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Engineering Specification for Construction of Truck Only and Vehicle Only Travelways in Missouri Phase 1

Prepared by Wilbur Smith
Associates and Missouri
Department of Transportation

FINAL REPORT

RI08-030

Engineering Specifications for Construction of Truck Only and Passenger Vehicle Only Travelways in Missouri

Phase 1

Prepared for the
Missouri Department of Transportation
Organizational Results Division

By:



September 2009

The opinions, findings and conclusions expressed in this report are those of the principal investigator and the Missouri Department of Transportation. They are not necessarily those of the U.S. Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

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16. Abstract The objective of this study is to provide information detailing the safety consideration specifications for the truck only and passenger only facilities for I-70 and I-44. The categories discussed in this report include: Traffic Operation and Truck Only Lane (TOL) Configuration, Public Policy Questions, Literature Review, and Public Outreach Tools.			
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Executive Summary

To improve safety and the efficiency of freight movement on I-70 and I-44 across Missouri the Missouri Department of Transportation (MoDOT) is investigating the possible separation of truck traffic from general purpose vehicles. The I-70 Supplemental Environmental Impact Statement (SEIS) completed in the summer of 2009 recommended truck-only lanes be separated from general purpose lanes by 30 to 40 foot grass medians. As part of this continuing effort, MoDOT contracted Wilbur Smith Associates and the Missouri University of Science & Technology to study a variety of issues entitled Engineering Specifications for Construction of Truck Only and Passenger Vehicle Only Travel ways in Missouri.

Figure 1 Proposed Truck-Only Lane Slip Ramp Configuration...¹



This report consists of the following nine technical memoranda covering Slip Ramp Spacing, Slip Ramp Safety Features, EMS Access to Truck-Only Lanes, Public Policy on enforcement, Effectiveness of Guard Cables with Trucks, Safety Considerations for Truck-Only Lanes, Public Outreach Promotional Strategy, Truck-Only Lane Promotional Tools, and a Truck-Only Lane Survey of EMS Providers.

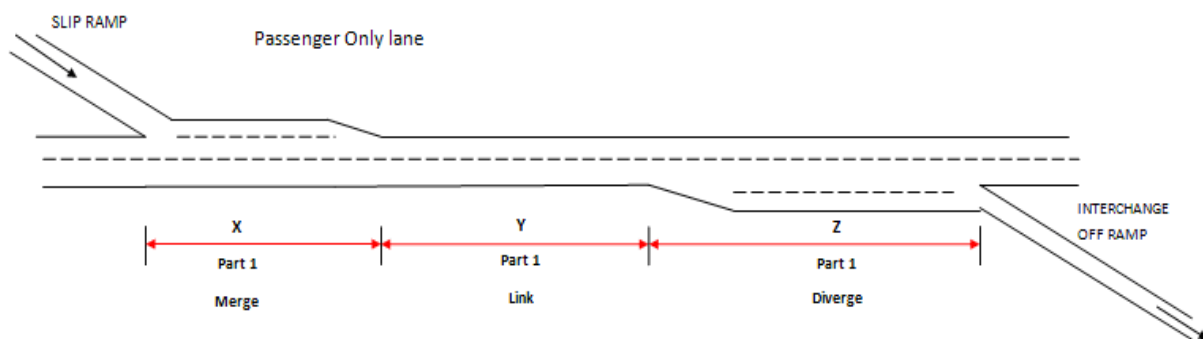
¹ <http://www.improvei70.org/pdf/08-04-01Handout.pdf> (Spring '08 handout)

Slip Ramp Spacing

The investigation into slip ramp spacing used a VISSIM micro traffic simulation model to investigate the proper spacing or location of slip ramps. The slip ramp spacing study made the following recommendations based on safe and efficient operations of the general purpose lanes:

1. Slip ramp design speed should be the same as the general purpose lanes.
2. The distance for trucks to weave in traffic is greater than the distance to accelerate or decelerate therefore the weaving distance controls the length of the acceleration/deceleration lanes,
3. Acceleration (merge) lanes should be 1,000 feet for moderate and 1,200 feet for heavy traffic.
4. Deceleration (diverge) lanes should be 800 feet for moderate and 1,000 feet for heavy traffic.
5. Weaving for trucks requires 1,500 feet for moderate and 2,000 feet for heavy traffic.
6. The total distance from slip ramp to off-ramp should be 3,300 feet to 4,200 feet.
7. Operations degrade for traffics flow between 150 and 200 trucks per hour and between 1,600 and 2,000 general purpose vehicles per hour.

Figure 2 Slip Ramp Spacing Configuration



Slip Ramp Safety Features

The investigation into safety features of slip ramps found or recommended the following:

1. Most literature covers HOV or managed lanes with limited specific research on the safety features of truck-only lanes.

2. The AASHTO High Occupancy Vehicle (HOV) Design Guide² allows the use of slip ramps due to limited right-of-way and/or high costs.
3. Safety improves with driver's familiarity therefore Missouri should consider a public education campaign on of truck-only lanes and slip ramps.
4. Slip ramp design should be location specific based on grades, speed limits, weaving distances, lane widths, median widths, etc.
5. Most safety issues involve the truck merging maneuvers from the left slip ramps to the right side exits. A 1992 study by the Texas Transportation Institute suggested merging distances of at least 3,500 to 3,750 feet which is consistent with the 3,300 to 4,200 feet recommended in the slip ramp location technical memorandum in this report.
6. Clear signage will be instrumental for the safe operation of truck-only lanes and creating designated truck merging zones may improve driver's expectations.
7. Critical geometric design criteria for slip ramp operations should be completed when investigating longer combination vehicles (LCVs).
8. Technologies are emerging that may increase safety at slip ramp facilities including ITS, ramp metering, vehicle detection, and on-board blind spot detection.

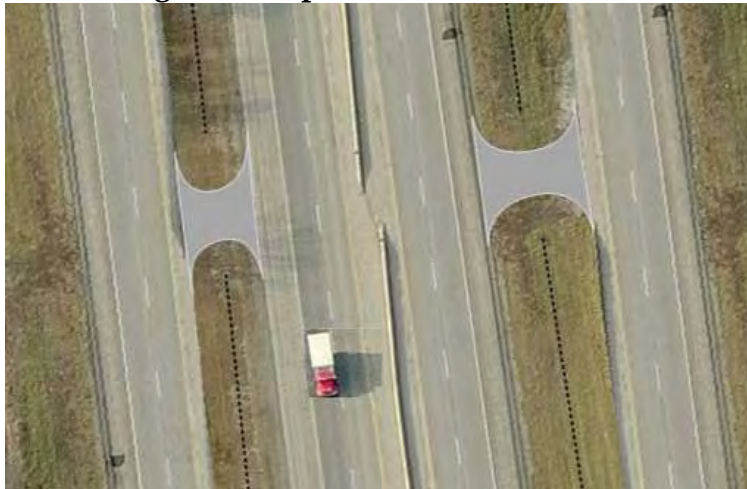
EMS Access to Truck-Only Lanes

This technical memorandum looked into the configuration and spacing of special access to truck-only lanes for emergency services. The memorandum recommended the following:

1. Current MoDOT standards for median crossovers are adequate for access across the medians to the truck-only lanes.
2. Emergency access opening in the truck-only lane median barriers should be lined up with the median crossovers (see figure 2.)
3. Mechanical gates or temporary access points may be required in locations with narrow shoulders adjacent to concrete traffic barriers.

² *Guide for the Design of High Occupancy Vehicle Facilities*. American Association of State Highway and Transportation Officials, Washington, D.C., 1992.

Figure 2 Proposed Rural EMS Access



Public Policy Technical Memorandum

The Public Policy Technical Memorandum discusses how to define trucks and enforce truck restrictions in the general purpose lanes. The memorandum discusses and recommends adopting existing federal rules on the definition of trucks and existing truck limitations used across the country. To help define the restriction on truck use of the general purpose lanes to local trips study recommends three options:

1. Distance from a trucks origin or destination to define local trips.
2. Commercial vehicle configuration as they differ between long and short hauls.
3. Purpose of the trip, a truck may only use the general purpose lanes to gain access for their intended purpose.

The enforcement recommendations borrow from the “virtual weigh station” concept currently in use across the country where information about the truck is encoded into an electronic manifest system available to law enforcement.

Effectiveness of Guard Cables with Trucks and Truck-Only Lanes

The technical memorandum on the effectiveness of guard cables on trucks found little literature dealing with of truck-only lanes and trucks except for those that measured failure of cable barriers in median crossover accidents. The studies that did measure crossover failures did not compare these to the number of successful applications involving trucks. However, these studies did indicate that guard cable greatly decreased injury and fatality accidents, prevented general purpose vehicles from

crossover accidents, and actually increased minor property accidents. There was one study however that recommended an improved anchor and tension system that would greatly improve the effectiveness of median guard cable systems in stopping these median crossover accidents. This type of improved system did show a dramatic improvement in crossover accidents including those involving trucks.

Safety Considerations for Trucks and Truck-Only Lanes

The safety considerations for truck-only lanes consisted of a literature search and summary of previous studies involving truck and truck-only lane issues. Many of the eleven studies discussed truck lane restrictions or operations but not specifically truck-only lanes. However, some of these findings may prove germane to the issues of truck-only lanes in Missouri. Some of the subject matter from these studies included:

1. The effectiveness of truck lane restrictions on capacity and safety.
2. Potential applications of truck only lane facilities.
3. The safety and operational aspects of existing truck lane restrictions.
4. The 2007 Corridors of the Future consideration for truck-only lanes.
5. Other studies involving how to improve or measure the safety of truck operations.

Public Outreach Promotional Strategy

This memorandum provides key information for the development of a public involvement strategy in the implementation of a truck-only lane facility. It recommended possible promotional strategies on how to communicate the safety and operational benefits of truck-only lanes. It discussed key audiences, possible concerns, communication methods, and data need. It also discussed current communication efforts on other MoDOT programs.

Truck-Only Lane Promotional Tools

This memorandum describes possible promotional tools, goals of the tool, approximate costs, target audiences, when to use the tool, advantages, and disadvantages. Some of the tools discussed included websites, billboards, kiosks, bulletin boards, brochures, mailers, public meetings, pod casts, radio advertisements, newspaper advertisements, video clips, PowerPoint presentations, small promotional items, earned media, and television advertisements.

Truck-Only Lane Survey of EMS Providers

The truck-only lane survey of EMS providers surveyed 132 state, city, county and private EMS providers along the I-70 and I-44 corridors on their impression of truck-only lanes. Approximately 33 percent of the providers completed the ten question survey. The survey indicated that, at least among EMS providers, there is no real opposition to truck-only lanes along I-70 and I-44. The most common concern from EMS providers is how and where access to truck-only lanes will be gained. Overall, the survey indicated that with continued communication and education, EMS providers felt that truck-only lanes would be beneficial to the interstate system and should improve safety.

Engineering Specification for Construction of Truck Only
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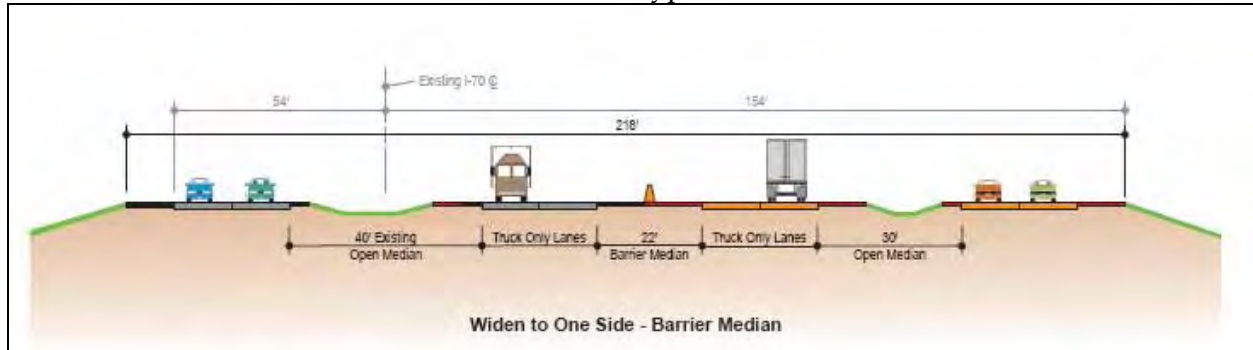
**Truck Only Lanes
Talking Points.**

Truck-Only Lanes Talking Points

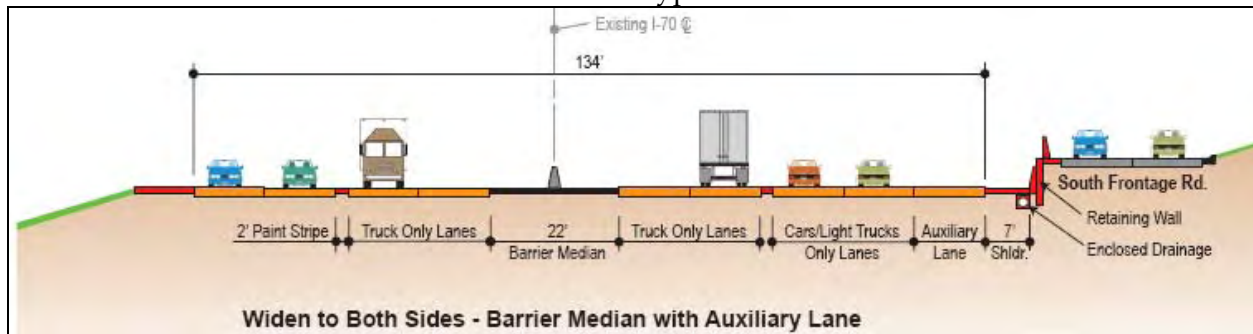
1. What are truck-only lanes?

Truck-only lanes are lanes designated for the use of trucks. The purpose of truck-only lanes is to separate trucks from other mixed-flow traffic to enhance safety and/or stabilize traffic flow.

Potential Rural Typical Section



Potential Urban Typical Section



2. Where could truck-only lanes be located?

Truck-only lanes could be located on Interstates such as I-70 and I-44. Truck-only lanes on I-70 are currently under study as part of the I-70 Supplemental Environmental Impact Statement (SEIS) between I-470 in Kansas City, Missouri and Lake St. Louis Boulevard in St. Louis, Missouri.

3. Why study truck-only lanes now?

- Truck traffic continues to increase on I-70.
- Many Missourians have asked if cars and trucks can be separated.
- New technologies make the separation more feasible.
- Missouri has an important role in the nation's ability to move freight and support the U.S. economy, as demonstrated by Missouri's designation within the federal Corridors of the Future program.

4. What are the benefits of truck-only lanes?

- Safety – Separating long-haul trucks from other traffic offers the opportunity for safer travel for all by reducing the number of car and truck interactions.
- Freight Efficiencies – Trucks play an increasingly important role in our economy and truck-only lanes offer Missouri and the nation's businesses greater efficiencies and reliability as they serve Missouri's businesses, farms, and families.
- Redundancy – By having essentially two sets of lanes in each direction (general purpose lanes and separate truck-only lanes) if either set of lanes needed to be closed for any reason, all traffic could be shifted to the other, allowing traffic to continue to flow on I-70.
- Constructability – Closing lanes on I-70 and I-44 for construction would create significant congestion and delays. The construction of separate, truck-only lanes could be accomplished with fewer impacts to travelers. A range of design- and construction-staging components could be expedited by constructing separate lanes.

5. What types of vehicles typically use truck-only lanes?

The vehicles that typically use truck-only lanes are commercial vehicles for moving materials, with three or more axles, and typically weigh 22,000 pounds or more.

6. Can trucks still use the general purpose lanes and local interchanges?

Yes. There will still be some trucks mixed with passenger traffic. Trucks going short distances and those trucks accessing local interchanges will both travel in lanes with passenger vehicles.

7. How would truck-only lanes work?

Trucks could access most Missouri locations via interchanges that would serve both trucks and other vehicles. Trucks would move between truck-only lanes and general purpose lanes (where trucks would travel with other vehicles) on slip ramps. They would access interchanges from general purpose lanes. Some locations might have interchanges that would keep trucks separated from other traffic.

8. What is a slip ramp?

A slip ramp is ramp that slips between lanes in the same direction (see picture).

9. What locations would have separate truck and general purpose interchanges?

All traffic would be able to access all of Missouri's interchanges. However, separate truck and general purpose interchanges could be constructed only where there is significant truck traffic.

The criteria for separate truck interchange locations is likely to include; standards for the amount of truck traffic, the ability of the connecting road system and community to accommodate that traffic, connectivity to inter-modal centers, and an evaluation of the impacts of the larger interchanges.

Slip Ramp Access



Source: www.improvei-70.org

10. How will truck-only lanes be enforced?

As with all highway laws, MoDOT will look to state and local law enforcement officials to enforce laws relating to highway travel. Fines or penalties are possible for improper use of truck-only lanes, but those have not yet been determined or proposed to Missouri's governing bodies for approval. Along with coordination and approval by Missouri's lawmakers, regulations will also need to be consistent with federal laws and guidelines.

11. When would construction of truck-only lanes begin?

There is no funding for design or construction, so there is no estimated start date for construction. The Missouri State Legislature is exploring a range of options that could help pay for improvements to I-70 and I-44 but currently there are neither local nor federal funds for the project.

12. Couldn't trucks travel on other highways?

MoDOT has explored diverting traffic to other highway facilities, but as part of the national interstate highway system, long-distance and local travelers will continue to use I-70 and I-44.

13. What is the Corridors of the Future program and how does that effort affect Missouri?

Nationally, there is growing emphasis on ensuring safe, efficient movement of freight. Designated by the U.S. Department of Transportation as a Corridor of the Future, I-70 is recognized as a critical artery in getting goods to customers and keeping the U.S. competitive in a global economy. The Corridor of the Future designation enables MoDOT to study the benefits and impacts of truck-only lanes on I-70 in more detail. Completing this additional analysis will position Missouri at the head of the line should more state and federal transportation funds become available.

14. What other states have truck-only lanes?

This innovative solution has emerged recently as a way to deal with truck safety and congestion issues. There are truck-only lanes that travel short distances in New Jersey, California, and Texas. Missouri and Georgia are the first states in the U.S. to look at state- or corridor-wide strategies to separate truck traffic for long distances, but no states have yet implemented truck-only lanes through entire corridors. The Georgia DOT Truck Study recommended not pursuing stand alone truck-only lanes. Because of MoDOT's planning strategies, Missouri is leading the nation in the evaluation of the impacts, costs, and benefits of truck-only lanes.

15. How would emergency vehicles access truck-only lanes?

Emergency vehicles would access the truck-only lanes at special access points similar to those used by emergency vehicles to access high occupancy vehicle (HOV) lanes.

Engineering Specification for Construction of Truck Only
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Sub Document:

**Slip Ramp Spacing
Technical Memorandum.**

Engineering Specifications for Construction of Truck Only and
Passenger Vehicle Only Travel ways in Missouri - Phase I: RI08-030
Slip-ramp Spacing Technical Memorandum

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Slip-ramp Spacing Technical Memorandum

Introduction

The Missouri Department of Transportation (MoDOT) is investigating the truck-only lane proposed improvements along I-70 and I-44 to accommodate the high percentage of truck traffic and to manage congestion along this freight intensive corridor. Access at locations of intense truck activity will be provided by grade separated truck interchanges; however, most of the 250 mile corridor is rural with little demand for access. These locations will be served by slip ramps (**Figure 1**). These slip ramps will provide access between the truck-only lanes and the general purpose lanes to allow trucks access to the general traffic interchanges. This concept is similar to managed lanes currently in use across the country.

Figure 1 Proposed Truck-Only Lane Slip Ramp Configuration...¹



Due to the exclusive heavy truck traffic using the slip ramps, the standard AASHTO design standards for HOV slip ramps may not apply. To this end MoDOT commissioned Wilbur Smith Associates and the Missouri University of Science and Technology to identify the minimum distance a slip ramp would need to be from an interchange to allow the safe and efficient operation of the slip ramp and general purpose lane. A micro simulation model using VISSIM was created using input from

¹ <http://www.improvei70.org/pdf/08-04-01Handout.pdf> (Spring '08 handout)

multiple sources including the I-70 Supplemental Environmental Impact Study (SEIS) and literature reviews associated with truck-only lanes.

Summary

The truck-only lane slip ramps for the I-70 and I-44 corridors were evaluated for rural traffic conditions. Different ranges for traffic volumes were used to help confirm the operational range for the corridor based on volumes from the I-70 SEIS. It was determined that in general the capacity for truck-only lanes operations ranged from 150 to 250 trucks per hour per lane while the upper range of capacity for the general purpose lane ranged from 1,600 to 2,000 vehicle per hour per lane. These upper ranges of capacity are much greater than the expected volumes for rural freeway operations and confirms the slip ramp capacity used in the I-70 SEIS.

The design speed for the truck-only lanes and general purpose lanes use in this study was 70 mph for the mainline and slip ramp and 50 mph for the interchange ramps. Grades of the slip ramp and weaving movements were assumed less than three percent. When grades are greater than percent, acceleration and stopping behavior of heavy vehicles would be affected and longer lengths of the segments would be required.

Heavy vehicles and their interaction with general purpose vehicles were simulated using VISSIM for three specific weaving movements consisting of the Merge, Link, and Diverge. The Merge represents a truck merging into the general purpose lanes from a ramp's acceleration lane. The Link represents a truck weaving across the two general purpose lanes. The Diverge represents a truck weaving into a ramp's deceleration lane. The merge-link-diverge movements were modeled for the trucks moving from the truck-only lanes to the general purpose lanes before an interchange identified as Part 1, and for the trucks moving from an interchange to the truck-only lanes after the interchange or Part 2.

To evaluate the slip ramp spacing, speed versus flow (traffic volume) plots were obtained from simulation results then analyzed for the truck-only lanes and general purpose lanes. Five different geometric configurations or cases were investigated for Part 1 (before the interchange) and again for Part 2 (after the interchange).

Part 1 with the slip ramp before the interchange produced the following results for the six different geometric configurations. Case 1 geometrics consisting of merge-link-diverge design lengths of 800'-900'-650' and an AASHTO recommended truck volume of 230 tph created unacceptable drops in operating speed of the general purpose lanes.

Case 3 geometrics consisting of merge-link-diverge design lengths of 1,000'-1,500'-800' performed well as most of the vehicles maintained acceptable speeds at peak flows while exiting the general purpose lanes. Cases 5 and 6 geometrics with design lengths of 1,200'-1,500'-1,000' and 1,200'-2,000'-1,000' performed well for higher volumes up to 300 trucks per hour. It can be concluded that higher flow rates can be achieved without a significant drop in the speeds of vehicles if additional merge, link and diverge lengths are provided.

The results for Part 2, slip ramps after the interchange, followed a similar trend with the operating speeds increasing with a corresponding increase in the segment lengths. Case 7 with design lengths of 800'-900'-650' did not perform well as both heavy and passenger vehicles slowed down below 50 mph. Cases 11 and 12 with the longest design lengths performed well and are recommended for high traffic volumes, while case 9 with design lengths of 1000'-1500'-800' was acceptable for moderate truck flow rate of 230 trucks per hour.

A composite of the recommended slip ramp lengths and configuration is shown in **Figure 17** at the end of this report.

Methodology

Heavy vehicles were simulated using VISSIM, a microscopic traffic simulation model, to enter and exit the truck-only lanes using the slip ramps. Similarly, the heavy and passenger vehicles were able to enter and exit the general purpose lanes using VISSIM at peak hours. To evaluate the slip ramp spacing, speed versus flow plots obtained from simulation results were analyzed for the truck-only lanes and general purpose lanes for six different cases.

VISSIM Coding

VISSIM codes the highway network using links and connectors. Links are road ways with lanes and connectors are used to connect different links. The truck-only lanes and general purpose lanes were coded in VISSIM as per the geometrics shown in **Figures 2 and 3**.

The lanes width specified were 12 feet and the median spacing was 30 feet. The taper length for single lane entrance ramps as per the AASHTO green book Exhibit 10-69 was set at 300 feet. The taper length of the single lane exit ramps as per the AASHTO green book Exhibit 10-72 was set at 250 feet.

The desired speed distribution for the truck-only lanes and general purpose lanes was set at 70 mph. The on- and off-ramp were set at 50 mph.

Figure 2 Schematics for the Different Segments of Part 1 of General Purpose Lanes

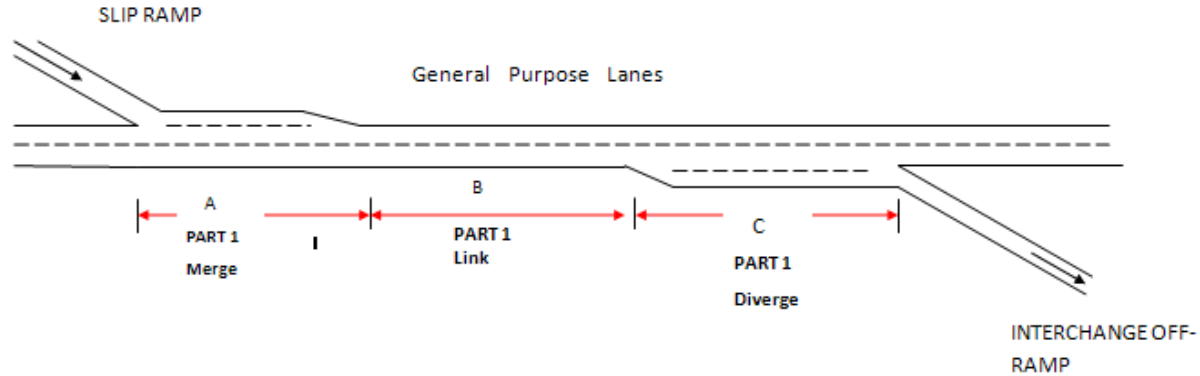
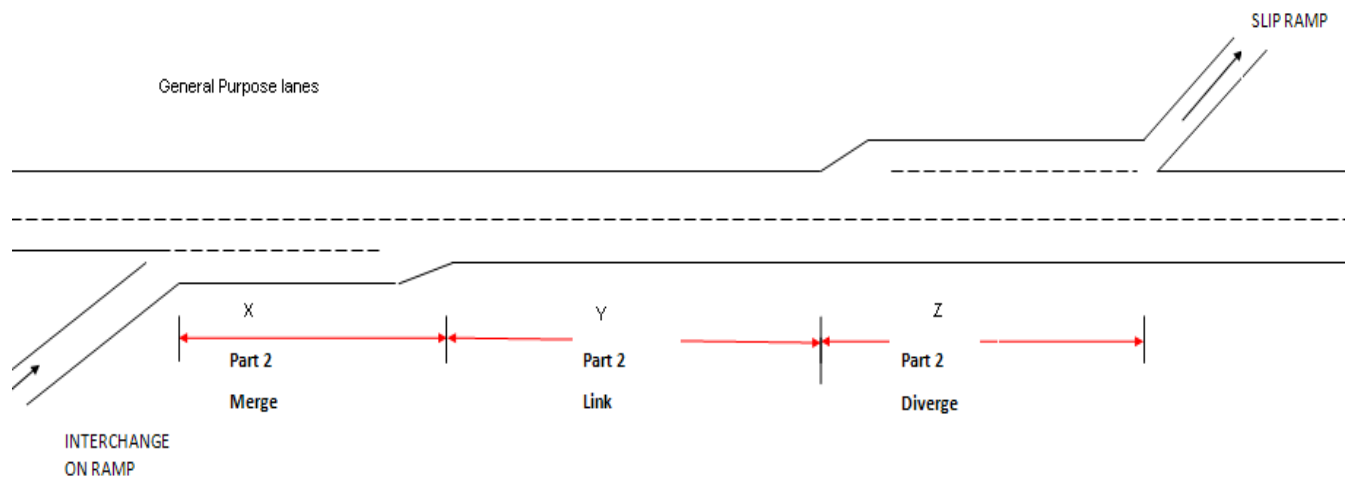


Figure 3 Schematics for the Different Segments of Part 2 of General Purpose Lanes



Routing Pattern

The vehicles are assigned a route to be followed while traveling on the truck-only lanes or general purpose lanes. Routing patterns also specify the number of vehicles that should exit using the slip ramps and the off-ramp.

