2.5 miles. On this section, both inner and outer segments have three lanes in each direction. The second section is located between interchanges 11 and 12 (MP 95.9) for a total of 5.3 miles. The inner roadway has three lanes per direction while the outer roadway has four lanes per direction. Speed limits are the same for all study sections as are other geometric features.

The New Jersey Turnpike Authority (NJTA) provided traffic volume information in annual average daily traffic to evaluate crash rates. The split for passenger car traffic between the inner and outer lanes is about 65 percent and 35 percent respectively. The NJTA also provided the crash data for this analysis, containing detailed information about severity, location, crash type, type of vehicle, day of the week, direction of travel, and time of day, among others. These data were only available as a printed computer output, limiting the amount of data that could be analyzed. In this 2002 dataset, there were 298 crashes, of which 78 involved trucks. All crashes used in this research occurred on the mainline. Some of the findings from analysis of all crashes are as follows:

- Overall, more crashes occur in the outer lanes than in the inner lanes.

- Sideswipe collisions occur more frequently than any other type of crashes in both the inner and outer lanes. Sideswipe collisions occur more frequently in outer lanes than inner lanes.

- Collisions with an object happen more frequently in the inner lanes, perhaps suggesting that the lower ground clearance of cars is a contributing factor in object collisions.

- Rear-end collisions occur more frequently in outer lanes than inner lanes, which may suggest increased speed variations or unstable traffic conditions.

- About 45 percent of all truck-related crashes are categorized as sideswipe collisions. This finding is similar to previous work on this subject *(18)*. However, trucks are not over-involved in rear-end collisions and run-off-the-road crashes, as reported in the referenced research (Golob and Regan).

- A larger proportion of crashes leading to an occupant injury occur when a truck is involved in a collision. Very few single-truck or truck versus truck crashes caused an injury.

A portion of the analysis evaluated the crash rate (in 10^8 vehicle-miles) by direction of travel and mile markers. Table 1 suggests that the crash rate in the outer lanes is almost double that in the inner lanes, given the same exposure. This outcome may indicate that truck traffic had an influence on crashes. The crash rates for the northbound and southbound traffic provide similar values.

Table 1. Crash Rates for Full Data with Trucks and Cars.

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

The data were further scrutinized to evaluate crash rates by isolating the passenger car and truck traffic exposure (buses excluded). In this analysis, for three out of four sections, truck-related crashes occur more frequently than passenger car only crashes given the same exposure. In other words, the number of truck crashes per truck is higher than the number of passenger car crashes per passenger vehicle, other factors equal.

Discussion of safety findings

Truck-related crashes account for more than 40 percent of all crashes occurring on the outer lanes, yet trucks account for only 30 percent of the traffic traveling on the outer lanes. This means that truck-related crashes are over-represented in outer lanes. Garber and Joshua noted the same outcome in their study of large-truck crashes in Virginia *(19)*. It is unclear whether truck traffic levels or traffic flow states or perhaps a combination of factors play a role in truck-related crashes.

The safety effects of truck volumes, defined as homogeneous and non-homogeneous traffic flows, is currently not well understood *(16, 17).* The two seminal studies arrive at opposite conclusions. Jovanis and Chang found that an increase in truck traffic increases truck-related crashes, whereas Hiselius established no such relationship. Since trucks have significant blind spots it may be reasonable to assume that increased truck traffic may lead to more sideswipe collisions compared to a similar facility with passenger car only (though other types of crashes are expected to increase, such as run-off-the-road crashes).

A significant amount of research has occurred over the last two or three years on the safety effects of traffic flow states on urban and rural freeways *(20, 21, 22).* The recent work has shown that vehicle density and volume-to-capacity ratios have a great impact on freeway safety, although the effects are more significant for urban freeways. Some have argued that a greater variance in the speed distribution of vehicles on a freeway segment increases the risk of collisions *(23, 24)*; however, not everybody agrees with this argument *(25)*. It is a well-known fact that increased truck traffic can have a significant impact on freeway operations *(15)*. Nonetheless, although a valid hypothesis, it is impossible to evaluate with the current data.

Given these findings, including the crash-reduction potential of homogeneous flows, there is a need to further quantify the safety impacts of exclusive truck roadways to estimate potential overall reductions in crashes. As part of ongoing research, TTI hopes to develop crash relationships for truck roadways to assist future decision-makers.

OPERATIONAL ASPECTS OF TRUCK ROADWAYS

The capacity of freeways serving passenger car traffic ranges from 2200 to 2400 passengers cars per hour per lane (pc/h/l) depending on speed *(15).* Level of service (LOS) E or capacity for truck roadways depends on a number of factors, not the least of which is the vehicles included and defined as a "truck." This research defined a truck as a vehicle with three or more axles that does not provide human transport as its primary function (i.e., not a bus). Unlike assessments of capacity based on passenger car traffic – which includes a range of vehicles with relatively similar performance and operating characteristics, the current research included vehicles ranging from gross vehicle weights of approximately 15,000 pounds to over 100,000 pounds. This research employed only a vehicle mix that is generally representative of the truck type distribution found in rural Texas areas (i.e., where the Trans Texas Corridor would most likely be constructed). Other factors that affect truck roadway capacity are presented later.