Traffic Composition

Traffic composition for both general purpose lanes and truck-only lanes are presented in **Table 1**. Heavy vehicles comprised of different types of trucks, buses, and passenger vehicles comprised of cars, SUVs, and bicycles.

Table 1 Vehicle Composition

Description	Percentage
TOL	
Buses	1.50
2 axle 6 tire single units	2.70
3 axle single units	2.20
4 > axle single units	0.03
4 < axle single units	6.70
5 axle single trailers	79.00
6 > axle single trailers	0.48
5 < axle multi trailers	4.60
6 axle multi trailers	2.60
7 > axle multi trailers	0.19
GPL	
Motor Cycles	0.64
Passenger cars	75.00
2 axle 4 tire single units	24.36

Vehicles Acceleration/Deceleration Behavior

Based on the literature review the acceleration/deceleration characteristics of the vehicles were specified in VISSIM. The primary vehicular characteristics specified in VISSIM were the maximum and desired acceleration, and the maximum and desired deceleration rates.

Traffic Inputs

Heavy vehicle peak flow rates used were 1,150 and 1,220 tph and for passenger vehicles was 2,500 vph. During the peak hours a maximum of 230 and 300 tph were assigned on the slip ramps and consequently exited the highway. Similarly, 230 and 300 tph entered the highway through the on-ramps during the peak hour. Two different peak flows were used for heavy vehicles to evaluate the threshold for exiting vehicles.

Driver Behavior

From the literature, Gomes et al. (2003), the driver behavior parameters were specified in VISSIM. The important driving parameters calibrated were:

1. Special driving behaviors were assigned to vehicles that need to perform lane changing maneuvers specific to truck-only lanes and general purpose lanes.

2. 'CC' parameters that specify the acceleration, headway time, stand still distance, etc. were specified.
3. The diffusion time or the wait time for the vehicles performing the different maneuvers was set to 60 seconds.
4. Link behavior types like weaving, merging, and diverging were created and assigned to different segments.

Slip Ramp Spacing

The ramp spacing is evaluated by studying the speed flow behavior of vehicles on the key segments of the general purpose lanes and recording the number of vehicles entering and exiting the slip ramp. The slip ramp spacing was determined by the sum of the length of the merge, link, and the diverge segments. Several different segment lengths were tried for both Part 1 and 2. **Tables 2** and **3** provide the segment lengths for Part 1 and 2.

Simulation Run

The simulation for each of the slip ramp spacing distance was run three times with three different random seeds. Random seeds simulate different driving behavior of drivers each time. The resolution was set to two simulation seconds for each time step. The first three cases in **Table 2** and **Table 3** were simulated with 230 tph and the last three cases were simulated with 300 tph.

Results and Discussion

Figure 2 shows the different links on the general purpose lanes that were studied for speed flow characteristics of vehicles before the interchange. **Table 1** shows the different cases simulated by changing the lengths of the segments specified in **Figure 2**. Different scenarios were simulated to determine the optimum lengths for the merge, diverge, and the link segments. It was observed that Case 1 with a merge length of 800 feet, link length of 900 feet, and diverge length of 650 feet consistently performed poorly with very low speeds for all vehicles during peak flows. For peak flow, **Figure 8**, the heavy vehicles slowed down to 30 mph to exit using the off-ramp. From **Figure 9** it can be observed that the exiting heavy vehicles also affect the speeds of passenger vehicles lowering them below 40 mph. This is a failed case with vehicles recording low speeds.

Table 2 Simulated Lengths for Part 1 (Before Interchange)

Cases	Merge A	Link B	Diverge C	Recommendation
Case 1: 800_900_650	800	900	650	Failed
Case 2: 800_1500_650	800	1500	650	Poor
Case 3: 1000_1500_800	1000	1500	800	Acceptable
Case 4: 1000_1500_1000	1000	1500	1000	Poor for higher volumes
Case 5: 1200_1500_1000	1200	1500	1000	Recommended for higher volumes
Case 6: 1200_2000_1000	1200	2000	1200	Recommended for higher volumes

Case 3 with lengths of 1,000, 1,500, and 800 feet for merge, link, and diverge sections, respectively is optimum for vehicles to maintain their speeds while merging or exiting. From all the figures it can be observed that vehicle speeds for this particular case are consistently between 50 and 70 mph. This is an acceptable case for heavy vehicles using the slip ramp with a peak flow rate of 230 trucks/hour. Greater design lengths were simulated but no significant improvements in vehicle speeds for the same peak flow were observed.

Additional analysis with increased flows was carried out for Cases 4 to 6 and it was found that Cases 5 and 6 performed well for higher volumes with vehicles slowing down at much higher volumes compared to the previous cases. With increase in merge and diverge lengths, the heavy vehicles were observed at lower speeds at flow rates of around 300 trucks/hr as compared to 230 trucks/hour in Cases 1, 2 and 3. As seen from **Figures 5, 7, and 9** passenger vehicles slowed down to below 60 mph at higher flow rates. It needs to be noted that the simulation was run with both the heavy vehicles and passenger vehicles reaching peak flows at the same time. The heavy vehicles during their peak flow do not slow down the passenger vehicles both on the merge and the diverge sections. Cases 5 and 6 with additional lengths are recommended if the general purpose lanes experience higher flow rates.

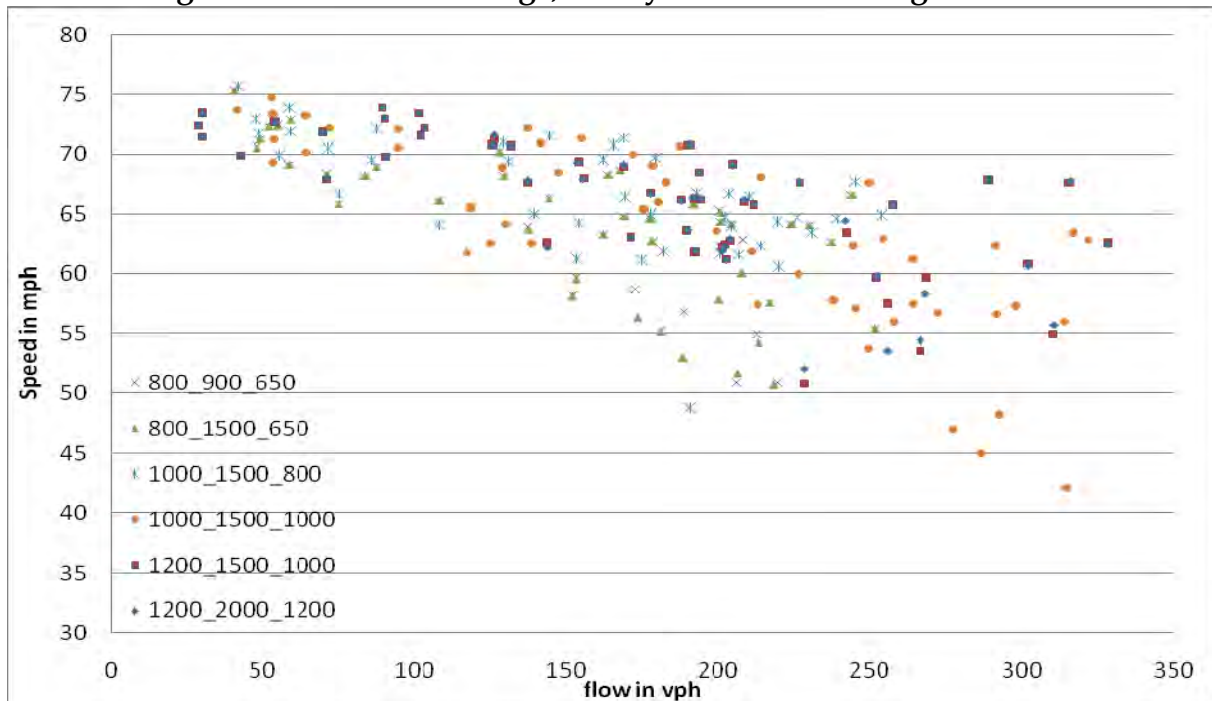
Figure 4 Before Interchange, Heavy Vehicles on Merge Section of GPL

Figure 3 presents Part 2 of general purpose lanes, i.e. after interchange. Speed flow characteristics of vehicles traveling on Sections X, Y and Z were analyzed. **Table 3** shows the different cases simulated for part 2. Cases 7 to 9 were simulated with normal peak flows and Cases 10 to 12 were simulated with higher peak flows. Similar trend was observed in the speed flow curves for the after interchange part with the additional lengths providing higher vehicular speeds.

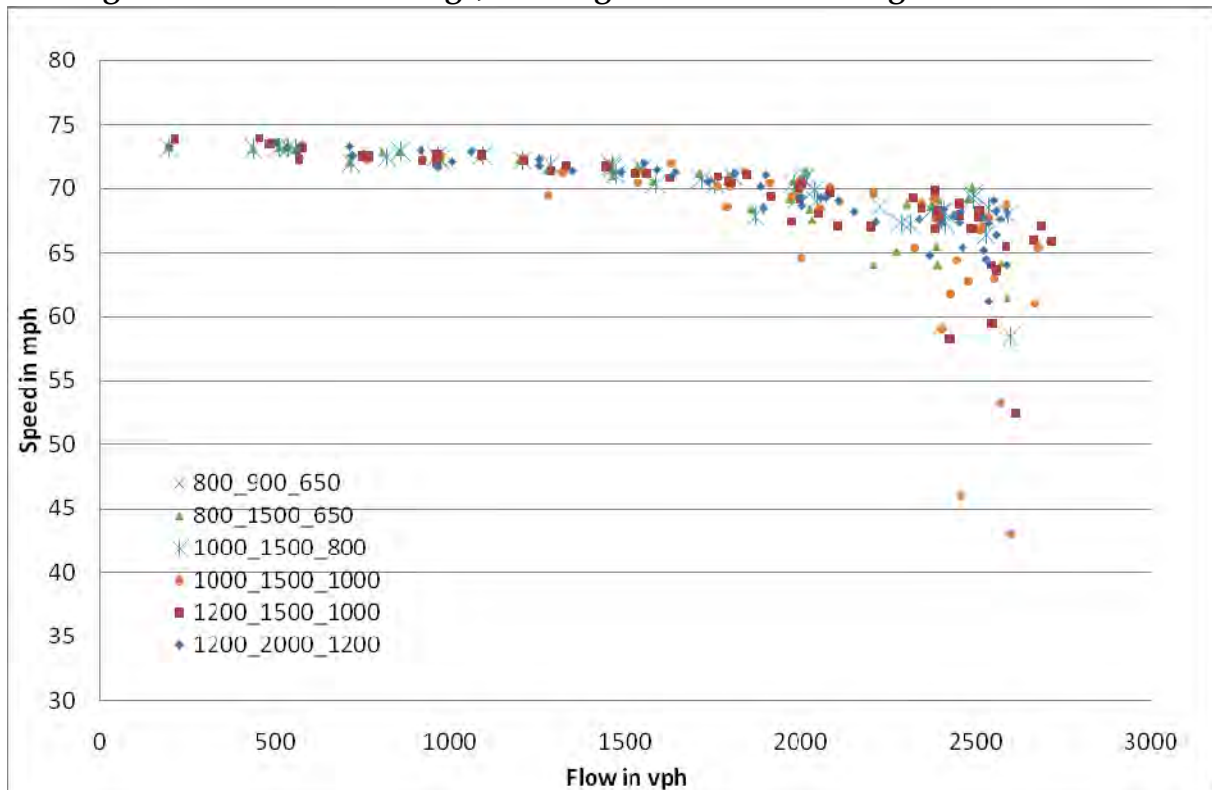
Table 3 Simulated Lengths for Part 2 of GPL (After Interchange)

Cases	Merge X	Link Y	Diverge Z	Recommendation
Case 7: 800_900_650	800	900	650	Failed
Case 8: 800_1500_650	800	1500	650	Poor
Case 9: 1000_1500_800	1000	1500	800	Acceptable
Case 10: 1000_1500_1000	1000	1500	1000	Poor for higher volumes
Case 11: 1200_1500_1000	1200	1500	1000	Recommended for higher volumes
Case 12: 1200_2000_1000	1200	2000	1200	Recommended for higher volumes

The speed of passenger vehicles were consistent in the merge and link sections with speeds varying from 60 to 70 mph for all the cases. In the diverge section for Case 7, the speeds of both the passenger vehicles and the heavy vehicles during the peak flows were very low compared to other cases that have greater diverge lengths. Case 7,

therefore, is not recommended as vehicles slowed down considerably on the general purpose lanes. Case 3 with a diverge length of 800 feet was found to be acceptable with the speeds of passenger vehicles above 60 mph. Additional analysis was carried out for longer segment lengths and higher peak flows and Cases 11 and 12 are recommended for higher traffic flow rates. Case 10 with diverge length of 1,000 feet was not found to be suitable for higher volumes but better compared to Case 9 for normal peak flows. It is recommended to increase the merge length for the heavy vehicles to accelerate to 70 mph.

Figure 5 Before Interchange, Passenger Vehicles on Merge Section of GPL



From the analysis it can be inferred that the governing lengths of merge, link, and diverge is the distance needed to complete the lane change of heavy vehicles from the slip ramp to the off-ramp and from the on-ramp to the slip ramp. The recommended merge length is 1,200 feet for peak heavy vehicles, for link length it is 1,500 feet for normal, and 2,000 feet for higher peak heavy vehicle traffic. Similarly, the recommended diverge length is 1,000 and 1,200 feet for the two traffic conditions.

The recommended lengths of merge, diverge, and the link would not be affected by the grade as long as it is less than three percent. In case it is greater than three percent,

acceleration and stopping behavior of heavy vehicles would be affected and longer lengths of the segments would be required.

Figure 6 Before Interchange, Heavy Vehicles on Link Section of GPL

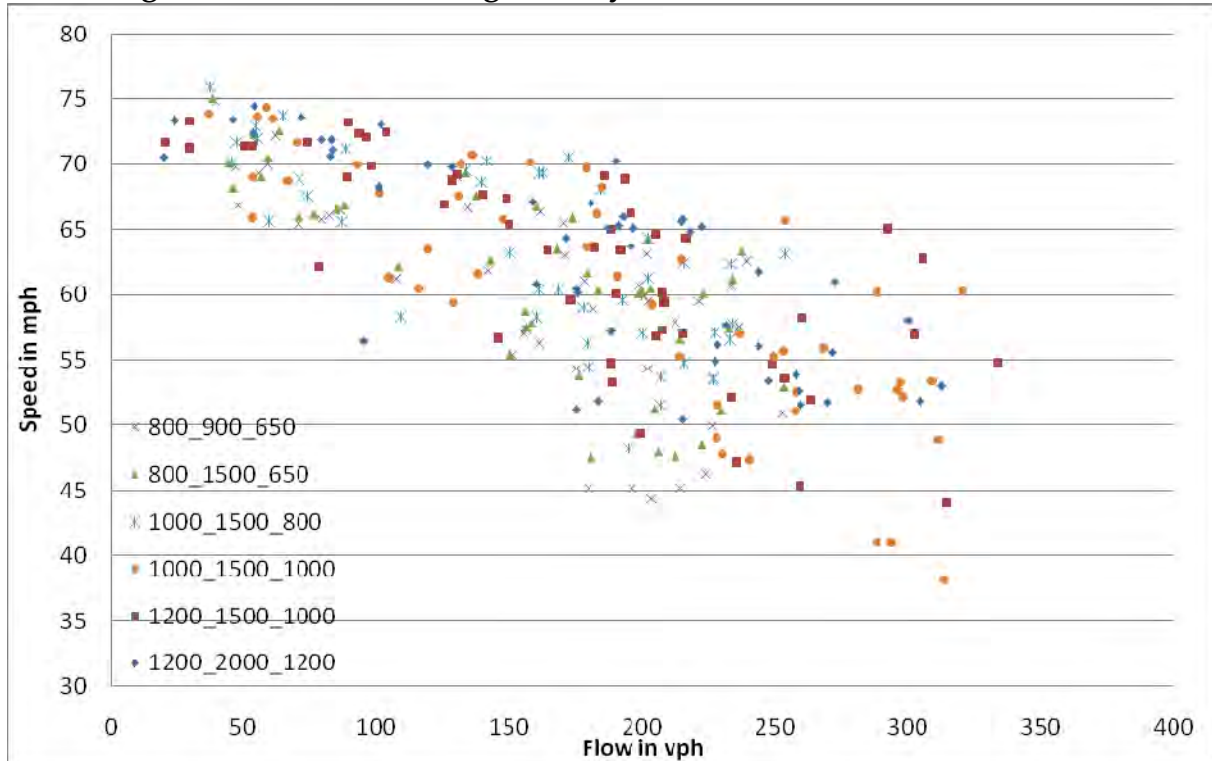


Figure 7 Before Interchange, Passenger Vehicles on Link Section of GPL

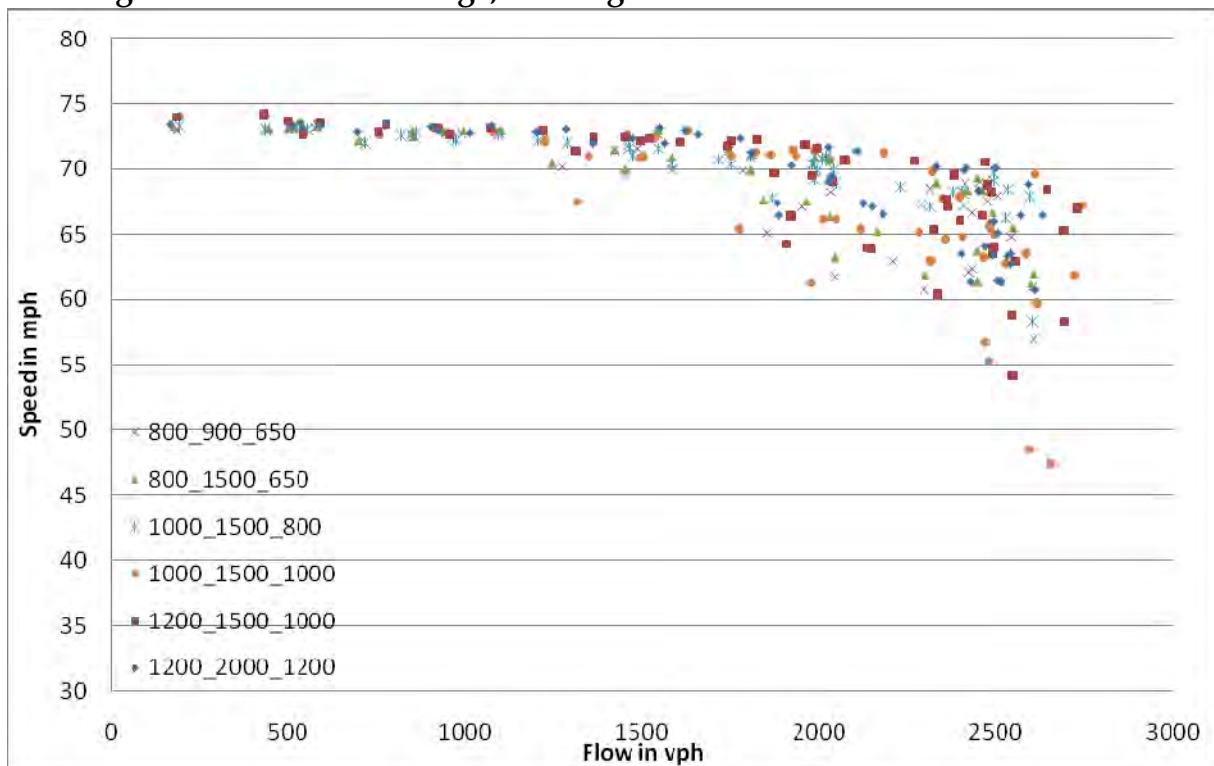


Figure 8 Before Interchange, Heavy Vehicles on Diverge Section of GPL

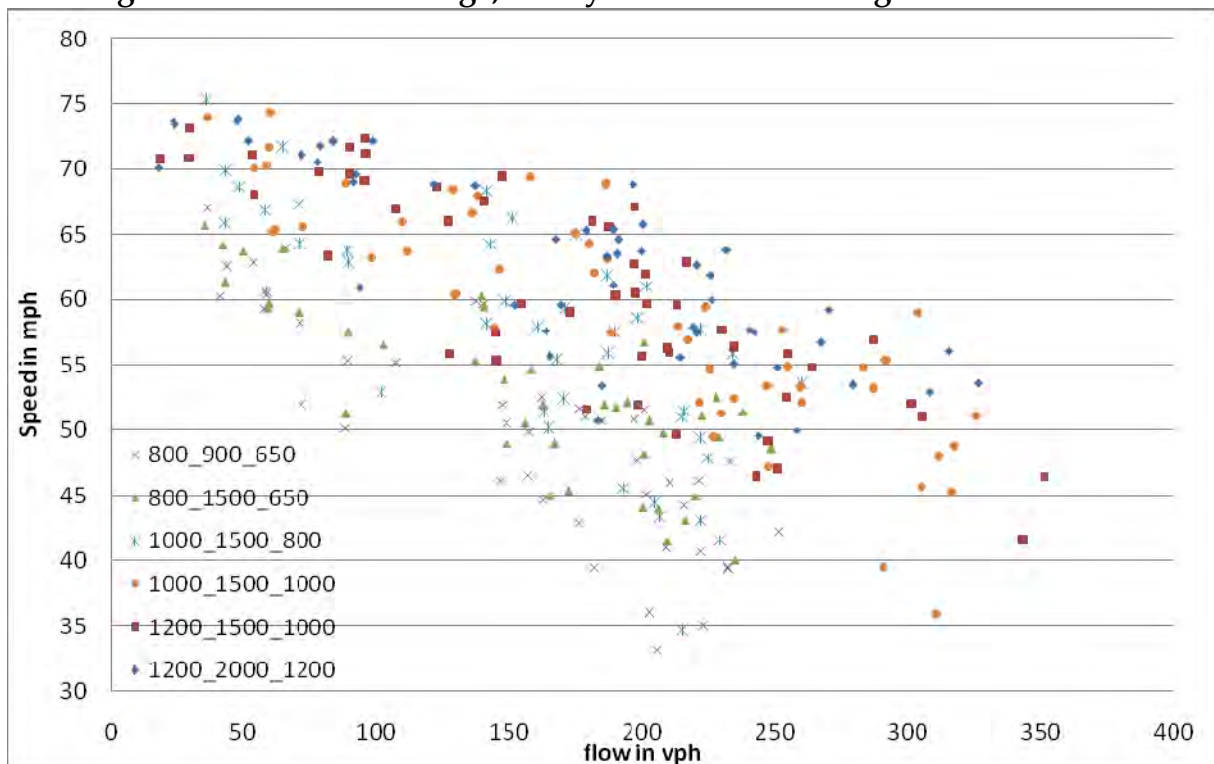


Figure 9 Before Interchange, Passenger Vehicles on Diverge Section of GPL

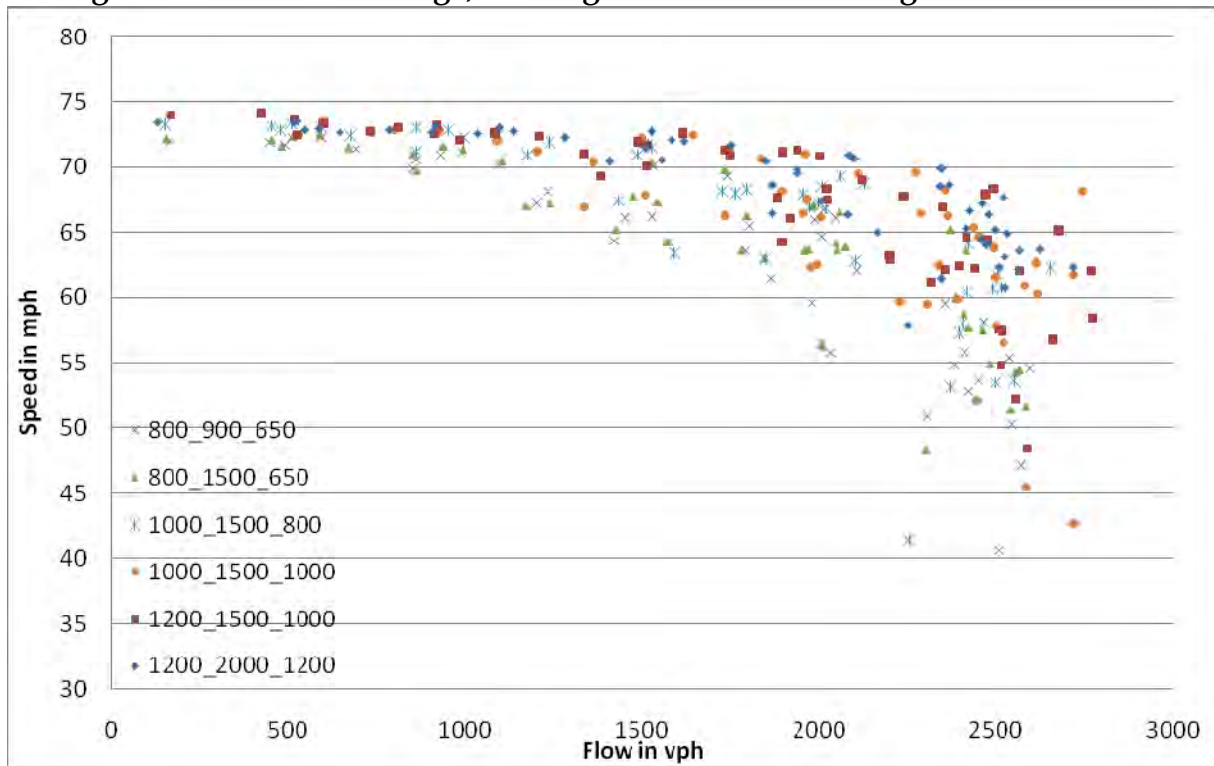


Figure 10 After Interchange, Heavy Vehicles on the Merge Section of Part 2 GPL

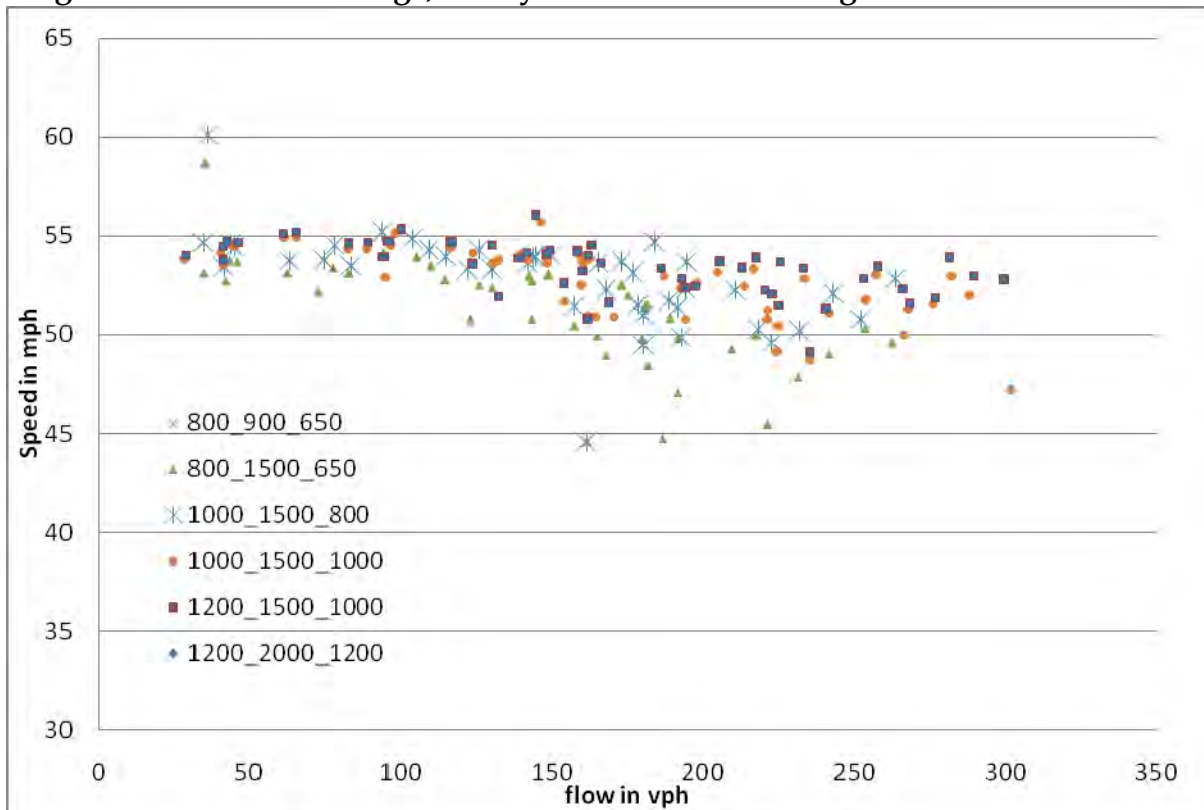


Figure 11 After Interchange, Passenger Vehicles on Merge Section of GPL

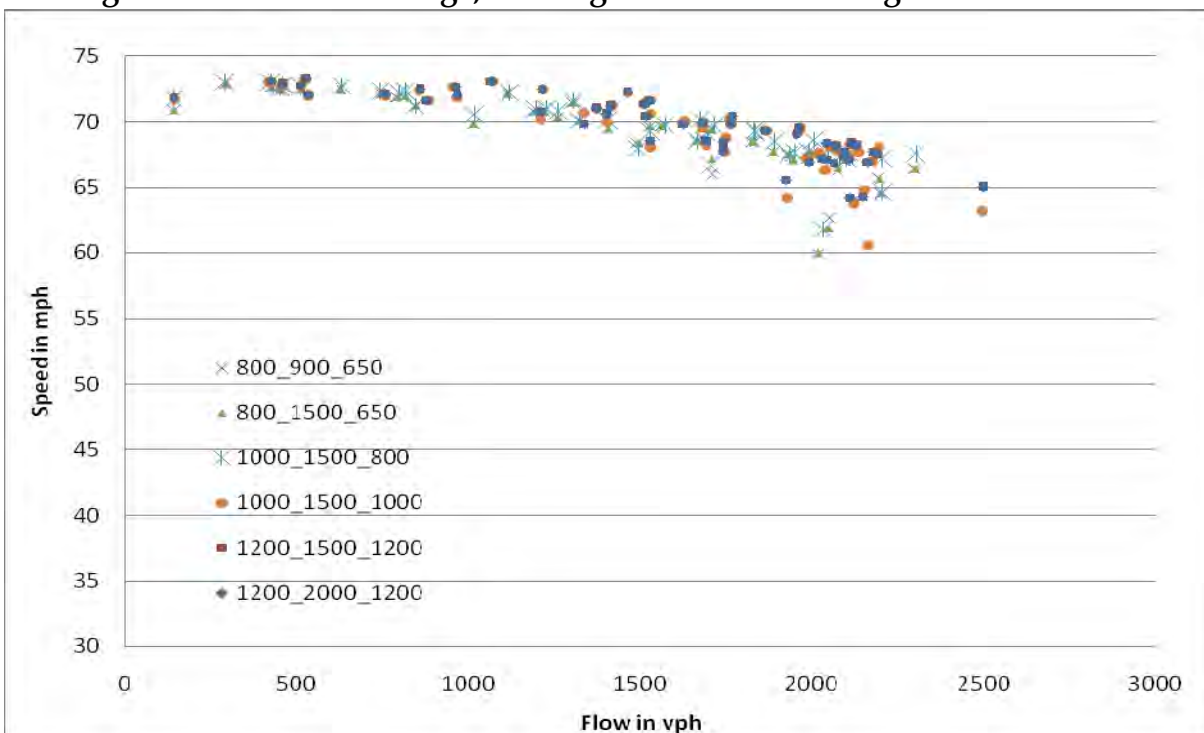


Figure 12 After Interchange, Heavy Vehicles on the Link Section of GPL

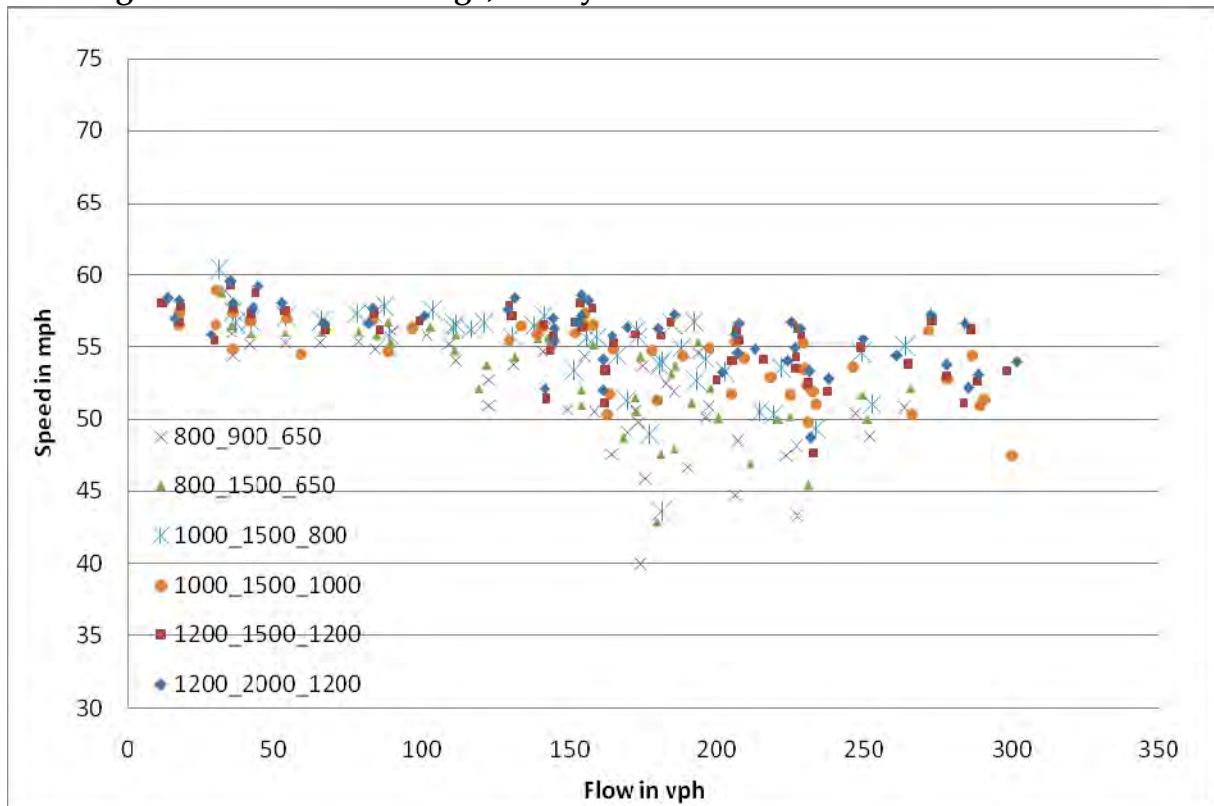


Figure 13 After Interchange, Passenger Vehicles on Link Section of Part 2 GPL

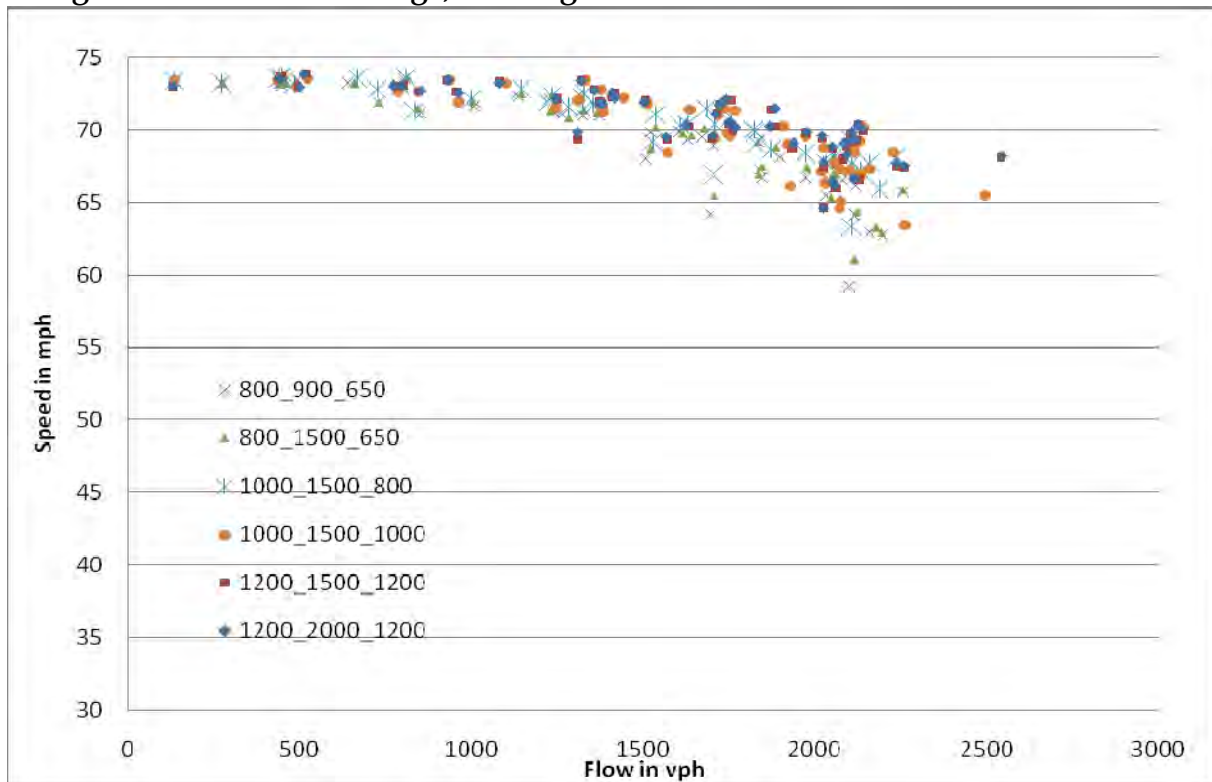


Figure 14 After Interchange, Heavy Vehicles on the Diverge Section of Part 2 GPL

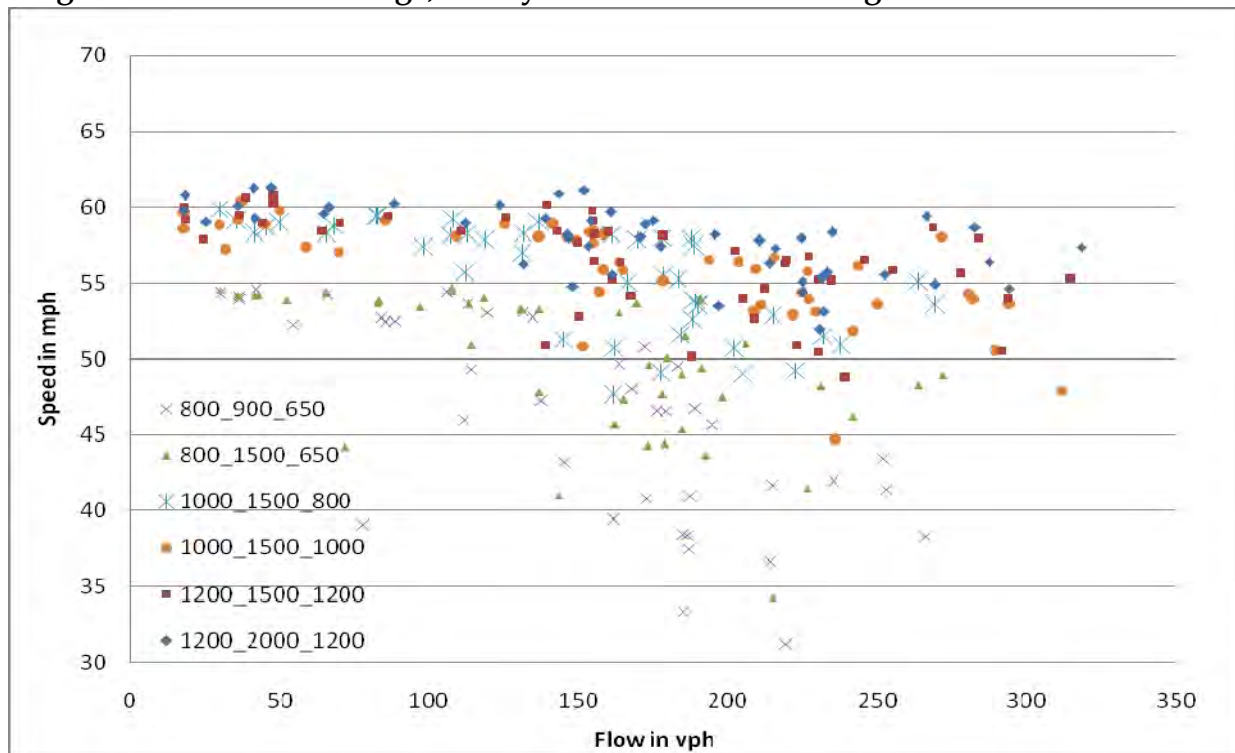
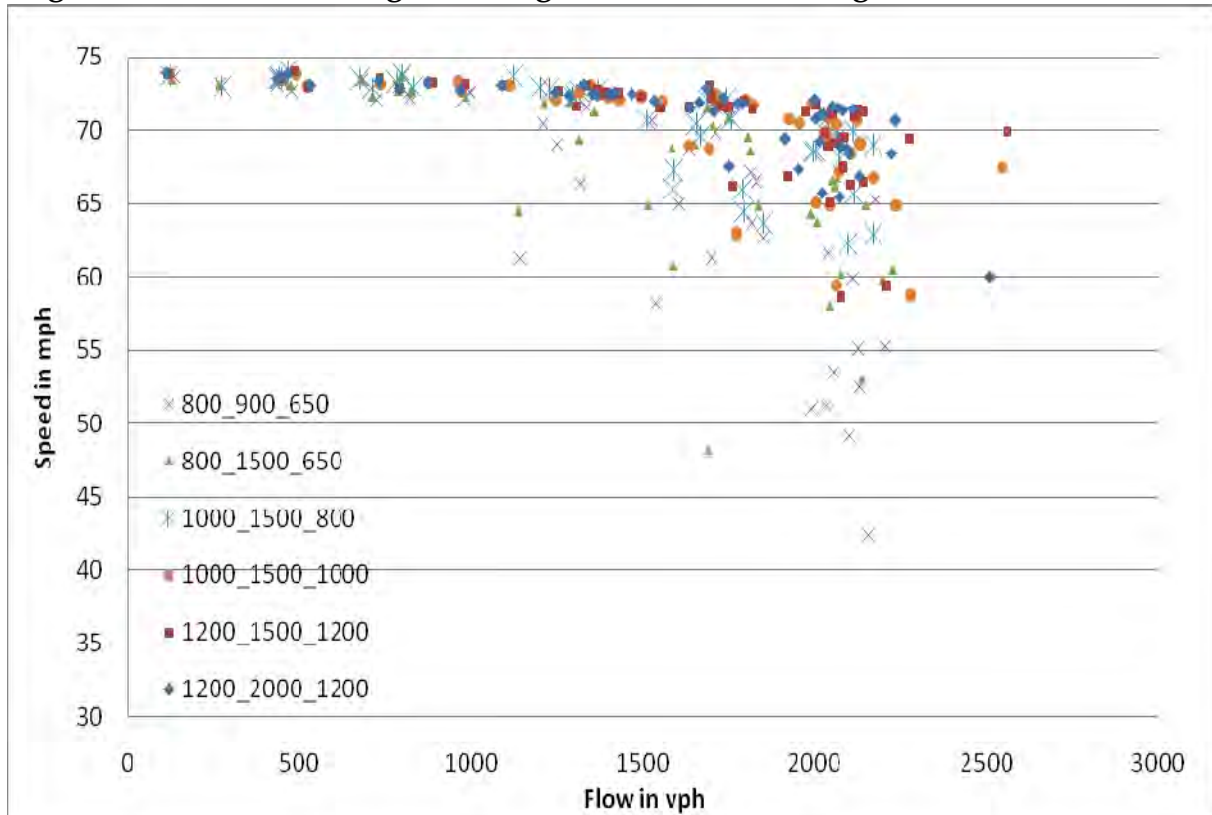


Figure 15 After Interchange, Passenger Vehicles on Diverge Section of Part 2 GPL

Literature Review

MoDOT is planning to build truck-only lanes on I-70. MoDOT's plan calls for widening and rebuilding the highway, setting aside two lanes exclusively for heavy vehicles and two for passenger cars, pickups and SUVs. MoDOT plans to add interchanges used exclusively by heavy vehicles, some used exclusively by cars, and new bridges. The goal is to separate heavy traffic, mainly truck traffic, from everyday automobiles, to improve the safety of both sets of travelers. According to MoDOT, heavy vehicles are involved in 28 percent of all accidents and 40 percent of fatal accidents on I-70 through Missouri. This review provides information about the slip ramp spacing used on truck-only lanes and the research carried out using simulation.

The main objective of this research is to identify the distance required for heavy vehicles to safely cross two general purpose lanes of traffic:

1. To get from the truck-only lanes using slip ramps to the interchange exit ramps.
2. To get from interchange on-ramps to truck-only lane slip ramps using simulation.

Managed Lane Ramp and Roadway Design Issues TTI Report (2003)

The TTI report presents the ramp design and truck performance. Researchers used simulation to obtain an appreciation of the effects of ramp spacing on freeway operations. Speed was the primary measure of effectiveness used to evaluate the effects of different ramp spacings, volume levels, and weaving percentages. The VISSIM microscopic traffic simulation model was selected for the ramp spacing and weaving simulation. One of the goals outlined was to quantify the effects of ramp spacing on freeway operations by considering both the spacing of the ramps to the freeway lanes and the ramps between freeway lanes and managed lanes. The key variables for the simulation scenarios were ramp spacing, initial freeway per lane volume, and percent of freeway entrance ramp traffic weaving to managed lane facility. The key findings are as follows:

1. Ramp spacing only affected average freeway speeds when the initial freeway volumes were very high (2000 veh/hr/ln) and ramp spacing was at the lowest value used in the simulation (1000 ft [305 m]).
2. Ramp spacing and entering volume levels are directly related. When ramp spacing increases, entering volume per ramp also increases so that the number of vehicles attempting to enter the corridor remains the same.
3. In each weaving level comparison, the average freeway speed dropped faster for the shorter ramp spacing. This shows that operations are more sensitive to small increases in traffic volumes when ramp spacing is shorter.

Sensitivity of Simulated Capacity to Modification of VISSIM Driver Behavior Parameters

This paper focuses on the sensitivity analysis of VISSIM 'CC' values to determine the change in capacity output. The analysis is undertaken for a simulation developed for the interchange of US-75 and SH-190 (George Bush Turnpike). This paper is used for the truck-only lane project to calibrate the CC values in the VISSIM. The findings are as follows:

CC0 (Stand Still Acceleration)

As CC0 value increased, capacity decreased. It is the dominant portion of the safety distance and therefore has pronounced impact on capacity

CC1 (Headway Time)

The calibrated model CC1 value was found to be 0.85.

CC2 (Following Variation)

This is the factor that restricts the longitudinal oscillation of vehicles in simulation. As CC2 value increases, the average capacity of the corridor decreases. As CC2 values decreases it shows that the simulation driver's following behavior is much more aggressive. This means that the driver will be speeding up and slowing down at a higher frequency.

CC3 (Threshold for Entering Following)

It controls the start of deceleration process. If a driver recognizes that it is following a slower moving vehicle, it defines how many seconds to reaching the safety distance before the driver should decelerate. It was found out that it has no significant effect on capacity.

CC4 and CC5 (Following Thresholds)

Smaller absolute values of CC4 and CC5 result in a more sensitive reaction of the drivers to the acceleration and deceleration of the preceding car. For smaller values, vehicles follow each other more closely throughout the simulation.

CC6 (Speed Dependency of Oscillation)

This parameter controls the effects of the distance on speed oscillation of following vehicles. Increase in the CC6 values results in driver's speed oscillation, increasing as the distance between the leader's vehicle and the following vehicle increases. This means that a driver will accelerate and decelerate more often when the distance to the preceding vehicle increases. It was not significant on capacity.

CC7 (Oscillation Acceleration)

CC7 controls the degree to which the speed oscillation produced by a vehicle is gentle and gradual or sudden and violent. CC7 had little effect on the roadway capacity.

CC8 (Acceleration from Stopped Condition)

This is bounded by the minimum and maximum acceleration values defined as the base data functions in the VISSIM. CC8 has a significant negative impact on capacity. As CC8 decreases so does the capacity of the road way.

CC9 (Acceleration at 50 mph)

CC9 affects the acceleration behavior of following vehicles when they are traveling at 50 mph that is unlikely speed in a bottle neck condition so has no significant impact on capacity.

Look Back Distance:

Look back distance is defined as the distance upstream of a ramp or a section of roadway requiring some degree of maneuvering that a driver begins to position for the maneuver, the distance upstream that a vehicle will begin to attempt to change lanes.

Table 4 Summary of Capacity Sensitivity to Parameter Modification

Parameter	Level	Value	Resulting Capacity (vph)	SE	t-Statistic	Degrees of Freedom	Critical t-Value	Significantly Different from Value at Calibration?
CC0 Default = 4.92	Low	2.0	8062	82.5	1.35	17	2.567	N
	Calibrated	4.8	8020	93.8	—	—	—	—
	Medium	5.0	8054	98.4	0.96	14	2.624	N
	High	10.0	7788	87.2	7.15	16	2.583	Y
CC1 Default = 0.90	Low	0.50	8074	99.2	1.50	14	2.624	N
	Calibrated	0.85	8020	93.8	—	—	—	—
	Medium	1.00	7888	82.7	4.24	17	2.567	Y
	High	1.50	6818	53.8	49.79	27	2.473	Y
CC2 Default = 13.12	Low	5.00	8119	106.0	2.63	14	2.624	Y
	Medium	10.00	8112	76.9	3.08	18	2.552	Y
	Calibrated	13.12	8020	93.8	—	—	—	—
	High	20.00	7803	89.2	6.59	16	2.583	Y
CC3 Default = -8.00	Low	-4	7976	79.4	1.44	18	2.552	N
	Calibrated	-8	8020	93.8	—	—	—	—
	Medium	-10	7980	94.4	1.17	15	2.602	N
	High	-15	8030	87.5	0.31	16	2.583	N
CC4 and CC5 Default = ±0.35	Low	0.1	8090	103	1.89	14	2.624	N
	Medium	0.5	8082	91.6	1.85	15	2.602	N
	Calibrated	1.0	8020	93.8	—	—	—	—
	High	2.0	7555	64.4	17.47	22	2.508	Y
CC6 Default = 11.44	Low	2.00	7989	99	0.86	14	2.624	N
	Medium	8.00	7943	91.1	2.29	15	2.602	N
	Calibrated	11.44	8020	93.8	—	—	—	—
	High	20.00	8033	91.4	0.37	15	2.602	N
CC7 Default = 0.82	Low	0.50	8035	83.4	0.47	17	2.567	N
	Calibrated	0.82	8020	93.8	—	—	—	—
	Medium	1.00	7990	89.2	0.90	16	2.583	N
	High	1.50	8053	92.3	0.98	15	2.602	N
CC8 Default = 11.48	Low	6.4	7638	95.3	11.03	15	2.602	Y
	Medium	8.0	7925	94.3	2.75	15	2.602	Y
	High	10.0	8005	87.3	0.47	16	2.583	N
	Calibrated	11.5	8020	93.8	—	—	—	—
CC9 Default = 4.92	Low	2.10	8024	96.3	0.12	15	2.602	N
	Medium	4.50	8002	83.5	0.56	17	2.567	N
	Calibrated	4.92	8020	93.8	—	—	—	—
	High	7.50	8034	84.1	0.45	17	2.567	N
Look-back distance Default = 656.2	Low	50	8316	74.6	10.14	19	2.539	Y
	Calibrated	300	8020	93.8	—	—	—	—
	Medium	5000	8193	75.6	5.87	19	2.539	Y
	High	1000	8307	67.3	10.50	21	2.518	Y

A Micro Simulation Model of a Congested Freeway Using VISSIM (2003)

This paper outlined a methodology for constructing and calibrating a simulation model of a unidirectional freeway with on-ramp control. It was tested on a 15-mile stretch of I-210 WB in Pasadena, California. This test site had an HOV lane with an intermittent

barrier, a heavy freeway connector, 20 metered on-ramps with and without HOV bypass lanes, and three interacting bottlenecks. The model construction procedure consisted of:

1. Identifying important geometric features
2. Collecting and processing of traffic data
3. Analysis of the mainline data to identify recurring bottlenecks
4. VISSIM coding
5. Calibration based on observations from item 3

The traffic data was collected from two sources and they are PeMS databases which gather 30 second and 5 minute data from over 30,000 miles of freeway in California and the manual counts that provided the ramp volumes between October 2001 and January 2002.

A qualitative set of goals was established for the calibration. These were met with relatively few modifications to VISSIM's driver behavior parameters. The goal for the calibration was to match more qualitative aspects of the freeway operation. These were:

1. Location of the three identified bottlenecks
2. Initial and final times for each of the three mainline queues
3. Extent of the queues
4. Utilization of the HOV lane
5. Onramp performance

The goal for the HOV lane was to approximate the flow values from PeMS. For the on-ramps, the only objective was to avoid large on-ramp queues that might obstruct the vehicle sources. It has been found out that in the car following models CC1 value has important influence on capacity and its value of -0.35/0.35 produced no congestion. Analysis of the supply and demand characteristics of the freeway lead to the conclusion that two of these bottlenecks were geometry-induced, while another was caused by weaving. A successful calibration of the VISSIM model was carried out based on this observation. This study has shown that the VISSIM simulation environment is well-suited for such freeway studies involving complex interactions. With few and well reasoned modifications to its driver behavior parameters, the simulation model is capable of reproducing the field-measured response on the on-ramps, HOV lanes, and mixed-flow lanes.

School Bus Acceleration Characteristics (1998)

This study was used to plot the acceleration/deceleration characteristics plots for buses in VISSIM. In this research several school buses performances data was collected that was used to construct speed/time/distance curves. The primary objectives of this research project included investigating performance characteristics of full-size school buses. Information was gathered as each school bus accelerated from a side street or driveway onto the through roadway. Data was also gathered for school buses accelerating up a grade and for school buses accelerating from a stopped position at a railroad crossing. Field personnel collected the data with the classifier/road tube and a video camera. The total number of school bus speeds available at each station were: 171 at 18 m, 129 at 100 m, 127 at 200 m, 77 at 300 m, 35 at 400 m, and 36 at 500 m. The measured speeds ranged between 17.1- 33.3 kph at 18 m, 31.7-53.9 kph at 100 m, 38.1-67.6 kph at 200 m, 43.1-72.1 kph at 300 m, 51.2-79.3 kph at 400 m, and 56.2-82.2 kph at 500 m. The data collected was used to plot VISSIM acceleration deceleration curves for buses.

Table 5 School Bus 12.5 Percentile Speeds and Acceleration Times

Distance (m)							
School Bus	0m	18m	100m	200m	300m	400m	500m
12.5 percentile Speed @ 10% CI (kph)	0	21.4	37.8	45.7	55.5	58.2	62.6
Cumulative Accel. Time (sec)	0	6	16.1	24.6	31.8	38.2	44.1

Strategies for Separating Trucks from Passenger Vehicles: Truck Facility Guidebook (2006)


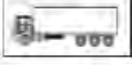

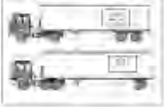

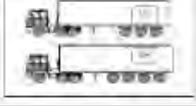



The main objective of this guidebook is to help Texas DOT engineers in setting up of exclusive truck lane facilities. This is carried out using a nine step process and the important points are:

1. Acquiring truck and non truck volume.
2. Predict future truck and non-truck volume.
3. Determine desired level of service.
4. Determine number of truck roadway lanes.

VISSIM is used to calculate the level of service values based on the characteristics, terrain factors, and interchange spacing. Additionally, CORSIM is used to evaluate and

model the truck roadways. Within CORSIM, all heavy vehicles featured a headway factor of 120, a jerk value of 7.0 ft/s², an emergency deceleration of 15.0 ft/s², and a maximum deceleration under normal conditions of 8.0 ft/s². The headway factor shows us that truck drivers generally allow greater spacing between vehicles than automobile drivers, and the jerk and acceleration values govern the acceleration and braking performance limits of heavy vehicles. These values were found to be reasonably consistent with truck performance data. CORSIM has a limited number of truck types available for inclusion in the model and the composition was as follows.