Research Methodology

From among the different types of simulation tools researchers selected a microscopic tool since these tools are the only kind with the flexibility to incorporate a variety of different vehicle types and constantly regulate their performance with respect to the roadway and the vehicles around them. Several different microscopic traffic simulation models exist for purposes of traffic flow modeling, but after considering model cost, flexibility in defining different truck types and operating characteristics, and available user support, the research team chose VISSIM *(26).* The research team began with a basic rural freeway model (TTC concept is basically rural) then created variations on this basic model to explore the capacity impacts of grades and entrance and exit ramps. To ensure adequate measurement of capacity effects and to thoroughly examine truck acceleration and deceleration, researchers modeled a 20-mile segment of a truck-only freeway. The VISSIM calibration consisted of truck performance modeling and truck facility modeling.

Truck Performance Modeling

This activity began with developing truck weight and power values which represented the Texas truck population. Researchers learned that the VISSIM default values pertaining to average and maximum acceleration and deceleration were the most reliable current source of this information and used them in the model. Utilization of the VISSIM features for specifying vehicle length and power were successfully used to create the correct truck "fleet" representative of Texas rural trucking conditions. In addition, broad calibration settings for VISSIM, including ramp advanced warning distances and individual vehicle's "look ahead" distance, were entered using representative values based on previous freeway operations research *(27)*.

Truck Facility Modeling

Before simulation modeling could begin, it was necessary to design a simulation experiment that would produce capacity estimates for the types of terrain expected in rural Texas. To most accurately replicate the terrain in Texas, the process used a range of grades from 0 to 4 percent and had two categories of grades – up to 2 percent for lightly rolling terrain and up to 4 percent for steeper rolling terrain. A random number generator determined which segments along the 20-mile section would be upgrade, level, or downgrade in both the 2 percent and 4 percent (graded) simulations. This activity produced a "terrain model" that defined the vertical geometry of the truck freeway simulation (two lanes each direction) along its length. Another detail that required resolution was the access density, or the spacing of entrance and exit ramps along the access-controlled truck lanes. Analysts decided to analyze a 20-mile section of truck lane facility with zero, two, and five interchanges.

Table 2 indicates capacity values in terms of maximum achievable flow rate at the network termination point for each of the fifteen simulation cases. The maximum truck capacity achieved was 1475 t/h/l (trucks per hour per lane), and the lowest "capacity" under prevailing conditions was 1025 t/h/l (where the grade was 4 percent, grades were found on 40 percent of the road length, and there were 5 interchanges per 20 miles). In general, having higher volumes per ramp (i.e., the two interchange per 20 mile cases rather than the five interchanges per 20 miles) had a stronger influence on capacity, but increased ramp frequency increased the likelihood that a ramp would merge at an upgrade.

The development of LOS tables for truck-only facilities was a straightforward process once the basic lane capacity value was known. Utilizing the same ratios provided for mixed-flow traffic in LOS tables contained in the HCM *(15)*, LOS ranges for trucks were established for the maximum density, minimum speed, maximum volume/capacity ratio and maximum service flow. Note that the density observed at maximum flow is the only value based directly on simulation results – all other values are based on LOS criteria ratios found in the HCM to establish LOS values for truck roadways based on the same relative criteria used for mixed flow within the HCM.

Table 2. Truck Facility Capacity (t/h/l [a]) Modeling Results from VISSIM

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

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

Truck Facility Level of Service

Designing Facilities Based on Operational Aspects

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

To simplify the evaluation of roadway corridors for truck-only roadways, the authors examined a broad range of possible operating conditions. The process varied the following aspects of the model with respect to one another, creating a total of 675 different scenarios that required modeling. The resulting information provided for decision-makers is a series of tables comparing the LOS for mixed flow with the LOS for separated flow. The user simply enters the appropriate table with the appropriate inputs of mainline truck and non-truck volume, terrain factor, interchange volume, and interchange spacing.

SUMMARY AND CONCLUSIONS

One candidate treatment for mitigating truck operational and safety impacts is exclusive truck facilities. There has been ongoing interest in exclusive truck roadways over the past few years as evidenced by a variety of research projects on this subject, but truck volumes and other criteria that point to the need for exclusive truck roadways have not existed until now. California, Virginia, and Texas are planning exclusive truck facilities to reduce some of the impacts of commercial vehicles along existing freeways. Operational and safety features of controlled access truck roadways cannot be evaluated by the traditional methods, so this research was necessary to develop a methodology using computer simulation.

Some of the unknowns pertaining to the safety aspect could potentially be answered through more sophisticated statistical analyses, combined with the use of disaggregated data (e.g., hourly flows, crashes per lane, etc.). For instance, incorporating volume-to-capacity ratios or vehicle density would certainly help determine the safety effects of traffic flow states as a function of truck traffic levels. Thus, the authors suggest additional work using disaggregated data in order to understand the characteristics of the differences in safety between outer and inner lanes.

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

Findings of the operational analysis indicate that the capacity of truck roadways ranges from 1025 t/h/l to 1475 t/h/l, depending on grades, interchange spacing, and proportion of exiting and entering truck traffic. Also, for average annual daily truck traffic (AADTT) values as high as 50,000 trucks per day in level terrain and 10 percent trucks exiting and entering at interchanges, the simulation results indicate that truck roadways with two lanes do not experience LOS values worse than LOS C.

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