Table 6 Truck Classification Schemes

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

The classification is used in the VISSIM truck-only lane simulation to model the truck-only lanes composition and truck characteristics.

Acceleration Lane Design for Higher Truck Volumes (2008)

The objective of this research project was to examine the speeds reached at certain distances by heavy vehicles accelerating onto the main lanes of a freeway, and offers recommendations about the lengths of acceleration lanes needed for heavy vehicles to accelerate to speeds closer to the speeds on the main lanes. This would reduce the degree to which entering heavy vehicles disrupt freeway traffic flow as they merge into the main lanes. The findings from this research are directed at locations with higher tractor trailer truck volumes, freeway interchanges like the truck-only lane interchange system. A literature review was undertaken to study the vehicle characteristics, adjustment factors for current acceleration lane design guidelines, acceleration lane design for heavy commercial vehicles, design criteria for high speed roadways, the operation of large trucks, and vehicular collision factors. Data collection was accomplished to record the speed, distance, time, and weight of the trucks as well as the volume of traffic on the freeway into which the trucks were entering.

Table 7 Tractor-Trailer Truck Speed at Acceleration Lane End

	truck speed			truck freeway speed limit (mph)	distance to accel. lane end (feet)
	min. (mph)	avg. (mph)	max. (mph)		
Alma EB	29	44	56	65	1750
Hope EB	35	51	64	65	2000
Joplin WB	23	37	45	70	1000
Lehi EB	31	41	52	65	1250
Marion SB	38	48	55	65	1850

The above table shows that the average tractor-trailer truck speeds at the end of the acceleration lanes were more than 10 mph below the posted truck speed limit at all of the data collection sites. They ranged from 14 to 33 mph below the posted truck speed limit. The maximum tractor-trailer truck speeds at the end of the acceleration lanes were also less than the posted truck speed limit. They ranged from 1 to 25 mph below the posted truck speed limit. Three out of five of the maximum truck speeds were 10 mph or more below the posted truck speed limit. The three data collection sites where the maximum truck speeds were closest to the posted truck speed limit were the three sites with the largest distances between the static truck weight scales and the end of the acceleration lane. The minimum truck speeds at the end of the acceleration lanes ranged from 27 to 47 mph below the posted truck speed limits. Based on data from this research, when a high composition of tractor-trailer trucks are entering the traffic flow on a freeway with a speed limit of 65 mph, a minimum acceleration lane length on the order of 2,700 feet is required just to allow an average vehicle on a level grade to get within 10 mph of the posted speed before the entry ramp ends. A length of almost 3,500

feet would be needed to accommodate the 10th percentile vehicle. These acceleration lane lengths were consistent with the magnitude as those found in NCHRP Report 505. It is suggested that acceleration lanes with lengths approximately equal to the values proposed by this project be considered at locations where significant volumes of trucks enter a freeway similar to slip ramps on the truck-only lane.

Identifying the Impact of Truck -Lane Restriction Strategies on Traffic Flow and Safety Using Simulation (2007)

The paper by Nicholas J. Garber focuses on the measurement of truck lane restriction strategies (TLRS) using conflict as the measurement of effectiveness (MOE). The MOEs used to evaluate the impact of different lane restrictions on operational performance were lane changes, average speed, speed distribution, and volume distribution. The software tool PARAMICS V3.0 is used for simulation. The simulation results showed that all the geometric and traffic characteristics had a significant impact on freeway safety and operation. In addition, truck percentage and volume were identified as key factors that had a significant impact on the selection of the optimal truck lane restriction strategy. Optimal alternatives of truck lane restriction strategies under different truck percentages and volumes were identified with the objective of reducing traffic conflicts and enhancing level of service (LOS). Guidelines were then developed for the application of truck lane restrictions under alternative traffic and geometric conditions. The field data for calibration were collected on the I-295 freeway section at Henrico where I-295 intersects I-64. The calibration parameters for PARAMICS are provided in Table 8.

Table 8 Calibration Parameters

Parameter	Description	Default value	Acceptable range
Mean headway (sec)	The mean target headway, in seconds	1.0	0.6 – 2.2
Mean reaction time (sec)	The mean reaction time of each driver, in seconds	1.0	0.3 – 1.9
Speed memory	Each vehicle has the facility to remember its own speed for a number of time steps. This memory facility is used to implement driver reaction time by basing the change in speed of the following vehicle on the speed of the leading vehicle at a time in the recent past. Changing the size of the speed memory allows the modeling of larger reaction times or smaller time steps	3	1 – 9
Curve speed factor	Set a factor to control the amount to which vehicles slow down due to curvature on road	1.0	1.0 – 5.0
Headway factor	The target headway for all vehicles can be modulated using this factor. For example, in a tunnel, the user might know that drivers commonly extend their headway by 50%	1.0	0.6 – 1.4
Link speed (mph)	The desired speed when the volume is low	65	60 - 80

Table 9 Optimal Parameter Set

Parameters	Calibrated Value
Mean headway (sec)	1.35
Mean reaction time (sec)	0.53
Speed memory	4
Curve speed factor	1.5
Headway factor	1.0
Link speed (mph)	72

The simulation network coded in this study is a straight five-mile freeway section with a varied number of lanes, grade, and interchange density. The lane restriction strategies applied depended on the number of lanes of the freeway in each direction. Grade was chosen as an independent variable. The posted speed limits were 55, 65, and 75 mph to cover a range around 65 mph which is a typical posted speed limit on interstate highways in Virginia. The traffic volumes on both main road and ramp were 100, 500, 1000, 1,500 to 2,000 vphpl to incorporate different LOS traffic conditions in the evaluation. For the traffic volume it is assumed that there are only two types of vehicles in the traffic mix: passenger cars and trucks.

Table 10 Four Configurations of Cars and Trucks in Simulation

Type	Length ft (m)	Height ft (m)	Width ft (m)	Weight (Tonne)	Top Speed mph (km/h)	Acceleration ft/s.s (m/s/s)	Deceleration ft/s/s (m/s/s)
Car	13.1 (4.0)	4.9 (1.5)	5.2 (1.6)	0.8	98.2 (158)	8.2 (2.5)	14.8 (4.5)
Truck	36.1 (11.0)	13.1 (4.0)	8.2 (2.5)	38.0	80.0 (128)	4.6 (1.4)	12.1 (3.7)

It also reports that the frequencies of lane-changing, merging, and rear-end conflicts increase with the increase in the interchange density. Apparently, more interchanges will increase the number of lane changes made by the vehicles that intend to get off the main road from exit ramps at the interchanges and increase the number of merging maneuvers for vehicles that intend to merge onto the main road from the entrance ramps

It concludes by stating that the influence of TLRS on conflicts and operational performances depends on investigated categories defined by the demand volume and

truck percentage. Generally, more significant impact is found when demand volume is greater and trucks occupy a larger portion in the traffic mix.

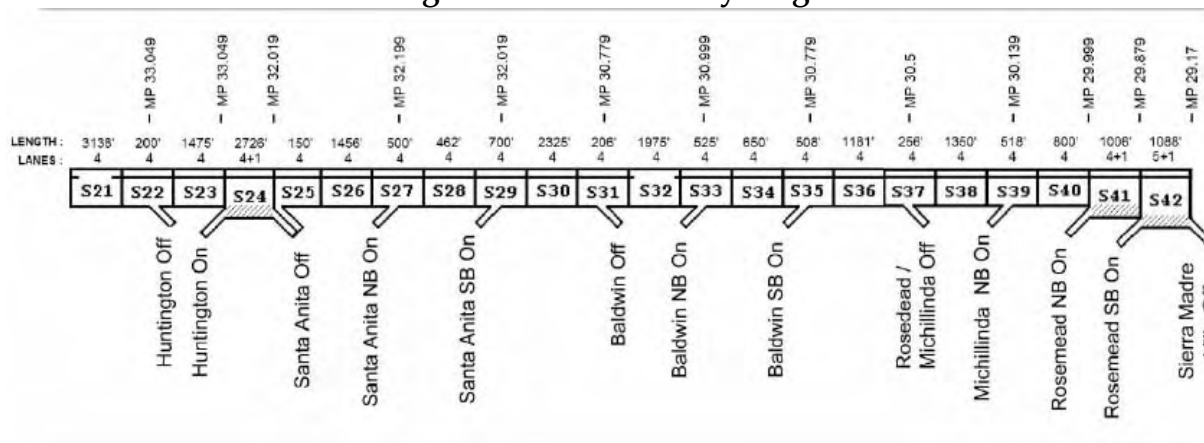
A Micro Simulation Model of a Congested Freeway Using VISSIM (2003)

This paper written by Gomes explains the procedure for constructing and calibrating a detailed model of a freeway using VISSIM. The calibration is done using a 15-mile stretch of I-210 West in Pasadena, California. Field data used as input to the model was compiled from two separate sources: loop-detectors on the on-ramps and mainline (PeMS), and a manual survey of on-ramps and off-ramps. The main steps of procedure are as follows:

1. Identification of important geometric features
2. Collection and processing of traffic data
3. Analysis of the mainline data to identify recurring bottlenecks
4. VISSIM coding

The procedure was applied to I-210 West, a freeway that presents several challenging features: 20 metered on-ramps, with and without HOV bypass lanes, an HOV lane with an intermittent barrier, an uncontrolled freeway connector, and several interacting bottlenecks.

Figure 16 I-210 Freeway diagram



Link types - Variations of following behavior (CC-) parameters

Suitable CC-parameters were taken to create realistic driving behavior. Three separate sets of CC-parameters were defined: Freeway, Hard Curve, and Soft Curve. Each was paired with a *merge link type* (with a 60 second diffusion time), giving a total of 6 link types. The Freeway and Freeway Merge types were used almost everywhere. One of the

findings of this study is that only modest adjustments to the CC-parameters were required to produce desired simulation response. Also, that capacity drops due to curvature can be reproduced with changes to the CC1 parameter alone.

Table 11 Calibrated CC Values

Link type	CC0	CC1	CC4 / CC5	Waiting time before diffusion
Freeway	1.7	0.9	-2.0 / 2.0	1
SoftCurve	1.7	1.1	-2.0 / 2.0	1
HardCurve	1.7	1.4	-2.0 / 2.0	1
Freeway Merge	1.7	0.9	-2.0 / 2.0	60
SoftCurve Merge	1.7	1.1	-2.0 / 2.0	60
HardCurve Merge	1.7	1.4	-2.0 / 2.0	60

(defaults: CC0=1.5, CC1=0.9, CCr/CC5=0.35/0.35, Waiting time = 60)

Adjustments to the look-back distance

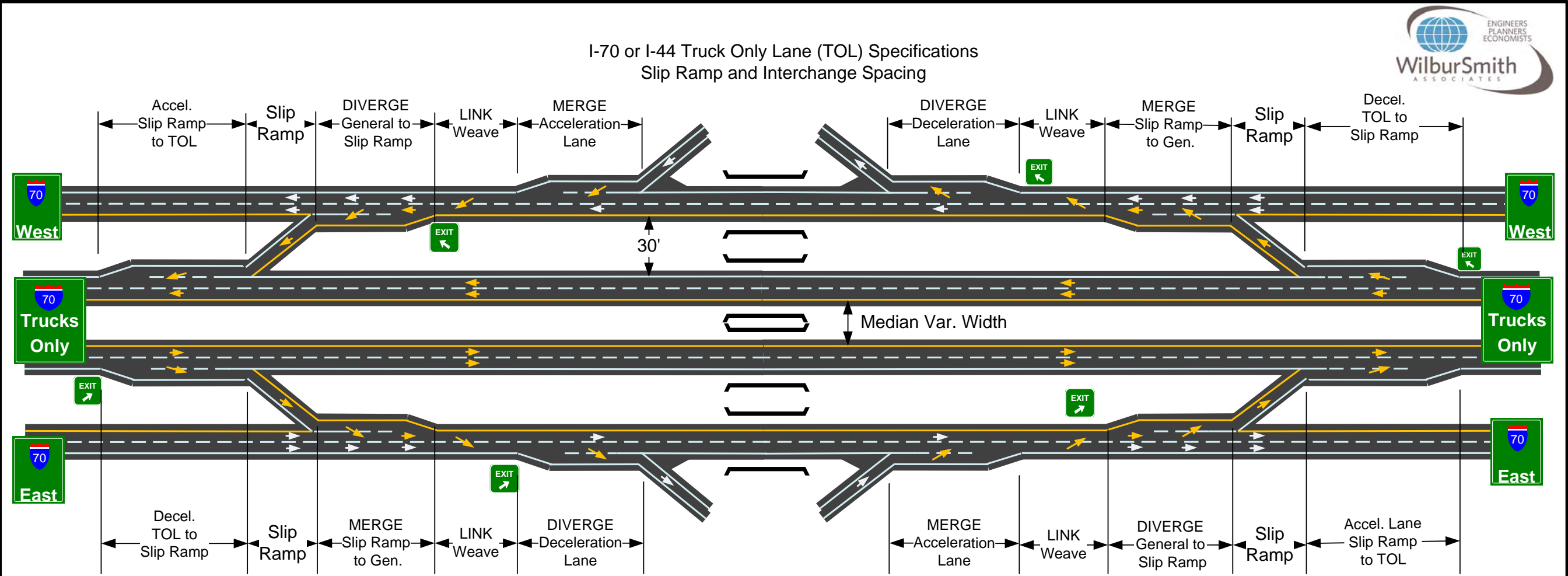
It was determined that the default look-back distance of 200 m is too small for large numbers of vehicles crossing over several lanes of traffic to reach their exits. On the other hand, increasing this value too much had the unrealistic effect of bunching up all of the exiting vehicles in the right-most lane, far upstream of their intended off-ramp. These vehicles then obstructed other upstream off-ramps and onramps. It was therefore necessary to tune the look-back distances individually for each off-ramp in a way that allowed vehicles sufficient weaving space while ensuring that these lane-change regions did not overlap.

Adjustments to the Waiting time before diffusion

Another modification that was found useful for eliminating the off-ramp blockages was to decrease the *waiting time before diffusion* parameter, from its default 60 seconds to 1 second. With this setting, vehicles that stopped at the emergency stop position on the mainline (at the off-ramp bifurcation) were immediately removed from the simulation, thereby minimizing the obstruction to the freeway. Eliminating these vehicles has little impact on the total travel time, since they are few and very close to their exit anyway. However, this adjustment is only recommended after the number of affected vehicles has been minimized by tuning the look-back distances. Also, one should be careful not to affect other bifurcations and/or lane drops within the network where larger waiting times are desired. For example, in the case of I-210, vehicles attempting to enter the freeway also frequently reached the emergency stop position at the end of the on-ramp/mainline merge sections (which contain a lane drop). To avoid these vehicles from being evaporated, a set of *merge* link types was created. These match their non-merge counterparts in all features except for the waiting time, which was set to 60

seconds for the merge types. Merge link types were used on all on-ramps and on-ramp merge sections.

Figure 17 Recommended Truck-Only Lane Slip Ramp Configuration



NOTES:

See Exhibit 10-71 of the AASHTO Green Book for Acceleration & Deceleration length adjustments due to grade.

Acceleration and Deceleration Lengths from Exhibits 10-70 and 10-72 of the AASHTO Green Book.

I-70 Gen & TOL Design Speed = 70 mph
General Purpose Ramp Design Speed = 50 mph
Slip Ramp Design Speed = 70 mph
Slip Ramp = 10,700' Radius reverse curve
SE=0.02 ft/ft for e_{max}=8%

Traffic Volumes	Distance between TOL cross over and Interchanges											
	TOL to Exit Ramp						Entrance Ramp to TOL					
	Diverge TOL to Slip Ramp	Slip Ramp 30' Median (rev curve)	Merge Slip to Gen.	Weave Section	General Diverge Lane	Distance to Interchange	Merge Accel. Lane	Weave Section	Diverge General to Slip Ramp	Slip Ramp 30' Median (rev curve)	TOL Merge Lane	Distance from Interchange
Moderate	800 ft	880 ft	1,000 ft	1,500 ft	800 ft	4,980 ft	1,000 ft	1,500 ft	800 ft	880 ft	1,000 ft	5,180 ft
Heavy	1,000 ft	880 ft	1,200 ft	2,000 ft	1,000 ft	6,080 ft	1,200 ft	2,000 ft	1,000 ft	880 ft	1,200 ft	6,280 ft
NOTE: Use 1,100 feet Slip Ramps for 40' Median and 1,435 feet ramp for 60' median												

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Engineering Specification for Construction of Truck Only
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RI 08 – 030.

Sub Document:

**Slip Ramp Safety Features
Technical Memorandum.**

Engineering Specifications for Construction of Truck Only and
Passenger Vehicle Only Travel ways in Missouri - Phase I: RI08-030
Slip Ramp Safety Features Technical Memorandum

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Introduction

The Missouri Department of Transportation (MoDOT) is investigating the truck-only lane proposed improvements along I-70 and I-44 to accommodate the high percentage of truck traffic and to manage congestion along this freight intensive corridor. Access at locations of intense truck activity will be provided by grade separated truck interchanges; however, most of the 250 mile corridor is rural with little demand for access. These locations will be served by slip ramps (**Figure 1**). These slip ramps will provide access between the truck-only lanes and the general purpose lanes to allow trucks access to the general traffic interchanges. This concept is similar to managed lanes currently in use across the country.

Figure 1 Proposed Truck-Only Lane Slip Ramp Configuration...¹



Existing literature on the design and operation of managed lanes is readily available; however, specific research on the safety features of truck-only lanes and slip ramps is limited; especially where truck-only lanes and slip ramps are combined. Although there is little existing research on slip ramps for truck-only lane facilities, research has been conducted for HOV lanes; which can offer appropriate operations and design criteria that will directly apply to new truck-only lane designs.

Until recently, very few exclusive facilities existed that restricted trucks to specific lanes while allowing other vehicles to use any lane.² This document presents a literature

¹ <http://www.improvei70.org/pdf/08-04-01Handout.pdf> (Spring '08 handout)

² Jasek, D. and Middleton, D. *Literature Review for the S.R. 60 Truck Lane Feasibility Study*. Southern California Association of Governments. June 1999.

review specific to the safety at slip ramps and the factors that influence their design and operation. It summarizes key issues related to the proposed I-70 truck only-lane slip ramp configuration. A future literature review will summarize the project team's analysis of the safety implications of truck-only lane facilities on a much broader scale.

Background

Several studies have examined safety features for HOV lanes. The findings from these studies can be easily applied to truck-only lane facilities. The Texas Transportation Institute (TTI) has conducted much of the most applicable research on managed lane facilities.

An exclusive lane feasibility study³ found that barrier-separated facilities were most plausible for congested highways where three factors exist:

- Truck volumes exceed 30 percent of the vehicle mix.
- Peak-hour volumes exceed 1,800 vehicles per lane-hour.
- Off-peak volumes exceed 1,200 vehicles per lane-hour.

Significant research exists regarding the interactions of various vehicles at managed lane facilities. The effects of these interactions can be negative unless mitigated through accurate ramp design. Factors influencing ramp design include design speed, sight distance, grades, turning radii, and horizontal and vertical curvature. These factors will be evaluated in future study tasks under the literature review of safety considerations for truck-only lanes. The intent of the present literature review document is to be a more focused analysis of design factors influencing CMV safety on slip ramps.

Factors Influencing Safety at Slip Ramps

Merging Traffic

User access is a primary consideration in the safe and efficient operation of truck-only lanes. Trucks must be able to access the truck-only lane facility safely and efficiently. Weaving across general purpose lanes to access a truck-only lane facility may present safety issues.

³ Jansen, B. and Rath, A. *Feasibility of Exclusive Facilities for Cars and Trucks*. Center for Transportation Analysis, Oak Ridge National Laboratory. April 1990.

Another safety consideration in truck-only lane analysis is interchange slip ramp geometric design. A 1998 study⁴ analyzed truck-involved crashes on Washington State freeways in conflict areas of merge or diverge ramps. It was found that truck crash frequencies were significantly different by conflict area (off-ramp, on-ramp, merge area, diverge area, upstream, downstream) and type (side-swipe, rear-end, roll-over), and that high-volume ramps have lower rates of truck crashes per truck-mile of travel. Therefore, the safety risk associated with a ramp is related to conflict area and crash type, and not related to truck volume. The findings of the research were used to develop a procedure for identification of high-risk locations for remedial action to improve safety. The tools developed for this analysis could be useful in identifying potential interchange and ramp designs, and modified for use in the safety evaluation of truck-only lanes.

The authors of a 1999⁵ study conducted by The Center for Transportation Research at the University of Texas at Austin observed and evaluated freeway entry ramp design speeds in four Texas cities. They determined that driver speeds on the observed entry ramps were often greater than 50 percent of the freeway design speed, and therefore recommended removing the AASHTO design criteria allowing for an entrance ramp design speed of 50 percent of the freeway design speed. They also concluded that freeway acceleration lanes should begin only when ramp drivers have an unobstructed view of freeway right-lane traffic.

Typical weaving scenarios were evaluated by TTI⁶ and are presented in **Figure 2**. They are:

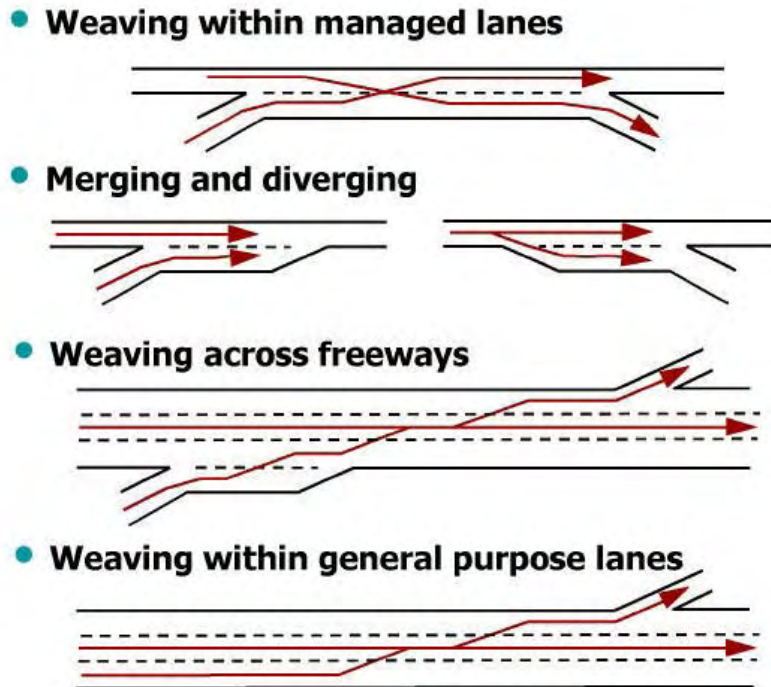
- Weaving within the managed lane.
- Freeway weaving from a managed lane exit to a freeway exit.
- Intra-freeway vehicle stream separation of vehicles destined for managed lane access.

⁴ Jansen, Awad, Robles, Kononov, and Pinkerton. *Truck Crashes at Freeway Ramps: Data Analysis and High-Risk Site Identification*. Journal of Transportation Statistics. Bureau of Transportation Statistics. January 1998.

⁵ Hunter, Machemehl, and Tsyganov. *Reevaluation of Ramp design Speed Criteria*. Center for Transportation Research. University of Texas at Austin. 1999.

⁶ Fitzpatrick, Brewer, Venglar, and Fenno. *Managed Lane Weaving, Ramp, and Design Issues*. Texas Transportation Institute.

Figure 2 Typical Weaving Scenarios for Managed Lanes



In a summary report⁷ completed in 2005, TTI constructed VISSIM models to examine 650 combinations of weaving distance, weaving complexity, and traffic volume conditions resulting in over 2000 vehicle simulations. The scenario most applicable to a truck-only lane slip ramp design is the analysis of weaving across three freeway lanes.

“For weaving across three lanes between a left-side managed lane exit and a right-side freeway exit ramp, modeling indicated that weaving and non-weaving freeway operations tend to stabilize at weaving distances greater than 3000 ft. for medium volumes and 3500 ft. for high volumes.”

It should be noted, however, that the provided weaving distances are only appropriate for freeway vehicle mixes with up to 10 percent heavy vehicles. Higher percentages of heavy vehicles require increasing the per-lane weaving distance. The study authors suggest a maximum of an additional 250 feet per lane. The study also recommended that the cross-freeway weaving and intra-freeway weaving are most appropriately studied using simulation tools such as CORSIM and VISSIM.

⁷ Kuhn, Goodin, Ballard, Brewer, Brydia, Carson, Chrysler, Collier, Eisele, Fenno, Fitzpatrick, Ullman, Ullman, Venglar. *Findings From Texas: Five Years of Research on Managed Lanes*. September 2005.

A similar report⁸ evaluated truck merging operations at four freeway on-ramp locations in California that had significant truck traffic. The study found that, on average, trucks required approximately 1,072 feet of merge space, compared to 498 feet for cars, and 489 feet for recreational vehicles. The authors found in most instances if drivers were provided more acceleration and merge space, more length was used to do so. In addition, they concluded that more than half of the merging maneuvers took place in the latter half of the length provided for merging. And finally, the longer the acceleration space available to merging traffic, the higher the speeds of the merging vehicles, which approached comparable speeds to the through vehicles already on the freeway.

Highway/Heavy Vehicle Interaction

In 2003, a TRB Synthesis report⁹ summarized state-of-the-practice information regarding safety implications from operating commercial trucks and buses on highways. The report also presents options for highway design improvements that could enhance the safe operation of commercial vehicles. It describes current highway design features, operational practices, and other initiatives of importance to commercial truck and bus safety. The results of this study will help identify and describe the operational characteristics that will have the most influence on the safe operation truck-only lane slip ramp facilities in Missouri:

- The 2004 AASHTO *Green Book* criteria for acceleration lane lengths at entrance ramps to major highways appear appropriate to accommodate average trucks, but do not appear to accommodate the lowest performance trucks currently allowed under Missouri State Law. Research may be needed to determine whether these lengths are appropriate for dedicated Truck Only Lane slip ramps.
- More research on the issue of differential speed limits is needed. The belief that lower heavy vehicle speeds will reduce accident rates is widespread but unproven. By contrast, fundamental traffic engineering principles suggest that accident rates increase as the variance of vehicle speeds on a facility increases. Highway agencies need better information on the safety effects of differential speed limits.

⁸ Tom and Fong. *A Case Study of Truck Merging Operations at Selected Freeway On-Ramp Locations in California*. FHWA. 1997.

⁹ *Commercial Truck and Bus Synthesis Report 3*. Transportation Research Board. 2003. Available online at: http://onlinepubs.trb.org/onlinepubs/ctbssp/ctbssp_syn_3.pdf

- Previous research on truck lane restriction has found no effect on safety. Further research based on field trials is desirable to establish whether lane restrictions have safety benefits.
- Many highway agencies are facing decisions about whether to reduce traffic congestion by building truck-only lanes or truck-only roadways. Research is needed to provide safety performance measures to assist highway agencies in such decisions.

Design Speed

The number of vehicles attempting to weave across the freeway lanes and enter a truck-only lane (or exit from one) can have a significant impact on the speed and operations of the freeway. Research conducted by Perera, Ross, and Humes¹⁰ evaluated acceptable ramp speeds for heavy vehicles and translated it into a safe operating speed through the use of computer simulation models. At the time of the study, the authors determined that the safe operating speed for heavy trucks was 13 to 18 mph lower than the corresponding AASHTO design speeds.

Potential Infrastructure Features to Address Slip Ramp Safety

Safely designing slip ramp infrastructure presents challenges regarding vehicular lane changing behavior, speed, and merging space. It is essential that these infrastructure design challenges be met, in order to minimize the negative impact of heavy vehicles at truck-only lane facilities. For this reason, a wide variety of solutions have been developed to address these challenges.

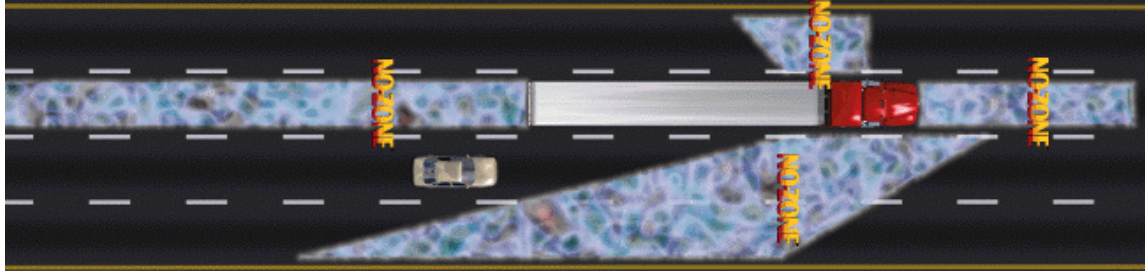
Technology

Vehicular Technology® has developed a computer-directed traffic-control system that was designed under the sponsorship of the Bureau of Public Roads. The technology is intended to increase the efficiency and safety of traffic merging maneuvers by detecting and tracking gaps in the merging lane of the freeway and by dynamically controlling ramp vehicles into these gaps. The description of this system is supported by a treatment of the parametric relationships governing traffic control on freeway, and reference to the historical development of merging control systems. A similar

¹⁰ Perera, H.S., H.E. Ross, and G.T. Humes. *Methodology for Estimating Safe Operating Speeds for Heavy Trucks and Combination Vehicles on Interchange Ramps*. Transportation Research Record 1280. Transportation Research Board, Washington, D.C., 1990.

technology could be developed to facilitate the safe merging maneuvering of trucks through the general traffic stream to the truck-only lane facility.

Figure 3 Blind Spots for Drivers of Large Commercial Vehicles¹¹



Another technology that could be implemented to increase the safe operations at truck-only lane facilities is “The Lookout™”¹² which is a state-of-the-art safety aid for trucks that helps truck operators locate people and objects in their blind spots. (**Figure 3**) The technology consists of ultrasonic sensors that can be placed on a truck or trailer along with an LED display unit mounted within the cab. The technology can be implemented into existing fleet operations and can handle up to 10 quick connect sensors and transferred between tractors in a transportation fleet. Lookout™ not only aids the driver in backing and changing lanes, but, when activated, also has an internal security alarm feature that alerts the driver when something or someone approaches the truck when it is standing still. **Figure 4** shows the LED display and the sensors mounted to a truck chassis.

Figure 4 Lookout sensor technology



In normal blind-spot mode, when an object is within eight feet of one of the sensors, the corresponding area is lit up on the display unit's truck outline. When the vehicle is shifted into reverse, the system automatically switches to backup mode and the display

¹¹ <http://www.nozone.org/index.asp>

¹² Road Management and Engineering Journal, with permission from January/March 2001 issue (Vol. 15, No. 2) of *The Bridge*, a publication of the Transportation Center at Michigan Technological University in Houghton, Michigan.

shows the distance between the rear of the vehicle and any object (a loading dock, for instance), flashing "0.0" when the distance is less than one foot. An audio alarm beeps more rapidly as the distance closes. The alarm mode can be used when the truck is parked, with the audio alarm sounding when anything comes within three feet of a sensor.

Each "smart" sensor is housed within a sealed, weather-tight enclosure, and all other components are built to withstand the rigors of commercial vehicle use. The system is manufactured by MPH Industries, Inc., a maker of police traffic radar, breath alcohol measuring instruments and other highway safety equipment.

Infrastructure Design

The WSA project team conducted a literature review on slip ramp infrastructure design issues. The following summarizes the findings of this literature review in several categories: alignment, lane marking treatments, signage, and channelization of traffic.

Alignment

Keller authored a study in 1993¹³ that summarized several recent studies evaluating the potential influences of ramp alignment, super elevation, and horizontal alignment. He concluded that:

- Motorists must receive consistent feedback regarding each element of the ramp geometry, especially when complex interchange designs are unavoidable
- Designing highways specifically for large trucks requires increased sight distance, simplified interchange layout, and more generous ramp radii
- Decision sight distance is desirable over stopping sight distance, however stopping sight distance plus 25 percent is an acceptable alternative

Lane Marking Treatments

In a study conducted for the FHWA in 2008¹⁴, the authors identified several cost effective lane marking solutions. They are:

¹³ Keller, J.A. *Interchange Ramp Geometrics—Alignment and Superelevation Design*. Transportation Research Record 1385. Transportation Research Board, Washington, D.C., 1993.

¹⁴ Rephlo, Carter, Howard, Katz, Robinson, Bedsole, Philmus. *Strategies for Improving Safety at truck-only lane Collection Facilities*. FHWA. May 2008.

- Bright longitudinal markings that extend upstream to give motorists plenty of time to prepare for merging vehicles.
- High-visibility flexible lane delineators to separate traffic.
- Flexible pop-up delineators that operate off air compression to improve performance in cold climates (currently being used by the New York State Thruway).

Signage

Adequate signage is instrumental in safe operations in and around truck-only lane slip ramps. Clear signs must be present to all motorists who encounter a truck-only lane facility. Motorists should encounter signage well in advance of a truck-only lane slip ramp facility. Information should be disseminated upstream and downstream of slip ramp facilities to effectively present the needed information and allow users proper time to react. Information must be presented within the managed lane corridor to drivers with varying levels of familiarity with truck-only lanes.¹⁵ Signage should be considered early in the design process, as an integral part of the infrastructure design.

Some agencies have found that changing speed limit signs from advisory to regulatory (black and white) makes a difference in speed compliance. Another signage option would be to use digital signs displaying real-time speed to vehicles. Signs upstream of the slip ramp may effectively reduce confusion at merging facilities.

The 2003 *Manual of Uniform Traffic Control Devices* (MUTCD)¹⁶ with Revisions 1 and 2, dated December 2007, provides several example layouts for both barrier and buffer-separated facilities in section 2E.59 “Preferential Only Lane Signs”. Some examples include:

- Entrance/exit plaques
- Distance/destination signs and
- Ramp guide signs

The MUTCD also adds several conditions concerning managed lane facilities that include:

¹⁵ Kuhn, Goodin, Ballard, Brewer, Brydia, Carson, Chrysler, Collier, Eisele, Fenno, Fitzpatrick, Ullman, Ullman, Venglar. *Findings From Texas: Five Years of Research on Managed Lanes*. September 2005.

¹⁶ Accessed online at: <http://mutcd.fhwa.dot.gov/>

- A minimum of one ground-mounted advance guide sign at least 0.5 miles prior to the entry
- Overhead signs used as a supplement to ground-mounted signs only, unless an engineering study identifies that ground-mounted signs are not appropriate
- Truck-only lane abbreviation or symbol to appear on all signs at entry and exit points and times of vehicle occupancy requirements, and
- Median-mounted signs for advance exit and other guide signs for both barrier and buffer-separated facilities

Knoblauch and Nitzburg¹⁷ evaluated high-speed roll over crashes of top-heavy trucks. Their research developed methods for treating interchange ramps that are prone to cause high center of gravity vehicles to lose control and overturn. The authors determined that the rear silhouette of a tipping truck, advisory speed limit, and arrow diagram were the most effective signs.

Examples of signage that could be developed for truck-only lane facilities on I-70 are included in the **Appendix**.

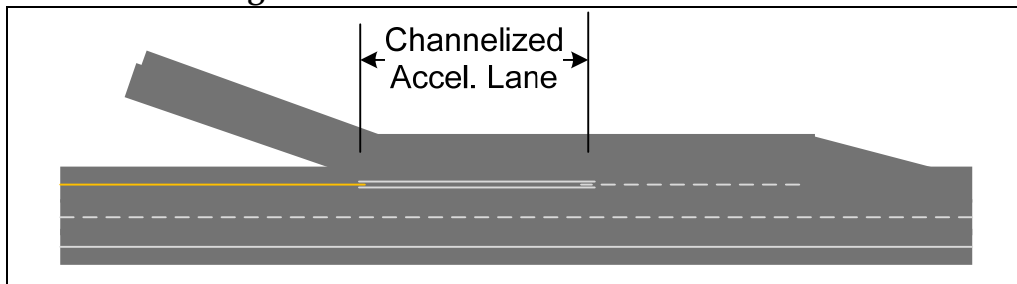
Channelization of Traffic

One strategy that is often used to mitigate unsafe lane changes near managed lane facilities is the channelization of traffic. In a study conducted for the FHWA¹⁸, the authors assessed strategies for reducing unsafe merging and lane changing behaviors at toll collection facilities. By separating traffic downstream from the slip ramp facility on a channelized acceleration lane, it is possible to reduce last-minute lane changes and increase the safety of the interaction of trucks with the general traffic stream. Some agencies even make it a policy to separate traffic until the slower traffic has accelerated to two-thirds of the normal operating speed. Other agencies have used a buffer lane or physical separation (concrete barrier) between the managed facility and the general purpose lanes.

¹⁷ Knoblauch, R.L. and M. Nitzburg. *Ramp Signing for Trucks*. Report FHWA-RD-91- 042. Federal Highway Administration, McLean, VA. 1991.

¹⁸ Rephlo, Carter, Howard, Katz, Robinson, Bedsole, Philmus. *Strategies for Improving Safety at Toll Collection Facilities*. FHWA. May 2008.

Figure 5: Channelized Acceleration Lane



Reducing Speeding

Vehicles traveling above posted speed limits in and around truck-only lane slip ramp facilities may create significant safety problems. As a result, some agencies operating managed lane facilities have implemented strategies that effectively combat speeding vehicles. Speed limit enforcement and the construction of physical features are two strategies discussed in the following.

One speed reduction enforcement strategy that has been implemented by the New York State Thruway is automated speed enforcement where cameras record violators and send a citation by mail. An effective strategy to deal with repeat offenders, should there be any, would be to double fines for speeding in slip ramp areas.

Speed can be controlled at truck-only lane slip ramps by the use of various lane treatments that encourage reducing speeds. The New York Thruway, for example, uses rumble strips upstream of the merging lane and transverse pavement markings to lower speeds in their managed lane facilities. They place brightly colored transverse markings spaced progressively closer to give approaching vehicles the illusion that they are increasing speed even when they are maintaining a constant speed. Another potential lane treatment is painting speed limits on the pavements at the approach to a slip ramp facility.

Truck Merging Zones

Combining several of the above methods into designated Truck Merging Zones would provide additional visual and informational tools for the driver of the general purpose vehicle. Prior to the slip ramp, a series of signs would alert the driver to the possible presence of trucks attempting to merge. This could then be further enhanced just prior to a slip ramp from the truck-only lanes with a warning light mounted on an advisory sign that would be activated by detectors along the slip ramp.

Conclusions

- The American Association of State Highway and Transportation Officials (AASHTO) High Occupancy Vehicle (HOV) Design Guide¹⁹ advises that where limited right-of-way and/or high costs prohibit the use of elevated flyover ramps, at-grade slip ramps can be used.
- Safety at any truck-only lane slip ramp facility will increase if its users are familiar with its design and operation. Missouri should consider implementing a public education campaign to familiarize users with the concept of operating slip ramps to access truck only lanes. If the concept is implemented, direct focus should be given to the various highway users that will be affected by the operation of these ramps. The project team suggests tailoring outreach to users of each of the vehicle types that will be permitted on the system, including: emergency medical responders, MoDOT personnel, general purpose users, and transportation industry sectors. This campaign will be further investigated through the public policy research portion of future study documents. Missouri should consider adding language related to truck only lanes to the Missouri Drivers Guide and in the CDL test.
- The project team should use the VISSM (or similar) model to analyze vehicle interactions in and around a truck-only lane facility. A study by Urbanik and Cate²⁰ suggests the model will quantify the benefits from truck-only lane restrictions in the form of reduced lane-changing activity; with little or no operational penalty.
- The geometric design of truck-only lane slip ramp facilities on I-70 should be developed in accordance with traffic modeling simulations. Speed limits, weaving distances, lane widths, etc. may need to be evaluated at each proposed ramp location; as each will have a different level of service (LOS) and traffic density.
- A bulk of the safety concerns related to truck-only lane slip ramp configurations are generated from the truck traffic merging maneuvers at these facilities. Operationally, weaving areas between on/off ramps and the slip ramps of the truck-only lanes generate concern. Trucks cross the general traffic stream and create safety hazards and disturb mainline traffic. The Texas Transportation

¹⁹ *Guide for the Design of High Occupancy Vehicle Facilities*. American Association of State Highway and Transportation Officials, Washington, D.C., 1992.

²⁰ Cate, M. and Urbanik, T. *Another View of Truck Lane Restrictions*. 2004.

Institute suggests merging lanes at a truck-only lane facility be at least 3,500 feet²¹. In areas with higher volumes of truck traffic, the study authors suggest adding an additional 250 feet of merging space. The project team will investigate the suitability of these estimates using a modeling approach in Missouri.

- Lane treatments and appropriate signage will be instrumental in developing safe operations in and around truck-only lane slip ramps. Clear signage is important for all motorists who encounter a truck-only lane facility. Information should be presented upstream and downstream of slip ramp facilities to effectively present the needed information and allow users proper time to anticipate and react to the truck-only lane slip ramps. Additional pavement treatments might increase safety at truck-only lane facilities. Treatments may include aggressive lane paintings, rumble strips, and lane barriers.
- It is expected that the project team will conduct several modeling scenarios to identify critical geometric design criteria for the slip ramps. The scope of this study does not currently include the investigation of longer combination vehicles (LCVs). If these vehicles were considered, they would dramatically impact the design and operation of slip ramp facilities.
- Technologies are emerging that may increase safety at slip ramp facilities. Ramp metering technology is being developed to guide traffic safely through merging maneuvers at truck-only lane facilities²². On-board technologies are also being developed. One warns truck drivers of approaching vehicles located in a trailer's blind spots. This reduces unsafe merging of large vehicles²³.

²¹ Kuhn, Goodin, Ballard, Brewer, Brydia, Carson, Chrysler, Collier, Eisele, Fenno, Fitzpatrick, Ullman, Ullman, Venglar. *Findings From Texas: Five Years of Research on Managed Lanes*. September 2005.

²² Vehicular Technology®

²³ Road Management and Engineering Journal, with permission from January/March 2001 issue (Vol. 15, No. 2) of *The Bridge*, a publication of the Transportation Center at Michigan Technological University in Houghton, Michigan.

Appendix

The following images are examples of established signs that could be used to present the necessary information to traffic that will be encountering slip ramp facilities. There are also several diagrams included that will aid in determining appropriate placement of signs. While establishing uniform signing for truck-only lanes is outside the scope of this study, these provide precedent for what might be done.



This sign could be modified slightly to notify general traffic users that trucks will be entering general purpose lanes ahead. It could read "trucks merging ahead" with an additional sign identifying the distance to the gore, for example, "½ mile ahead."



A sign similar to this could notify mainline traffic not to block the truck merging lane ahead.



Warning signs should notify mainline traffic well in advance of truck only lane slip ramp facilities. A similar sign to the one at right could read "Truck-Only Lane Ahead."



Secondary warning signs should be developed to notify traffic as slip ramp facilities approach.

Overhead signs will be necessary to differentiate exclusive lanes from general purpose lanes. Qualifications for exclusive lanes should be simply described so they will be understood by the highway users that will encounter them. The sign at right is an example sign that is used to identify high occupancy vehicle (HOV) lanes.



These signs would be used where drivers will encounter merging truck traffic. The plaque is a modification from sign W4-4a "TRAFFIC FROM LEFT". Flashing lights activated by sensors from the slip ramp would add additional emphasis when trucks are present.



Advisory signs should be used throughout the upstream and downstream areas at slip ramp facilities urging highway users to drive cautiously as they navigate through merge/diverge areas.



It is important to advise appropriate speeds for all traffic types. If travel speeds are different for trucks and general traffic, signs should be created for each, with posted speed limits easily identifiable.

This sign is an example of a variable message sign that can be used to notify traffic of upcoming hazards.



The following diagrams were gathered from the MUTCD. They present example signing spacing for several managed lane designs.

Figure 2E-46. Example of Signing for the Entrance to Barrier-Separated HOV Lanes

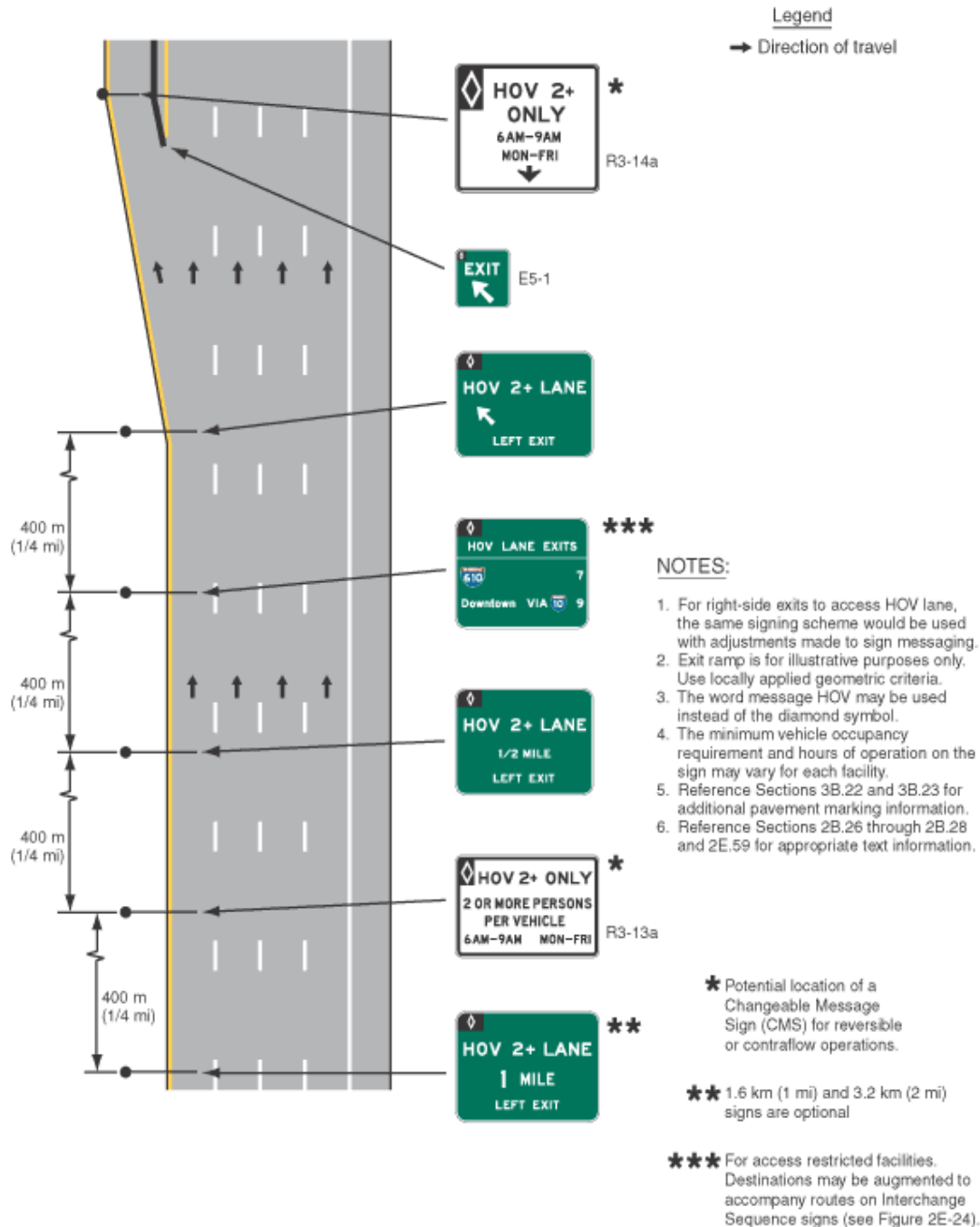


Figure 2E-47. Example of Signing for the Intermediate Entry to and Exit from Barrier- or Buffer-Separated HOV Lanes

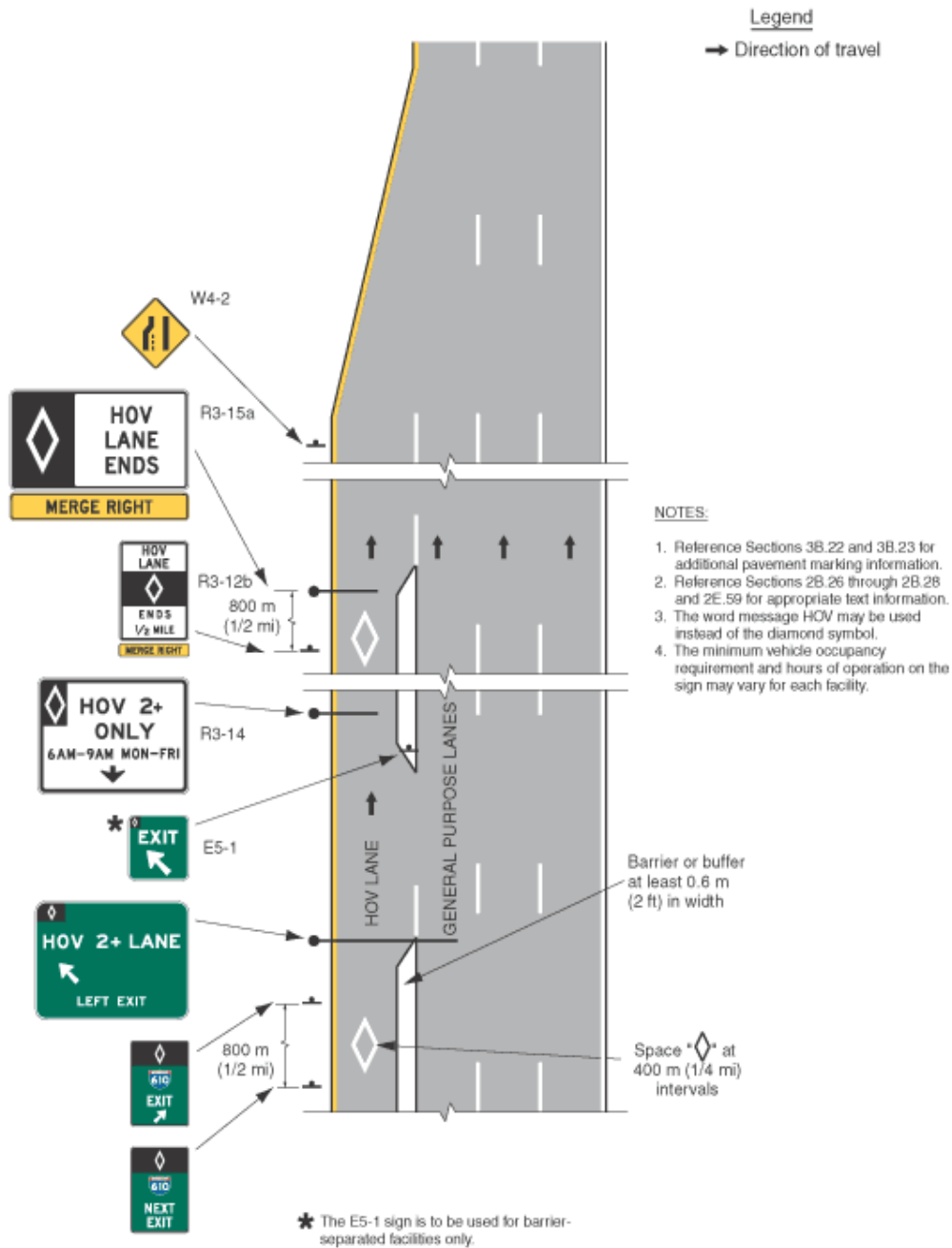
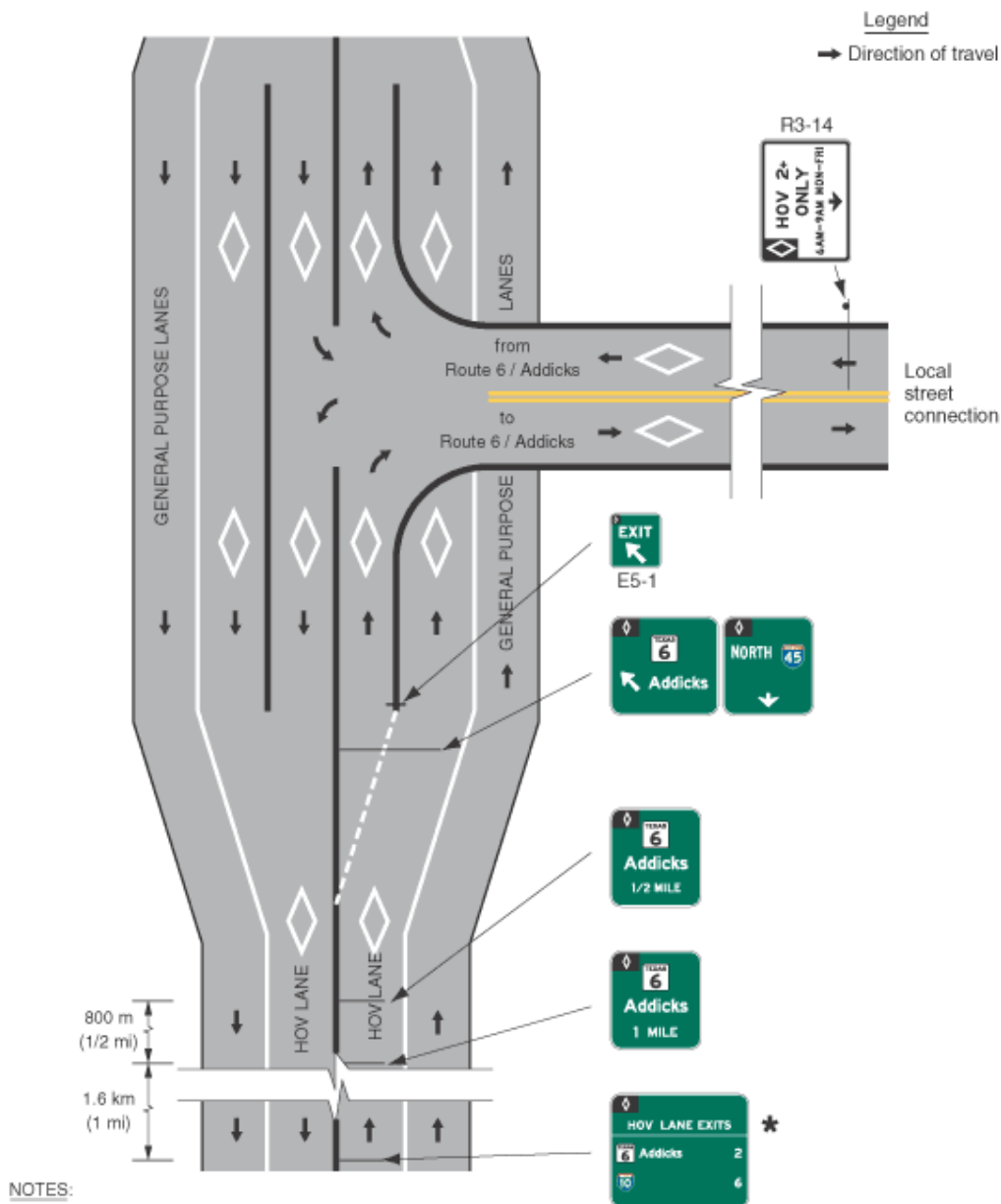


Figure 2E-51. Example of Signing for a Direct Access Ramp to an HOV Lane from a Local Street

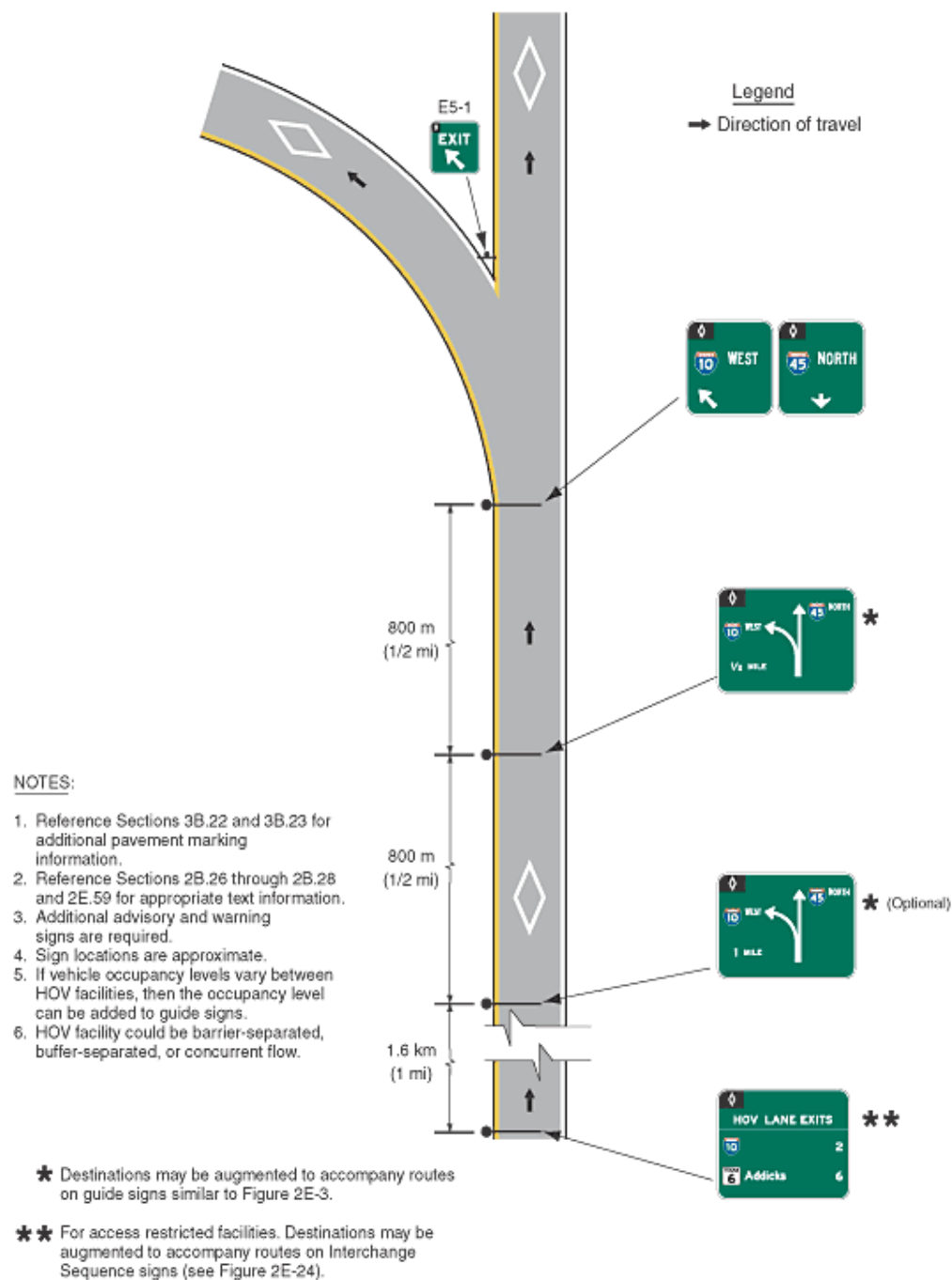


NOTES:

1. Reference Sections 3B.22 and 3B.23 for additional pavement marking information.
2. Reference Sections 2B.26 through 2B.28 and 2E.59 for appropriate text information.
3. Additional advisory and warning signs are required.
4. Sign locations are approximate.
5. HOV facility could be barrier-separated, buffer-separated, or concurrent flow.

* For access restricted facilities. Destinations may be augmented to accompany routes on Interchange Sequence signs (see Figure 2E-24).

Figure 2E-52. Example of Signing for a Direct Access Ramp between HOV Lanes on Separate Freeways



Engineering Specification for Construction of Truck Only
and Passenger Only Travelways in Missouri – Phase 1.
RI 08 – 030.

Sub Document:

**EMS Access To Truck-Only Lanes
Technical Memorandum.**

Engineering Specifications for Construction of Truck Only and
Passenger Vehicle Only Travel ways in Missouri - Phase I: RI08-030
Emergency Access Technical Memorandum

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Introduction:

The Truck-Only Lane concept being considered by the Missouri Department of Transportation will provide a limited access facility for trucks separate from the general purpose vehicles. This limited access and separated facilities will provide a more efficient and safer infrastructure for the movement of people and goods. One of the chief safety concerns for this facility, and freeways in general, will be how to provide access for emergency vehicles for incident management.

Emergency Vehicle Crossovers

Limited access facilities present travelers with the ability to go long distances with minimal disruptions, greatly enhancing the flow and the safety of traffic. However, when incidents do occur, it can be difficult for emergency vehicles to access the site without going many miles out of their way. These detours increase both the response time to the injured and the delay to impacted traffic.

To provide emergency vehicles shorter routes, emergency crossovers have been added to limited access facilities. These crossovers are built to a much different standard from typical roadway entrance and exit ramps, as they are not intended for the traveling public. It is assumed that the only vehicles using these facilities are emergency or maintenance vehicles, driven by trained personnel and with warning lights and other safety features on the vehicles. A typical rural crossover is shown in **Figure 1**.

Figure 1 Typical emergency crossover located on I-70 outside of Columbia, MO



(Courtesy of Google Street View)

Emergency crossovers are typically located in the median between opposing directions of traffic on a limited access facility. They provide the ability for emergency vehicles to cross from one direction to the other without driving many miles to an interchange. These crossovers can be from a frontage road to the limited access facility or on a limited access facility between general purpose and express lanes. These latter two applications are typically gated to prevent the public from entering the facility in an unsafe manner.

Basic Warrants

The intent of emergency crossovers is to provide specialized vehicles the ability to quickly change directions on a limited access facility or to provide access to the facility. Generally then there is no need to construct crossovers in the vicinity of a full interchange as the emergency vehicles can use the interchange to change directions. Crossover spacing between interchanges should limit detours. Research into Midwestern applications indicates a spacing anywhere from one to five miles is appropriate. While crossovers are typically inexpensive, one mile spacing is generally viewed by the industry as excessive; however, at the other extreme, a five mile spacing can easily result in emergency vehicles having to go eight miles (four in each direction) or more to locate and arrive at an incident. At typical highway speeds, this represents approximately ten minutes of precious delay in responding to potential life threatening situations. A 2.5-mile spacing is a good balance between minimizing response time and cost.

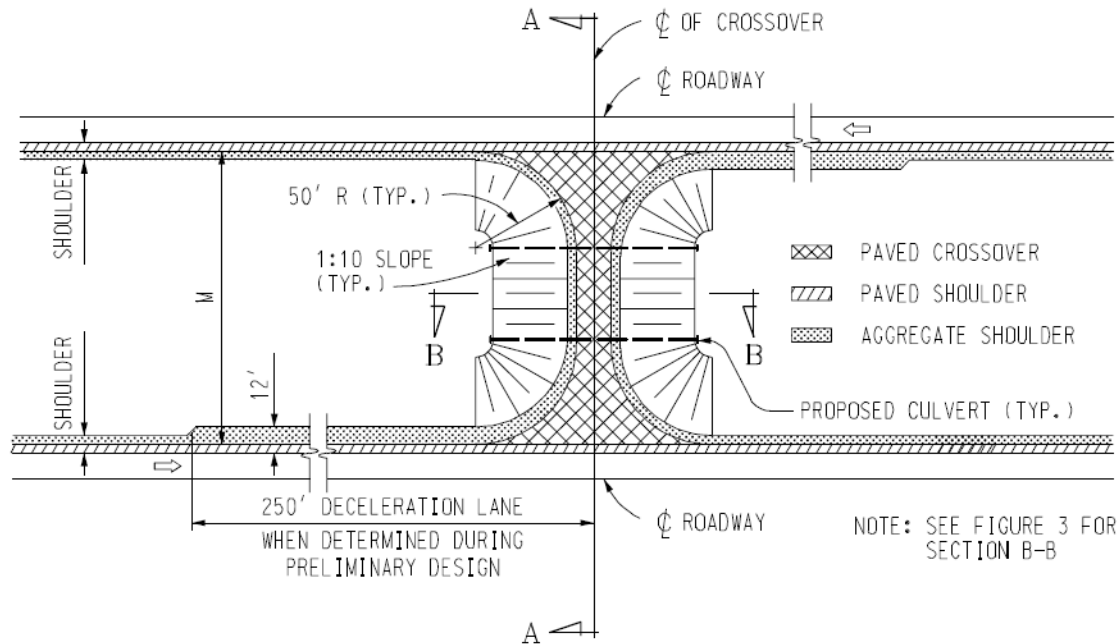
There are always some exceptions to these spacing rules. For example, crossovers are often located at the change of jurisdictions to allow maintenance vehicles a safe location in which to turn around. Also, ends of long structures without a crossover, such as bridges or tunnels, may warrant additional crossovers to ensure adequate system level response. Crossovers may also be located to enhance and improve snow operations. In order to facilitate clearing interchanges, crossovers are often constructed within a set distance from the ramp termini. Other issues such as drainage or crossing structures may warrant the relocation of crossovers to slightly shorter spacings. Spacing should not be increased more than $\frac{1}{4}$ mile.

Basic Design Requirements

This section pertains to crossovers for allowing emergency or maintenance vehicles to access adjacent travel lanes. Layouts of a rural and urban crossover are shown in **Figure 2** and **Figure 3**. The keys to good design are minimum width of the crossover opening and minimum width of the median from edge of pavement to edge of pavement. While it is assumed the authorized personnel using these facilities are trained and may be driving specialty vehicles, the openings must be wide enough to allow vehicles (especially trucks such as snow plows and fire trucks) to successfully and safely exit the pavement from one direction and enter the pavement in the other direction.

Figure 2 Typical rural median crossover

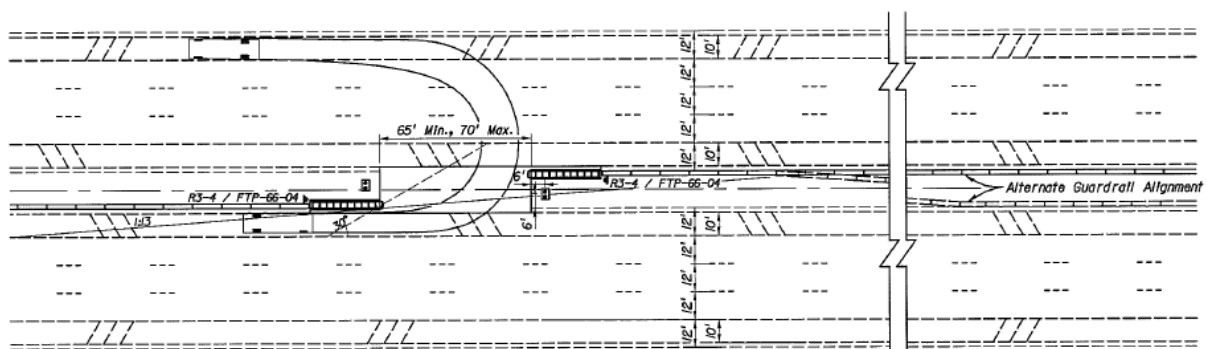
TYPICAL DESIGN OF MAINTENANCE CROSSOVER
WHERE M IS GREATER THAN 100'



Source: Michigan DOT

Figure 3 Typical urban median barrier opening

*Median Barrier Opening For
Crossovers on Limited Access Facilities
Typical Layout*



LEGEND:

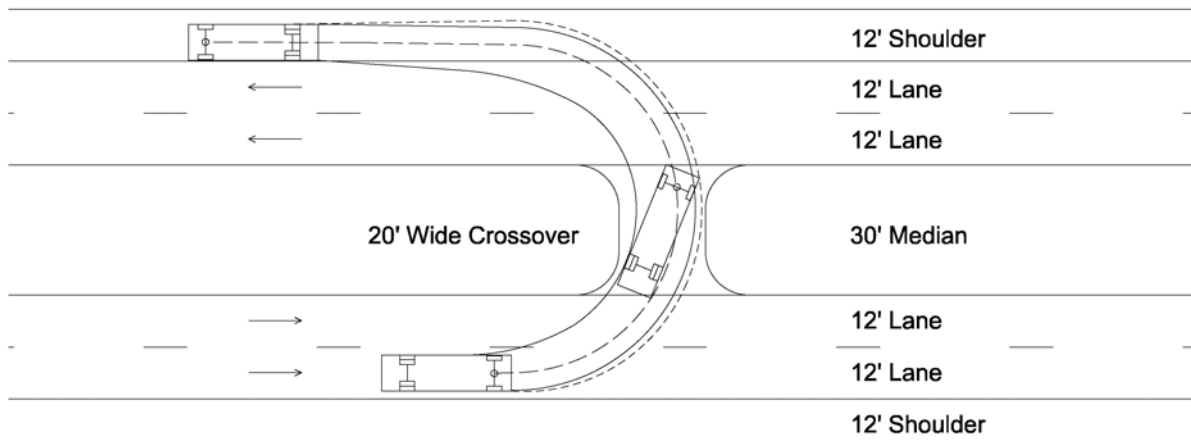
- Crash Cushion
- Barrier
- Sign
- Double Yellow Delineator

Source: Florida DOT

A crossover must meet certain basic roadway requirements related to the design vehicle that uses it. These include drainage, barrier end treatments, and sight distances. The design may require a pipe or culvert to ensure drainage is not adversely affected, and the driving surface must be constructed to a minimum standard. In many rural locations, the driving surface may be aggregate – vehicles are not expected to use this surface often or at high speed. The slopes should be such that any errant vehicle that leaves the roadway does not encounter a hazard approaching the crossover from the median. Also, crossovers should be located in such a manner as to provide adequate sight distance from the roadway to ensure roadway vehicles have adequate distance to stop for emergency vehicles. Any signing or other fixed hazards must meet clear zone requirements or be adequately designed for break away. Barriers and guardrail must have proper end treatments.

For most applications, the crossover is designed so that a vehicle has adequate room to approach the crossover from the inside shoulder and sit perpendicular to traffic in the crossover without the vehicle infringing upon a travel lane in either direction. While it is desirable to have enough room in the crossover so that the emergency vehicle can turn and enter the inside shoulder of the opposing traffic without entering a travel lane, it is recognized that in urban areas it is rare to have enough median width to do this. Especially in application to truck only or express lanes created in an existing median, it is expected that right of way will be limited. This is due to the AASHTO standard single unit vehicle length of 30 feet and a standard clear zone distance of 30 feet. Therefore, the minimum requirements for a crossover are full shoulders (12-14 feet) approaching and departing from the crossover, and a minimum pavement edge to pavement edge of 30 feet. While it would be desirable to have additional room for a vehicle in the crossover, these vehicles are not expected to loiter in the crossover.

The turning radius of a single unit truck is 42 feet. Two 12-foot travel lanes and a 30-foot median and 12-foot outside shoulder for a typical rural cross section adds up to 102 feet (**Figure 4**). This should be adequate to accommodate most common maintenance and fire department vehicles to turn from the outside lane of one direction to the other direction assuming that they would be able to use the full roadway to make their u-turn. This would place the vehicle nearly perpendicular to the travel lanes while in the crossover. Smaller vehicles (i.e., police cars) have a much smaller turning radius and can complete the maneuver using fewer traffic lanes, generally one in each direction.

Figure 4 Turning Radius Layout

The width of crossover pavement or width of gap in the barrier wall, from the studied ranges from 20 to 26 feet. This typically accommodates most vehicles that are able to maneuver to approaching the crossover at an angle nearly perpendicular to the centerline of the roadway. If the emergency vehicle is parallel to the centerline, then a much larger gap is required. This parallel approach is generally discouraged because the larger gap increases the likelihood of an errant vehicle leaving the roadway and crossing to the opposite direction through this gap. At highway speeds, the smaller gap (approximately 24 feet) would require a vehicle to make near a 90 degree turn and within a very small window of opportunity along the freeway.

Off-System Emergency Access

Occasionally, local emergency responders are not in proximity to an interchange. When this is the case, gates can be installed along the right of way line with gravel (or other low cost) driveways from the local access road to the shoulder of the travelway. The gates are typically padlocked, with the local police, fire and EMS responders having keys to the lock. Garage door type mechanisms are possible, but generally power is not available in isolated areas. An example of a gate is shown in **Figure 5**.

Figure 5 Off system emergency access gate from frontage road to I-94 outside of Sturtevant, WI



(Courtesy of Google Street View)

Gate locations must be determined on an individual basis. The designer should assume no access is to be provided unless requested through a local agency.

Standards

Little federal guidance to the design of emergency crossovers exists. AASHTO's 2004 *A Policy on Geometric Design of Highways and Streets* recommends that the width crossovers "should be sufficient to provide safe turning movements", and that crossovers "should not be placed in restricted-width medians unless the median width is sufficient to accommodate the vehicle length".

Most of the specific design standards are unique to individual agencies, although most follow the general design elements identified above. Specific to Missouri are the following standards (Engineering Policy Guide, Category 240):

240.1 Location

When selecting a location for a maintenance and emergency crossover, the guidance contained in AASHTO's *A Policy on Geometric Design of Highways and Streets* should be used in addition to the following general guidelines:

1. Maintenance and emergency crossovers should not be located closer than 1,500 feet to the end of a speed-change ramp or to any structures such as bridge columns or guardrail located in the median.
2. Maintenance and emergency crossovers should be located only where the Design Entering Sight Distance is provided.
3. Maintenance and emergency crossovers should not be located within curves requiring superelevation.
4. Spacing of crossovers should be every 2.5 miles.
5. Interchanges that are closer than 2.5 miles apart should not have maintenance and emergency crossovers unless a defined need exists for maintenance, emergency, medical or law enforcement purposes.

240.3 Maintenance and Emergency Crossover Construction Requirements

1. Crossovers shall be constructed with an aggregate surface no wider than 20 feet and with turning radii of not more than 10 feet.
2. To be inconspicuous to mainline traffic, the surface should be depressed below shoulder level.
3. Side slopes should be constructed 1V:10H or flatter to minimize their effect as obstacles to uncontrolled vehicles that may enter the median.
4. If possible, the crossover should be located where a pipe is not necessary. All drainage structures constructed in the median must be built to current safety standards. Refer to Standard Plan 606.41 for drainage piping plans and pipe end treatment options.
5. The surface shall not be upgraded to a higher type surface.
6. Crossovers are to be in good repair at all times.
7. Signing for a maintenance and emergency crossover shall be in accordance with 903.5.53 AUTHORIZED AND EMERGENCY VEHICLES ONLY.

Other states have adopted guidelines that are outlined in their design manuals, or identified as state or agency standards. A summary of their requirements compared to MoDOT requirements is presented in **Table 1**.

Table 1 Agency Location and Design Standards for Emergency Crossovers

	MoDOT	Texas DOT	Florida DOT	Michigan DOT	Illinois Tollway
Minimum Interchange Spacing requiring Crossovers	2.5 miles	3 miles	--	--	--
Minimum Spacing between Crossovers	2.5 miles	1 mile	--	1 mile	3 miles for urban, 5 miles for rural
Maximum Spacing between Median Crossovers	--	--	--	10 miles	--
Allowed in Urban Areas	--	In general, not provided	Not allowed	--	Yes
Minimum Distance from Interchange Ramp	1,500 feet from Accel./Decel. Lane	1 mile	1.5 miles	1,500 feet from Accel./Decel. Lane	1,500 feet from Accel./ Decel. Lane
Minimum Distance from Bridge Column/Guardrail	1,500 feet	--	--	--	--
Sight Distance Requirements	Entering sight distance	Adequate stopping sight distance	Above minimum stopping sight distance	--	Above minimum stopping sight distance
Curves with Superelevation	Crossover not allowed	----	Crossover not allowed	----	--
Minimum Median Width	--	Wide enough to permit official vehicle to turn between inner freeway lanes	40 feet	--	--
Maintenance Sections	--	--	--	Dual crossovers at end of maintenance sections	--
Crossover Width	20 feet, max.	--	24 feet, min.	--	35 feet
Crossover Turning Radii	10 feet, max.	--	20 feet	--	--
Deceleration Shoulder	--	--	--	Yes	Yes
Surface Level	Depressed below shoulder	--	Flush with shoulder	Flush with shoulder	Designed for drainage
Surface Type	Aggregate surface	--	Paved surface	Paved surface	Paved surface
Sideslopes	1V:10H	--	1V:10H	1V:10H	--

Issues Specific to Truck-Only Lanes

Truck-only lanes are dedicated lanes, typically separated by a barrier or median from the general traffic lanes. They are designed to help move freight more efficiently.

While general traffic lanes are designed so a typical truck can safely navigate turns, ramps, and intersections, truck-only lanes must accommodate larger vehicles including combination vehicles. These lanes are often in the median of an existing facility which would mean traffic to the right of the truck-only lanes runs in the same direction, and traffic on the left runs in an opposite direction.

Given enough available right of way, simple wide crossovers can be installed to accommodate any emergency vehicle. Even in situations with limited shoulders and no available right of way, the emergency vehicle crossovers should be designed to handle any emergency vehicle operating at a low speed.

However, emergency vehicle crossovers may sometimes be used by the general public. In the event of a full road closure, often vehicles are allowed to use crossovers or are directed to turn around in order to prevent sitting in stopped traffic for many hours while an incident is cleared. While larger combination vehicles are allowed in the truck-only lanes, they should not have to negotiate an emergency crossover. The general assumption in this study is that accommodating this operational option is not cost effective and it would be problematic to have the larger vehicles mixed with the general traffic, even for short distances. If the larger, heavier vehicles are trapped by an incident, it will be incumbent upon the local jurisdiction to remove the closure as quickly as possible. A well designed incident management program should be able to address the vast majority of issues that the truck-only lanes will face.

If the truck-only lanes operate with a limited shoulder and barrier wall, openings in the barrier wall should be temporary. One such temporary opening from Barrier Systems, a supplier, is shown in **Figure 6**. However, if there is not sufficient shoulder for an emergency vehicle to safely stop between the two different lanes, it is recommended that there be some warning system installed upstream of the crossover. This could be a DMS, or could be a warning sign with flashers. Whatever the design, the vehicles in the truck-only lanes need advance warning.

Figure 6 Example of a temporary barrier gate for express lane emergency access (by Barrier Systems) in barrier wall along I-94 in Chicago, IL



(Courtesy of Google Street View)

Unique to truck-only lanes and express lanes is the alignment of the crossovers. In a typical roadway, there is only one crossover since there are only two separated travel ways. In a truck-only lane application, there are four – the two general purpose lanes in opposite directions, and the two truck only lanes in opposite directions. If the crossovers were staggered, they could easily aid response in one direction. As an example a northbound crossover from the easternmost general purpose lanes to the northbound truck-only lanes would be created. The next crossover could be 1,500 feet north to allow a vehicle to merge and cross traffic before coming to the northbound truck only lane to southbound truck-only lane crossover. The next crossover could be located 1,500 feet south, again allowing a vehicle to merge into traffic and get across the lanes. However, if an emergency vehicle was approaching from the south, they would have to back track against traffic 1,500 feet to get to the next crossover, and then backtrack again 1,500 feet against traffic to get to the third crossover. This pattern would aid one direction and hinder the other. By placing the crossovers perpendicular to each other, an emergency vehicle can directly cut across traffic to the next crossover. Considering the lights on the vehicle, and most states having laws about slowing down around emergency and maintenance vehicles, it is believed this application is the safest.

It is important that these crossovers be part of an overall incident management plan. Local emergency responders need to be trained consistently in how to best respond to incidents. Additionally, local tow contractors should meet certain standards and may require specialized vehicles such as rotating arm lifts that can access a damaged vehicle across a barrier wall from an adjacent lane.

Figure 7 Offset barrier openings showing movement A flowing with traffic in the inner lanes, while movement B flows *against* traffic in the inner lanes and should therefore be avoided. A second median gap would allow for movement B with no flows against the traffic.

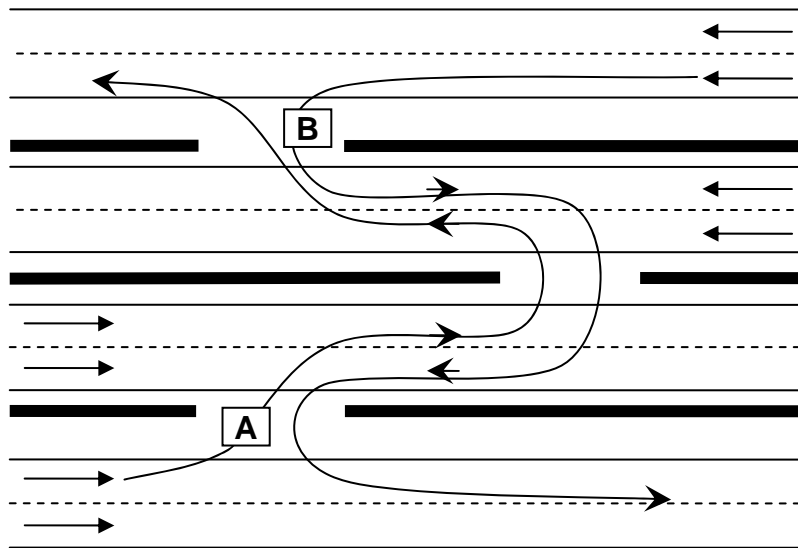


Figure 7 Offset Barrier Opening

Figure 8 Parallel barrier openings showing both movements A and B crossing traffic in the inner lanes.

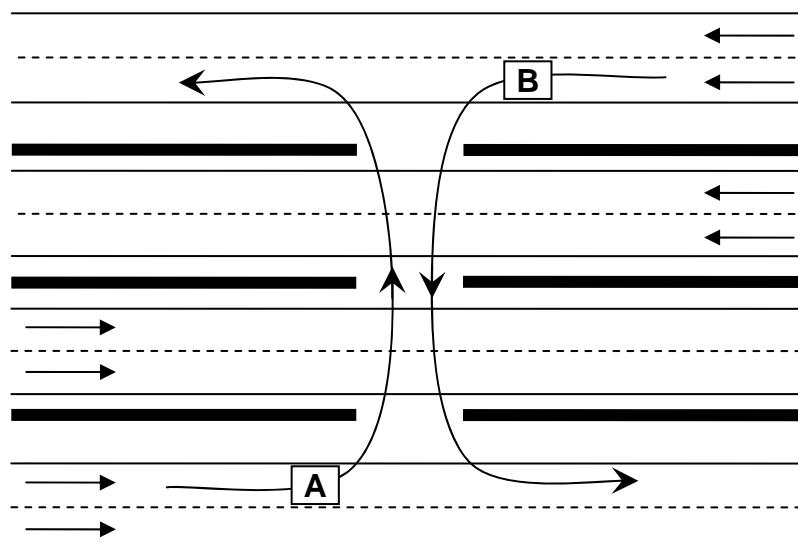


Figure 8 Parallel Barrier Openings

Recommendations

Based on the available information and standards identified in this report, the following are the recommendations relative to the emergency vehicle access design:

General:

- Spacing should be generally every 2.5 miles, with no crossings required for emergency access purposes near an interchange.
- Multiple crossovers should be placed in coordination so that emergency vehicles can get across multiple lanes easily.
- Off system emergency access should be considered on a case by case analysis.
- All crossovers should be part of a well designed incident management plan.

Rural Missouri Configuration (Figures 9 and 10)

- 20-feet wide crossover with break in guard cable (cable is optional)
- Crossover gates optional
- Widen shoulder for approach
- 30-feet wide median barrier opening
- Offset median barrier with crashworthy end treatments for opposing traffic
- Barrier opening lined up with median crossovers

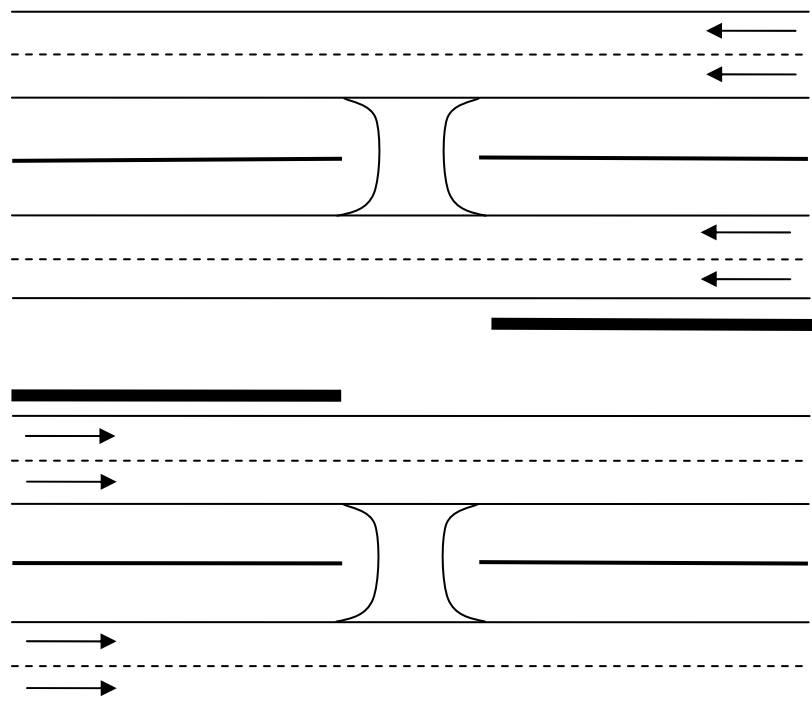


Figure 9 Median Open & Crossovers With Guard Cable



Figure 10 Proposed Missouri Rural Configuration

Urban 3-Barrier Configuration (Figure 11)

- 35 foot wide medians
- Wider shoulders approaching and leaving the opening
- Parallel barrier openings
- Offset barrier for opposing traffic

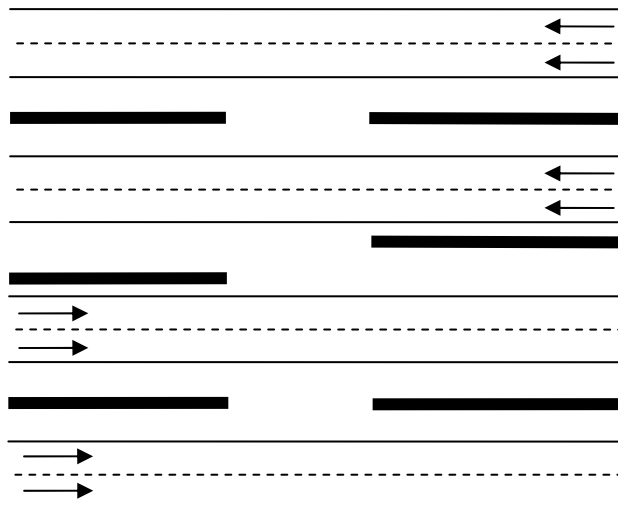


Figure 11 Urban 3-Barrier Configuration

Urban – Limited Shoulders (Figure 12)

- Use temporary systems such as “Barrier Systems”
- Provide advance warning systems

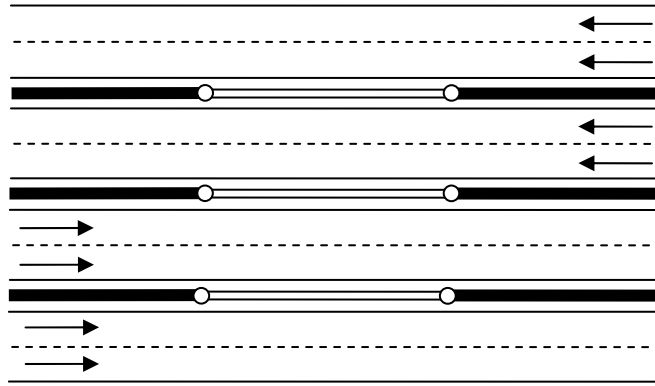


Figure 12 Urban With Limited Shoulders

Engineering Specification for Construction of Truck Only
and Passenger Only Travelways in Missouri – Phase 1.
RI 08 – 030.

Sub Document:

**Public Policy
Technical Memorandum.**

Purpose

The purpose of this task is to define the vehicles intended for use on truck-only lanes and provide a practical tool for the enforcement and regulation of truck-only lanes on I-70 in Missouri.

Background

Traditionally highways in the United States have been designated on the basis of their primary role in an interconnected network - broadly defined by the federal "functional class" designations:

Functional classification is the process by which streets and highways are grouped into classes, or systems, according to the character of service they are intended to provide. Basic to this process is the recognition that individual roads and streets do not serve travel independently in any major way. Rather, most travel involves movement through a network of roads. It becomes necessary then to determine how this travel can be channelized within the network in a logical and efficient manner. Functional classification defines the nature of this channelization process by defining the part that any particular road or street should play in serving the flow of trips through a highway network.¹

Table 1 FHWA Hierarchy of Functional Highway Systems

Rural areas	Urbanized areas	Small Urban areas
Principal arterials	Principal arterials	Principal arterials
Minor arterial roads	Minor arterial streets	Minor arterial streets
Collector roads	Collector streets	Collector streets
Local roads	Local streets	Local streets

Understanding what types of vehicle are using Missouri's roadways and the nature of the trip (the customers they serve) can help define the prevalent roadway purpose and vehicles typically traveling the facility. Roadways are designated and designed to serve different types of traffic. Therefore, understanding the various definitions of a commercial motor vehicle on and adjacent to the I-70 corridor will help the project team outline enforcement strategies for the corridor. The following research is intended to further the understanding of how truck-only lane facilities would serve local, regional, and how through traffic would use a truck-only lane facility in Missouri.

Overview of Existing Federal and State Safety Regulations in Missouri

The safety of commercial motor vehicles, drivers and companies is governed at the federal level by the Federal Motor Carrier Safety Administration under federal regulations found in the Code of Federal Regulations Title 49. In general, federal motor carrier safety regulations apply to all employers, employees, and commercial motor vehicles, which transport property or passengers in interstate commerce.

Effective August 28, 2004, Missouri also adopted federal safety regulations with respect to intrastate motor carriers, as follows:

Code of Federal Regulations Parts 100 through 180 (Hazardous Material Regulations) and Parts 382 through 397 (Safety Regulations) generally pertain to:

- *Any person operating any Commercial Motor Vehicle with a Gross Vehicle Weight Rating (GVWR) or Gross Combination Weight Rating (GCWR) greater than 10,000 pounds in Interstate Commerce.*
- *Any person operating any Commercial Motor Vehicle with a Gross Vehicle Weight Rating (GVWR) or Gross Combination Weight Rating (GCWR) greater than 26,000 pounds in Intrastate Commerce, unless transporting any amount of Hazardous Materials.*

Missouri Intrastate Exemptions

- A. Vehicles with less than 26,001 pounds Gross Vehicle Weight Rating (GVWR) or Gross Combination Weight Rating (GCWR) unless transporting passengers or any amount of Hazardous Materials.*
- B. Vehicles licensed for 60,000 pounds or less and are used exclusively to transport solid waste (Intrastate only);*
- C. Vehicles licensed for 42,000 pounds or less and the license plate has been designated for farm use by the letter F (Intrastate only), unless such vehicle is transporting hazardous materials;*
- D. Persons having a valid Missouri Chauffeur's License on May 13, 1988 are not subject to the medical requirements of Part 391.41 (In intrastate commerce only).²*

Within the federal safety regulatory scheme, the regulations are categorized into the following general groups:

- Company regulations
- Vehicle regulations
- Drivers regulations
- Hazardous Materials regulations

Within each category certain exemptions apply, for instance, under the vehicle regulations category exemptions apply to the transportation of school children, non-compensated passenger transport, and emergency vehicles. More information about specific vehicle exemptions can be found in 23 CFR Section 390.1, Subpart A.

Exemptions from federal safety regulations applying to drivers also exist based upon the nature of the business or where the commercial travel is occurring. For example, 49 CFR Part 391 establishes the minimum qualifications for persons who drive commercial motor vehicles for or on behalf of motor carriers. A general exemption from these driver requirements are provided in 49 CFR Part 391, Subpart A:

- (a) Farm custom operation. The rules in this part do not apply to a driver who drives a commercial motor vehicle controlled and operated by a person engaged in custom-harvesting operations, if the commercial motor vehicle is used to—
 - (a)(1) Transport farm machinery, supplies, or both, to or from a farm for custom-harvesting operations on a farm; or
 - (a)(2) Transport custom-harvested crops to storage or market.
- (b) Apiarian industries. The rules in this part do not apply to a driver who is operating a commercial motor vehicle controlled and operated by a beekeeper engaged in the seasonal transportation of bees.
- (c) Certain farm vehicle drivers. The rules in this part do not apply to a farm vehicle driver except a farm vehicle driver who drives an articulated (combination) commercial motor vehicle as defined in §390.5. (For limited exemptions for farm vehicle drivers of articulated commercial motor vehicles see §391.67.)

The federal motor carrier safety regulations as adopted by Missouri also provide exemptions from driver duty status record keeping requirements (i.e. the drivers log book) for short-haul operations. Short-haul operations are generally defined as when

the driver operates wholly within a 100 air-mile radius of the normal work reporting location. (see 49 CFR, Section 395.1)

In Missouri specific exemptions are provided to farm drivers of trucks that operate within 150 air-miles of their farm, wholly within Missouri, and who are not hauling for-hire or placarded hazardous materials. Farm truck drivers meeting these conditions are exempt from CDL and drug and alcohol testing requirements.³

Defining a commercial motor vehicle

The definition of a commercial motor vehicle (CMV) within the context of this report provides a suggested regulatory scheme for enforcing inclusion/exclusion of vehicles that may use truck-only lanes across I-70. There are several entities throughout the corridor, each with a potentially different definition of a CMV.

Recently the state determined that trucks with a registered gross weight in excess of 48,000 pounds will be prohibited from driving in the far left lane of urbanized highways that have at least three lanes of traffic in each direction. State law enacted in 2008 already prohibits trucks heavier than 24,000 pounds from driving in the left-most lane of I-70 within three miles of the intersection with state Route 370 in St. Charles County.

The FMCSA defines a commercial motor vehicle as¹: any self-propelled or towed motor vehicle used on a highway in interstate commerce to transport passengers or property when the vehicle:

- Has a gross vehicle weight rating or gross combination weight rating, or gross vehicle weight or gross combination weight of 4,536 kg (10,001 pounds) or more, whichever is greater; or
- Is designed or used to transport more than eight passengers (including the driver) for compensation; or
- Is designed or used to transport more than 15 passengers, including the driver, and is not used to transport passengers for compensation; or
- Is used in transporting material found by the Secretary of Transportation to be hazardous under 49 U.S.C. 5103 and transported in a quantity requiring placarding under regulations prescribed by the Secretary under 49 CFR, subtitle B, chapter I, subchapter C.

¹ <http://www.fmcsa.dot.gov/rules-regulations/administration/fmcsr/fmcsrruletext.asp?chunkKey=0901633480023892>

The Missouri DOT defines a CMV as: a motor vehicle designed or regularly used for carrying freight and merchandise, or more than eight passengers but not including van pools or shuttle buses. In Missouri, farm trucks are considered a CMV if they meet or exceed certain weight ratings⁴. A truck is considered a CMV if it has a gross vehicle weight rating (GVWR) or gross combination weight rating (GCWR) of:

- 10,001 lbs. or more and is operated across state lines (interstate), or
- 26,001 lbs. or more and is operated wholly within Missouri (intrastate), or
- Is between 10,000 and 26,001 lbs. and carries any amount of hazardous materials.

Kansas City defines a CMV⁵ as any self-propelled or towed vehicle used on public highways to transport passengers or property when:

- The vehicle has a gross vehicle weight rating or gross combination weight rating of 10,001 or more pounds;
- The vehicle is designed to transport more than 15 passengers, including the driver; or
- The vehicle is used in the transportation of hazardous materials in a quantity requiring placarding under regulations issued by the secretary of transportation under the Hazardous Materials Transportation Act (49 USC App. 1801-1813).

St. Louis defines a CMV⁶ as a motor vehicle designed, used or maintained primarily for the transportation of property and so licensed. (Ord. 57831 1 (part), 1979: 1960 C. 820.530.) 17.02.570.

Columbia, Missouri also publishes a definition of a CMV. ⁷ It is a motor vehicle designed or regularly used for carrying freight and merchandise or more than eight passengers but not including van pools or shuttle buses.

Since many of the commercial motor vehicles using the potential I-70 truck-only lane facility would be subject to either state or federal safety requirements, it would appear prudent to apply the federal definition of a commercial motor vehicle to the corridor.

Truck Route Designations

In addition to the functional network roles discussed at the outset, Congress and FHWA have also defined the primary networks from a policy standpoint for encouraging interstate commerce and heavy truck travel. The National Network (NN) of Highways includes: (1) the Interstate Highway System and (2) other highways designated by the states in response to the Surface Transportation Assistance Act

(STAA) of 1982. The National Network, sometimes referred to as the national truck network consists of highways submitted to FHWA as being capable of safely handling larger commercial motor vehicles. The criteria provided to states for guidance in designating NN routes is found in Chapter 23 of the Code of Federal Regulations (CRF), Section 658.9:

- (1) The route is a geometrically typical component of the Federal-Aid Primary System, serving to link principal cities and densely developed portions of the States.
- (2) The route is a high volume route utilized extensively by large vehicles for interstate commerce.
- (3) The route does not have any restrictions precluding use by conventional combination vehicles.
- (4) The route has adequate geometrics to support safe operations, considering sight distance, severity and length of grades, pavement width, horizontal curvature, shoulder width, bridge clearances and load limits, traffic volumes and vehicle mix, and intersection geometry.
- (5) The route consists of lanes designed to be a width of 12 feet or more or is otherwise consistent with highway safety.
- (6) The route does not have any unusual characteristics causing current or anticipated safety problems.
- (c) For those States where State law provides that STAA authorized vehicles may use all or most of the Federal-Aid Primary system, the National Network is no more restrictive than such law. The appendix contains a narrative summary of the National Network in those States.

In establishing the NN, federal law also required states to provide trucks with “reasonable access” from the NN to terminals and to facilities for food, fuel, repairs, and rest. No state may deny access within one mile. Terminals are defined as any location where freight originates, terminates, or is handled in the transportation process. Access must be allowed up to 1.61 km (one mile) from the NN by the most reasonable and practicable safe route. For access to terminal and service facilities beyond 1.61 km (one mile) from the NN, the route may be requested from the state. Access must be granted if the state does not act upon a request within 90 days, access is automatically granted. If access is granted to one vehicle type, it applies to all vehicles of the same type, regardless of carrier.

States must also allow access between the NN and points of loading and unloading to household goods carriers, motor carriers of passengers, and any truck tractor-semitrailer combination in which the trailer or semitrailer has a length equal to or less

than 8.53 m (28 feet), or 8.69 m (28.5 feet) for appropriately grandfathered equipment, and which generally operates as part of a truck tractor-semitrailer-trailer combination.

Table 2 shows the access provisions for Missouri and its surrounding states.

Table 2 Missouri and Surrounding State's Access Provisions

State	Distance (in miles) Allowed from the National Network
Arkansas	Unlimited
Illinois	One mile access from a Class 1 highway unless prohibited by signage; 5 miles from Class 1, 2, or 3 highways on the state highway system at 80,000 lb. and on locally designated routes and streets at 73,280 lb. to points of loading and unloading and to service facilities
Iowa	To nearest truck stop for food, fuel, or lodging
Kansas	Unlimited, All U.S. and State routes
Missouri	10 miles

Defining a local truck trip

Option 1: How local truck trips are defined with respect to truck-only lanes on I-70 must be considered within the context of the intended purpose of the facility. If the primary purpose of truck-only lanes is to carry long-haul truck freight through the state with minimal impact on the safety and congestion of general purpose lanes, then prohibiting commercial trucks that are operating within a defined air-mile distance, for instance local trips could be defined as those occurring within a 50, 100, or a 150 mile air radius of the home base of operations. Similar standards are used to apply certain exemptions from commercial motor vehicle safety requirements for farm truck drivers in Missouri. The air-mile radius concept also has precedence in federal regulations with regard to defining commercial operating zones. Using an air-mile radius approach would be relatively straight forward to define and enforce.

Option 2: Another option for defining local trips could be based upon the commercial vehicle configuration. Generally speaking, single unit trucks are widely used for regional short-haul operations, while tractor semi-trailer or tractor, semi-trailer, trailer combinations are generally used for longer haul operations. Interstate long-haul combination vehicles tend to have five axles or more, with a 53 foot semi-trailer, allowing these vehicles to achieve the maximum gross weight of 80,000 pounds and/or the maximum cubic capacity universally allowed on the Interstate Highway System across the U.S. Carriers that operate combination vehicles for local haul operations, for instance convenience store suppliers, may operate shorter semi-trailers, with a single

rear axle to improve handling and maneuvering capabilities. Thus another straight forward approach for limiting short-haul use of a truck-only lane facility would be to allow only combination commercial vehicles of five axles or more, with semitrailers at or exceeding 48 feet in length.

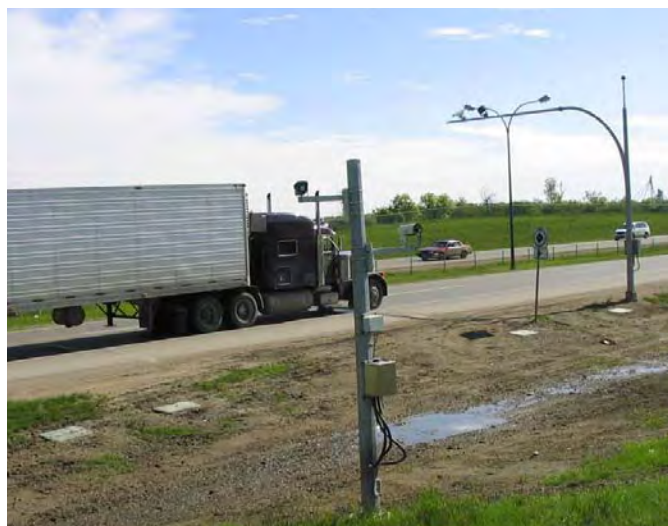
Option 3: Another option for defining local truck trips can be determined from the basis or reason for the trip. For instance, many states exempt a first haul from farm field to first point of delivery or processing from various vehicle and driver regulation. In urban settings, local truck trips are often defined as the transportation of goods between two locations within a project area, or within the urban region. The New York City DOT defines a local truck trip as a trip with an origin and destination for the purpose of delivery, loading or servicing within a borough. The city has developed an extensive network of truck routes in the region for the purpose of delivering goods and services. Trucks may only use non-designated routes for the purpose of gaining access to their final destination. For example, a truck trip originating in Staten Island and traveling to Queens would be required to use the through route network while passing through the borough of Brooklyn en route to Queens. If the destination in Queens was not immediately accessible from the through truck route, the driver would then have to travel on the local truck route network to complete the trip. However, a truck going from one end of Queens to the other is permitted to travel on the local truck route network.

Enforcement of Local Truck Trip Regulations

To effectively implement local truck trip regulations on a TOL facility, a non-invasive, low cost procedure for enforcing regulations will need to be developed. One option could include the investigation of enforcement technologies currently being used in "virtual weight station" applications.

Virtual weigh station systems use stationary or portable weight-in-motion scales for vehicle weighing, height detectors for vehicle dimensioning, and digital camera technologies to capture images of a truck's license plate or USDOT number.

Images are processed by an Optical Character Recognition (OCR) system



on the central computer that reads the numbers in the captured image. A central computer then checks for credentials and permitting information for the identified vehicle and verifies that the height and weight are in compliance. If a vehicle is out of compliance, the central computer sends a signal to an enforcement authority computer or communications device, indicating that the vehicle should be stopped for enforcement.

If an air mile radius approach as described in **Option 1** were used, the license plate image can be matched against database records to ascertain if the carrier's home base is within the specified air-mile radius. If the truck belongs to a local business, a photo of the vehicle can be sent to the owner with a warning of a violation. Repeated violations could trigger a roadside enforcement action. A similar approach can be used for **Option 2**, based on vehicle dimensions. **Option 3**, would likely required a roadside stop and manual inspection of shipping papers to determine the reason for the trip.

¹http://www.fhwa.dot.gov/planning/fcsec2_1.htm

² Safety Compliance Manual, Motor Carrier Services Division, Missouri Department of Transportation - April 2008.

³ Highway Safety for Missouri Farm Trucks, Motor Carrier Services Division, Missouri Department of Transportation. <http://www.modot.mo.gov/mcs/documents/FarmTruckSafety07.pdf>

⁴ Missouri Department of Transportation. Motor Carrier Services. *Highway Safety for Missouri Farm Trucks*. Located online at: <http://www.modot.mo.gov/mcs/safety/documents/FarmTruckSafety07.pdf>

⁵ <http://www.municode.com/Resources/gateway.asp?pid=10156&sid=25>

⁶ <http://www.slpl.lib.mo.us/cc/code/data/t1702.htm>

⁷ http://www.gocolumbiamo.com/Council/Code_of_Ordinances_PDF/documents/chapter_14.pdf

Engineering Specification for Construction of Truck Only
and Passenger Only Travelways in Missouri – Phase 1.
RI 08 – 030.

Sub Document:

**Literature Review on
Effectiveness of Guard Cables
with Trucks and Truck-Only Lanes.**

Engineering Specifications for Construction of Truck Only and
 Passenger Vehicle Only Travel ways in Missouri - Phase I: RI08-030
 Literature Review on Effectiveness of Guard Cable with Trucks and Truck-Only Lanes

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INTRODUCTION

To meet ever increasing freight truck traffic, enhance safety and reduce congestion, the Missouri Department of Transportation (MoDOT) is investigating truck-only lane improvements along I-70 and I-44. As a part of developing engineering specifications for construction of truck only and passenger only travel ways in Missouri, MoDOT commissioned this literature review to identify and summarize existing literature on guard cable effectiveness with trucks. Additionally, this review provides information about the type of guard cables in use, effectiveness based on type of median barriers, and cross median crash statistics. **Figure 1** shows the typical layouts of two types of guard cables in use.

Figure 1: Typical guard cable layout¹



Low-tension Guard Cable



High-tension Guard Cable

The purpose of this technical memorandum is to gain understanding on effectiveness of guard cables in enhancing the safety of trucks in truck-only lanes. The studies identified in this technical memorandum detail the design guidelines, operational performance of cable barrier systems, feasibility constraints in implementing guard cables, and crash effectiveness statistics.

¹ Source: http://epg.modot.mo.gov/index.php?title=606.2_Guard_Cable.

SAFETY EFFECTIVENESS AND OPERATING PERFORMANCE OF THREE-CABLE MEDIAN BARRIER ON INTERSTATE 5 IN OREGON (2003)

Realizing that median crossover crashes often result in fatality or severe injuries, the Oregon Department of Transportation (ODOT) commissioned this study to compare crash analysis before and after installation of guard cable. This study contains not only before-after accident statistics but also an economic comparison of the cost of the barrier system. The analysis is based on the crash severity for period of three years over a 21.9 mile divided highway. Key findings include the study of cable barrier impacts, underrides, and penetrations from maintenance records, and police crash reports. Economic analysis in this report includes cost estimates for the repair of guard cable over the evaluation period. Estimated repair costs and crash comparison in other states is summarized in **Table 1**.

Table 1: Comparison of crashes with other states²

	Oregon	North Carolina	Iowa	New York
Study Period in Years	4.1	1.8	2.0	3.0
Km Cable Median Barrier (mi.)	35.2 (21.9)	13.7 (8.5)	NA	NA
Repairs/Year	44	71	29	NA
Repair Cost/Accident (\$)	\$1,419	NA	\$543	\$328
Repair Cost/Post (\$)	\$320	\$86	\$90	NA

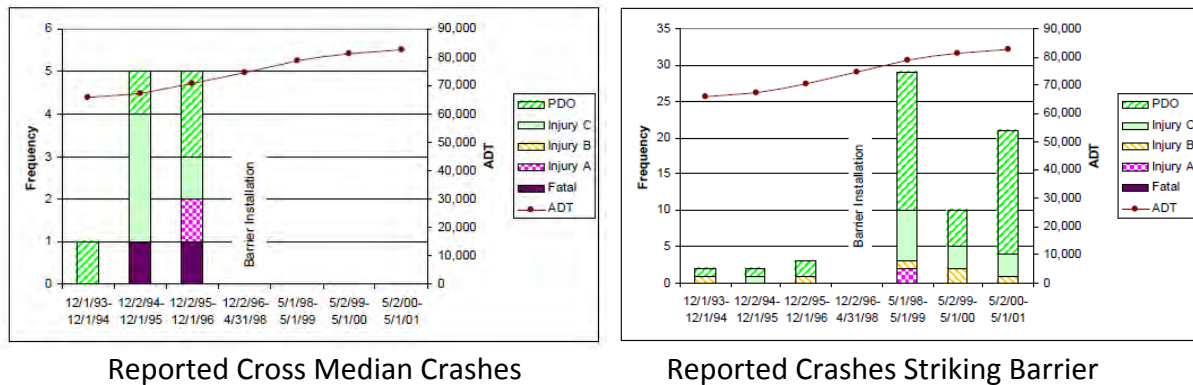
NA: Not available

Costs adjusted to 2001 assuming 4% inflation.

The crash analysis reported no crashes due to vehicles crossing over the median after installation and 60 crashes striking the barrier (See **Figure 2**).

² Source: Monsere, C.M., B. Sposito and S. Johnston. 2003. "Safety effectiveness and operating performance of a three-cable median barrier on Interstate 5 in Oregon" submitted to Institute of Transportation Engineers 2003 Annual Meeting, Seattle, WA, USA.

Figure 2: Cross median crashes and striking barrier crashes³



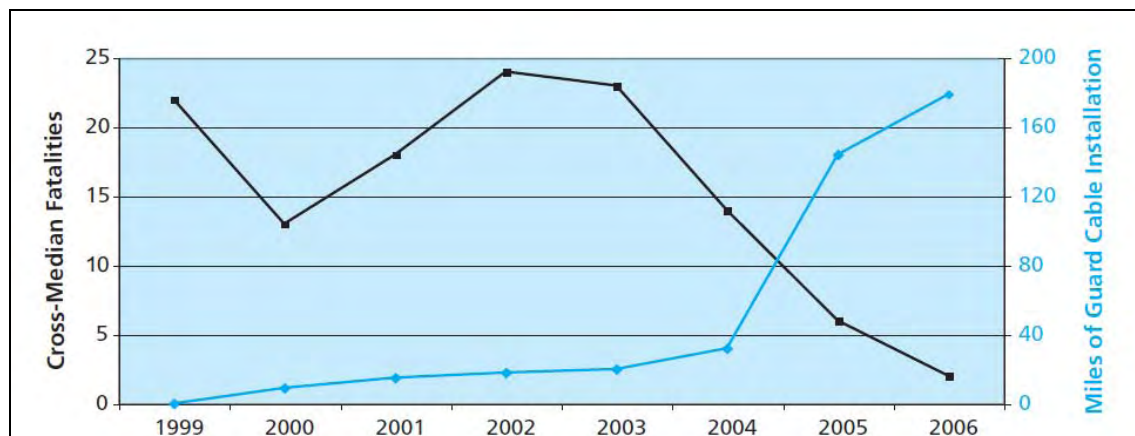
The study indicates that the cable barrier system was effective in reducing the severity of crashes but, as expected, increased in minor injury and property damage crashes. Two complete penetration of the cable barriers by large vehicles or trucks were identified which may indicate that cable barriers are not totally effective for these vehicles. Nonetheless, this report concludes that guard cable is an effective measure to prevent the cross median accidents.

³ Source: Monsere, C.M., B. Sposito and S. Johnston. 2003. "Safety effectiveness and operating performance of a three-cable median barrier on Interstate 5 in Oregon" submitted to Institute of Transportation Engineers 2003 Annual Meeting, Seattle, WA, USA

ELIMINATING CROSS-MEDIAN FATALITIES (2007)

According to a crash analysis by safety professionals of MoDOT, cross median fatalities endanger more drivers than any other type of fatality accident along Missouri freeways. This report identifies the basic problems underlying cross median fatalities, the solution to resolve the problem, and possible application and benefits of the solutions. The conclusion of the report are as follow: 1) Median cable barriers are found to be an effective solution; 2) for long-distance installation on rural interstates, the cable barrier is more cost-effective than concrete barrier or a guard rail; and 3) cross median fatalities have drastically declined as more guard cable is installed. (See **Figure 3**)

Figure 3: Cross median fatalities and miles of cable median barriers installed on I -70⁴.



As shown in **Figure 3**, median cable barriers installed in Missouri caught 95 percent of vehicles entering the median and prevented the vehicles from entering the opposing lanes. Installation of guard cable barrier for 179 miles on the freeway has practically eliminated cross median roadway deaths.

⁴ Source: 2. MoDOT, Brian Chandler. "Research Pays Off - Eliminating Cross-Median Fatalities: Statewide Installation of Median Cable Barrier in Missouri" 2007 Annual TRB meeting.

THREE-CABLE MEDIAN BARRIER FINAL REPORT

The main focus of this report submitted to the Oregon Department of Transportation (ODOT) is to evaluate the effectiveness of the three-cable barrier system in preventing crossover accidents on I-5. The report also estimates maintenance and repair costs of the cable barrier. The report also discusses; 1) design and construction of weak post three-cable barriers, 2) impacts of cable median barriers, and 3) maintenance costs and repair costs.

Assuming guard cable barriers are to be installed at a median width greater than seven meters, the advantages and disadvantages of installation of guard cables are listed as follows:

Advantages:

1. Cost of installation is inexpensive compared with other barrier systems
2. Forces on the occupants of the vehicles during a crash are low compared with other types of barriers.
3. Cable barriers have good crash test performance (up to a 2,000 kg pick-up).
4. System is aesthetically appealing.
5. Sight distance problems are minimized.

Disadvantages:

1. Barrier damage is increased in a typical accident, when compared to other systems.
2. Damaged installations need to be repaired or replaced quickly since the damaged run may be ineffective until repaired.
3. A minimum clear space is required behind the barrier for cable deflection and periodic retensioning of the cables is also required.

The crash statistics in this study reports 53 hits from December 1996 to March 1998, and three cable barrier crossover accidents involving semi-trailer trucks. This indicates that the guard cable barrier may not be fully effective in stopping the trucks on truck-only lanes.

As part of estimating the construction costs, this analysis compares the installation and maintenance costs of cable barrier and concrete barrier. **Table 2** summarizes the system costs for the two barriers.

Table 2: Comparison of system costs⁵

Median Barrier Type	Installation Cost (\$/km)	Annual Maintenance & Repair Cost (\$/km/year)
Cable (actual)	\$27,366	\$2,014
Concrete, including base (bid)	93,504	35

The five relevant findings from this report were: 1) cable median barriers were cost effective; 2) three incidents penetrated the cable barrier resulting in crossover accidents, 3) the fatality rate dropped from 0.6 per year for 1987 through 1996 to zero per year for the study period; 4) the injury accident rate increased from 0.7 per year for 1987 through 1996 to 3.8 per year for the study period; and 5) none of the median barriers used in Oregon were designed to stop larger vehicles because it was not cost effective.

⁵ Source : Brett Sposito, E.I.T. and Sam Johnston, P.E. 1998. "Three-Cable Median Barrier Final Report" submitted to Oregon Department of Transportation, Salem, Oregon 97310

2007 CABLE MEDIAN BARRIER REPORT (2007)

The main goal of this report submitted to the Governor of Washington state was to assess cable median barrier performance by reviewing fatal collisions and other cross median collisions similar to an incident that occurred on I-5 on February 13, 2007 in Marysville (shown in **Figure 4**). The report describes the Washington Department of Transportation's (WSDOT's) cable median barrier program as one of the opportunities to reduce the toll of collisions involving vehicles crossing the median into on-coming traffic.

Figure 4: I-95 Incident in Marysville



Figure 5 illustrates the trend of miles of cable median barriers installed and cross median collisions for past seven years (2000-2007). The study identified the following results of cable median barrier installation:

- During the seven years, crossover median collisions decreased 74 percent (from about 42 collisions per year to about 11 per year) after the cable median barrier was installed.
- Disabling and deadly median collisions dropped 71 percent, from about 18 per year to about five per year.
- Except four fatal median crossover collisions which occurred on I-5 in Marysville, there have been no fatal cross median collisions since the cable median barrier was installed.

Recommendations made in the report are as follows:

- Continue the use of cable median barrier as a general practice on suitable highways with medians of appropriate width.
- Pursue research and development needs that were brought to light during the review of the February 13, 2007 collision.
- Install concrete barrier on I-5 in Marysville, the most noteworthy recommendation to the many citizens who have expressed their concern about the freeway in Marysville (See **Figure 6** for the cross sectional design).

Literature Review on Effectiveness of Guard Cable with Trucks and Truck-Only Lanes

- For cable median installation and placement, create procedures to install the cable-securing wedge in low-tension cable barrier systems.
- Provide design engineers with additional dimensions of fabricated parts and materials specifications for low-tension cable barrier systems.
- In choosing installations for both cable median barrier and concrete median barrier, WSDOT should consider crash history as well as median characteristics and traffic volumes; **Table 3** specifies other recommendations according to the crash rates.

**Figure 5: Total miles of cable median barriers installed and cross-median collisions
(State of Washington, 2000-2007)**

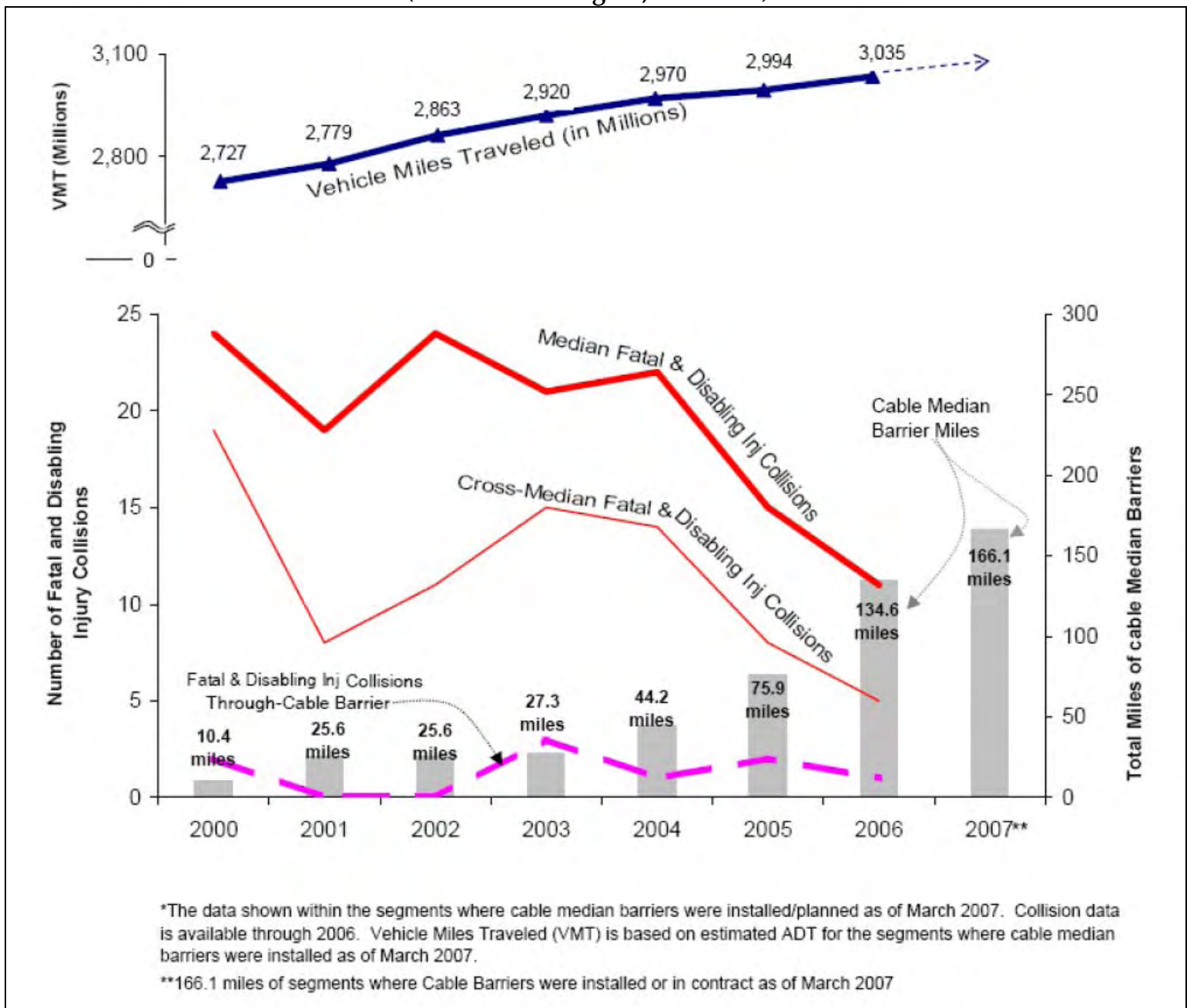


Figure 6: I-5 median cross section - Marysville recommendation

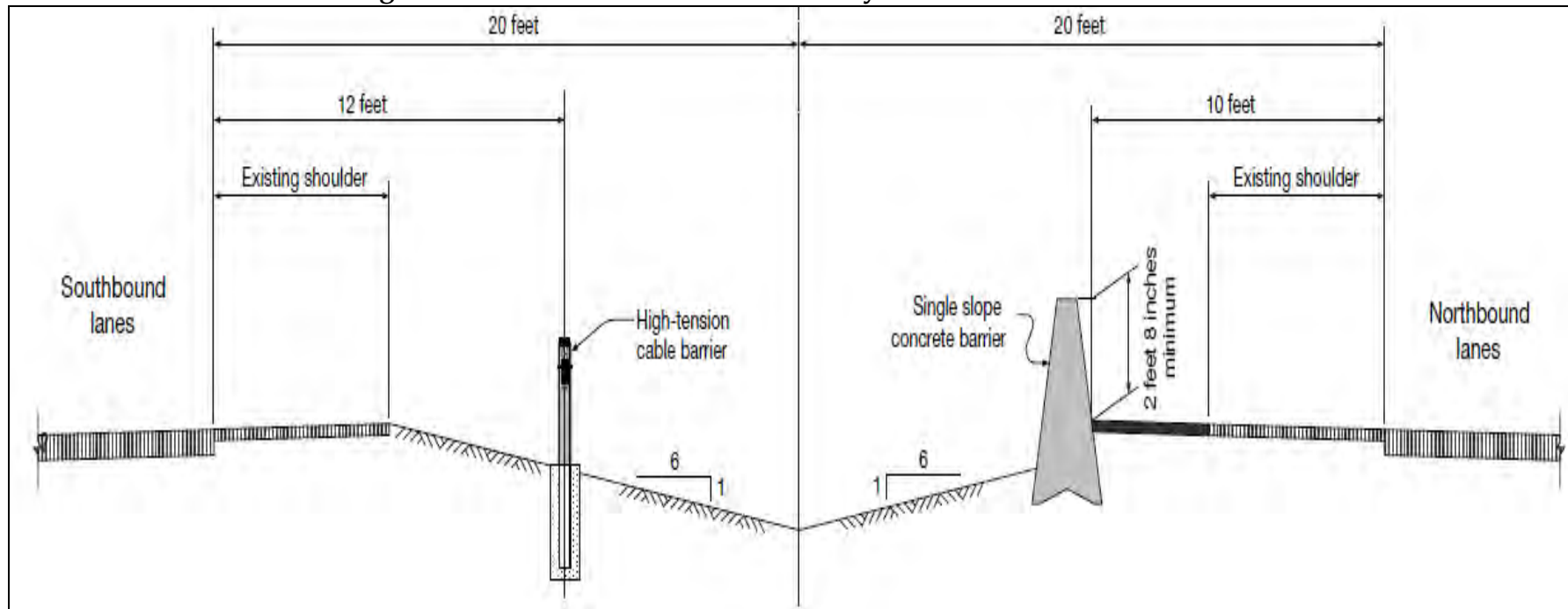


Table 3: Median barrier installation recommendations

Crash rate † Cross-median crashes of per 100 million vehicle miles traveled	Site characteristics	Action
More than 1	No median barrier, median 30 feet or wider and 6:1 or flatter slopes.	Evaluate cost benefit of using a cable median barrier.
More than 2	No median barrier, 30- to 50-foot wide median, 6:1 or flatter slopes, average daily traffic more than 75,000 vehicles and in rural/urban transition area.‡	Evaluate cost benefit of using a double run of cable, w-beam guardrail, thrie-beam guardrail or concrete median barriers.
More than 0.75	30- to 50-foot wide median, cable median barrier, 6:1 or flatter slopes, average daily traffic more than 75,000 vehicles per day and in rural/urban transition area.‡	Evaluate cost benefit of replacing a cable median barrier with w-beam, thrie-beam or concrete median barriers.

2008 CABLE MEDIAN BARRIER REPORT, REASSESSMENT, AND RECOMMENDATIONS UPDATE (2008)

The main goal of this updated report submitted to the Governor of Washington State was to have an independent review of cable median barriers following the fatal cross median collision on I-5 in Marysville on February 13, 2007. This report reviewed WSDOT's cable median barrier policy and statewide cable median barrier performance, and later made recommendations for WSDOT's research program. This updated report considers a newly laid 43 miles of cable median barrier in addition to a 177 mile stretch evaluated in the previous report. It was found that with the inclusion of another 12 months of data, the downward trend in high-severity collisions remains constant. **Tables 4** and **5** compare crash records before and after the installation of cable barrier. The key findings of this report are: 1) cable barriers significantly reduce deaths and serious-injury collisions (**Table 4**); 2) median collisions and collision rate increases (**Table 5**); 3) fatal and serious-injury collision rates have dropped significantly; 4) cable barrier is more effective in stopping vehicles in the median than concrete barrier; 5) no barrier can prevent injury and death in every crash; and 6) the use of cable barrier has been adopted nationwide.

Table 4: Cable median barrier's effect on cross-median collisions

	Before	After	Percent change
Annual cross-median incidents	54.4	14.9	-73%
Cross-median collision rate (per 100 million vehicle miles of travel)	1.85	0.58	-69%
Annual serious-injury cross-median collisions	8.6	1.5	-83%
Annual fatal cross-median collision	5.0	2.2	-57%

Table 5: Collision rate data "before" and "after" cable barrier installation

	Before	After	Percent change
Annual median collisions	223	561	+152%
Median collision rate (per 100 million vehicle miles of travel)	7.64	14.66	+92%
Annual serious-injury median collisions	16.6	5.2	-69%
Annual fatal median collisions	8.2	4.4	-47%
Serious-injury median collision rate (per 100 million vehicle miles of travel)	0.57	0.22	-62%
Fatal median collision rate (per 100 million vehicle miles of travel)	0.28	0.12	-56%

In addition, this study compared the applicability of high tension cable barrier and low-tension cable barrier by crash types (**Table 6**). The report also compares different types of median barriers performance (**Table 7**).

Table 6: Comparison of low- and high-tension cable median barriers

Barrier type	Barrier performance	Reported collisions	Not stated	No injury	Possible injury	Evident injury	Serious injury	Fatal
Low-tension	Contained in median	640 (87.0%)	16 (2.2%)	507 (68.9%)	62 (8.4%)	47 (6.4%)	6 (0.8%)	2 (0.3%)
	Redirected	52 (7.2%)	3 (0.4%)	40 (5.4%)	5 (0.7%)	3 (0.4%)	1 (0.1%)	0
	Cross-median	43 (5.8%)	0	14 (1.9%)	8 (1.1%)	10 (1.4%)	6 (0.8%)	5 (0.7%)
High-tension	Contained in median	316 (74.9%)	2 (0.5%)	254 (60.2%)	33 (7.8%)	24 (5.7%)	2 (0.5%)	1 (0.2%)
	Redirected	91 (21.8%)	4 (0.9%)	68 (16.1%)	12 (2.8%)	7 (1.7%)	1 (0.2%)	0
	Cross-median	14 (3.3%)	0	6 (1.4%)	2 (0.5%)	3 (0.7%)	1 (0.2%)	2 (0.5%)

Table 7: Comparison three median barriers systems

Barrier type	Reported collisions	Not stated	No injury	Possible injury	Evident injury	Serious injury	Fatal
Cable barrier	1,158	25 (2.2%)	890 (76.9%)	122 (10.5%)	94 (8.1%)	17 (1.5%)	10 (0.9%)
Cable barrier (without Marysville)	865	21 (2.4%)	672 (77.7%)	87 (10.1%)	69 (8.0%)	13 (1.5%)	3 (0.3%)
Beam guardrail	2,204	55 (2.5%)	1,317 (59.8%)	493 (22.4%)	284 (12.9%)	40 (1.8%)	15 (0.7%)
Concrete barrier	7,004	156 (2.2%)	4,106 (58.6%)	1,772 (25.3%)	837 (12.0%)	96 (1.4%)	37 (0.5%)
Total	10,366	236 (2.3%)	6,311 (60.9%)	2,387 (23.0%)	1,215 (11.7%)	153 (1.5%)	62 (0.6%)

HIGH TENSION CABLE MEDIAN BARRIER: A SCANNING TOUR REPORT

This “Scanning Tour Report” submitted to the Federal Highway Administration (FHWA), Accelerating Safety Activities Program (ASAP) and the Illinois Department of Transportation (IDOT) identified the effective and efficient approaches for reducing the number and severity of freeway median crossover crashes. Representatives from the states of Illinois, Iowa, Minnesota, and Wisconsin DOTs, and the University of Illinois participated in an objective scanning tour of existing cable barrier to 1) learn from states with experience in the use of high-tension cable barriers (see **Figure 7** for types of high-tension cable barriers), and 2) gather information on system characteristics and performance from the companies that manufactured the high-tension cable barrier systems. The key observations that are presented in report are as follows:

- 1) There was noticeable reduction in crash severity compared to other barrier systems, no fatalities had been recorded on crashes at locations with high-tension cable barriers, and very few crashes had showed barrier penetration.
- 2) While bidding processes and specifications for high-tension cable systems differed among the states, they all require a specific maximum dynamic deflection. Warrants for installation of median cable barrier generally depended on crash history, roadway geometry, and traffic volumes.
- 3) High-tension cable barriers may be installed on the shoulder or median, and are recommended for slopes no steeper than 6H:1V.
- 4) Socket posts are preferred in spite of the high installation cost because the speed and ease of replacement.

With regard to trucks and guard cable, this report provides information about the performance of high tension cable barriers, construction, design, testing, maintenance, and repair costs.

Figure 7: Types of high tension cable systems



U.S. High Tension Cable System



Brifen Wire Rope Safety Fence System



CASS System



Safence System

CABLE GUARDRAIL

The objective of this report submitted to the Colorado Department of Transportation (CDOT) is to monitor the performance of cable guardrail installed in Colorado. In order to monitor the guard cable performance, the CDOT team collected three years of information on accident, maintenance, repair data and severity of damage to the system. The analysis evaluated the performance of Brifen Wire Rope Safety Fence (WRSF) installed in long roadway curves. This report also compares effectiveness of guard cable and guard rail in terms of snow drifting problems. As a part of performance evaluation the report compared the performance characteristics of different cable systems as shown in **Table 8**.

Table 8: Performance characteristics of guard Cables

Item	Brifen WRSF	Trinity CASS	Trinity CASS	Trinity CASS	SC 3-Cable	Safence 350 4RI	W-Beam
# of Cables	4	3	3	3	3	4	---
Post Spacing *(may be spaced less)	10'-6" * (3.2m)	6'-6" (2m)	9'-10" (3m)	16'-5" (5m)	16'-0" curves $R \geq 700'$	8'-2" * (2.5m)	varies
Deflection test 3-11 Note 1	7'-10" (2.4m)	6'-9" (2.06m)	7'-11" (2.4m)	9'-2" (2.8m)	?	8'-10" (2.7m)	~ 3 ft.
Cable Diameter (strands)	$\frac{3}{4}"$ (3x7)	$\frac{3}{4}"$ (3x7)	$\frac{3}{4}"$ (3x7)	$\frac{3}{4}"$ (3x7)	$\frac{3}{4}"$	19 mm	---
Tensioned to lb-ft (Note 2)	2,500 – 8,100	3,500 - 7,300	3,500 - 7,300	3,500 - 7,300	none	1,800 - 7,000	---
Functional after hit?	yes	yes	yes	yes	no	yes?	varies
Maximum Slope for non-shoulder placement	$\leq 6:1$	$\leq 6:1$	$\leq 6:1$	$\leq 6:1$	$\leq 6:1$	$\leq 6:1??$	$\leq 10:1$
Installation segment lengths	See installed systems	250' to 10,000'	250' to 10,000'	250' to 10,000'	Up to 2000'	Up to 36,000'	---
Approved Terminal Note 1	Yes (gating)	Yes (gating)	Yes (gating)	Yes (gating)	? (gating)	No	Yes
Median width min.	Dependent on post spacing				≥ 24 ft.	Dependent on post spacing	
Project data:							
Cost per ft	\$12 - \$15 Note 3				\$11		\$11.44
Typical hit damage	5 Posts						
--typ. repair time	1 Hr						
--typ. cost	<\$300				\$1000		

Note 1 – NCHRP 350 TL-3 (3/4 Ton truck)

Note 2 – Cable tension is set according to manufacturer specifications depending on the ambient temperature at the time of tensioning.

Note 3 – Installed Costs for CDOT test projects.

The systems evaluation for guard cable assessed the following issues:

- Performance in controlling and reducing vehicle damage and injuries in accidents.
- Costs for parts and labor, and length of time between the accident and the repair.
- Availability of parts to keep the systems working properly.

This report also identified no snow drift and accumulation problems with guard cable as the posts do not obstruct the wind flow nor allow any snow accumulation. In this sense, guard cable barrier is best suitable for snow areas. From a performance point of view, this report indicates that except for one incidence that penetrating the system in the median on I-25, the guard cable has proven to be more efficient in constraining vehicles than other systems.

The report pointed out that the height of the cables above the ground is very important to the proper function of the cable guardrail system. Particularly, in areas where heavy snow is thrown over and through the cable system by snowplows, the impact of the snow and ice on the cables and posts may be strong enough to break or pop out the locator pegs, allowing the cables to sag below the design height. So, it may be necessary to replace the pegs and reposition the cables to the proper height periodically.

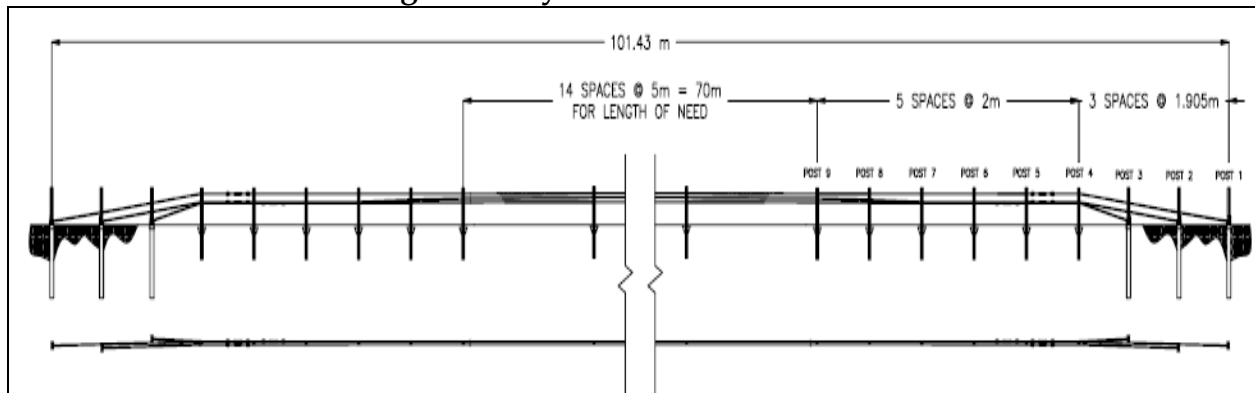
CABLE AND WIRE ROPE BARRIER DESIGN CONSIDERATIONS: REVIEW

This TRB paper identified the areas of rope barrier design improvement and develops guidelines for more efficient working of the barriers. The paper recommended the cable barriers remain taut to 1) improve interaction with the vehicles, 2) reduced dynamic deflections, and 3) minimized maintenance costs. The dynamic deflections are further influenced by other factors like tension in the cable, post spacing, and horizontal curvature. The influence of system lengths and curvature on the maximum dynamic deflection was tested using computer simulation with BARRIER VII simulation code. Identifying two important questions of deflection and effect of spring compensator on barrier impact, the report calculates them using the following equations:

- a) In estimating the total dynamic deflection (d), the report uses $d = PL/4t$, where, 'L' is the length of cable with tension 't' with load at mid span 'P'.
- b) The maximum load that the spring compensator achieves is given by spring constant and maximum throw

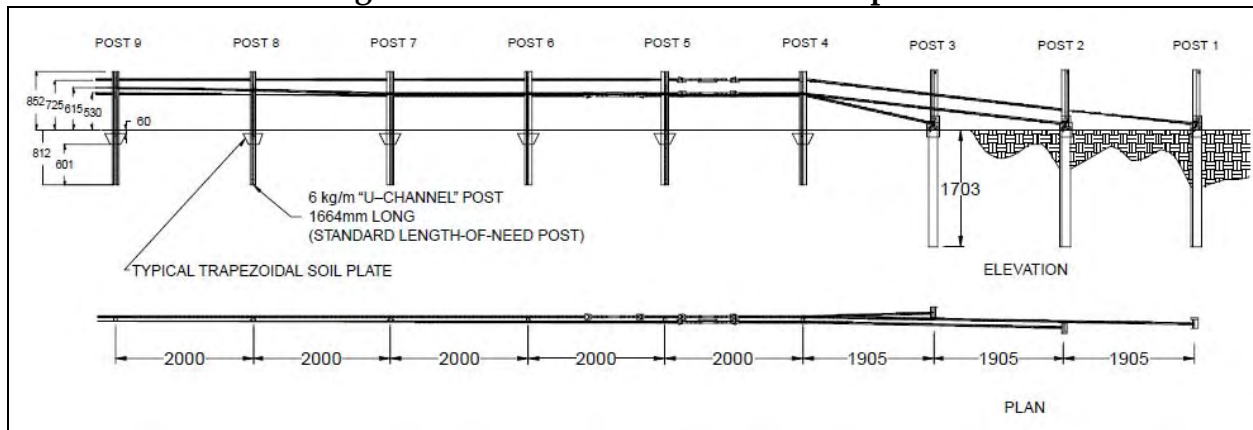
The simulation model was used to simulate a 2,000 kg pickup truck with 100km/hr speed at 25 relative to tangent. The layout of installation and tested are shown in the **Figure 8**.

Figure 8: Layout of Test installation



This study recommended a new terminal developed for anchorage of cable barrier systems use Cable Release Post (CRP) (See **Figure 9**.). This approach allows the system to accommodate a high level of initial tension that helps reduce barrier deflection during the impact. Spring compensators were removed to permit higher initial tension.

Figure 9: New cable barrier terminal plan



It is also believed that maintenance costs should be reduced when adequate anchorage is provided. The improved high initial tension and reduced deflection possibly make this modified guard cable design more effective for trucks and the implementation of truck-only lanes in Missouri.

WASHINGTON STATE CABLE MEDIAN BARRIER IN-SERVICE STUDY

The paper presented at the 83rd Annual TRB meeting 2004 focuses on documentation of Washington state experience with cable median barrier. The paper discussed the analyses of the initial installation cost, maintenance costs, maintenance experiences, and accident history before and after installation as well. Using accident and maintenance data associated with 24.4 total miles of cable median barrier located in three distinct locations along I-5, the following were the key findings made in the report:

- Cable median barrier installation cost was estimated to be approximately \$44,000 per mile.
- The average cost per repair was found to be \$733, and maintenance repair cost per mile was found to be \$2,570 annually.
- The time between cable barrier damage notification and repair was estimated to be about two days and the time required to repair it was about 30 percent less than that required for W-beam guardrail.
- The societal benefit of cable median barrier was calculated to be \$420,000 per mile annually.
- Cable median barrier was found to be a cost effective solution to median crossover accidents.

This report also provided installation costs by barrier. The costs are as follow:

- Cable median barrier: \$8.33/feet or \$44,000/mile
- W-beam guardrail: \$13.65/ feet or \$72,000/ mile
- Precast concrete barrier: \$24.64/ feet or \$130,000/ mile
- Single Slope concrete barrier: \$44.94/ feet or \$237,000/ mile
- Cast in Place concrete barrier: \$79.36/ feet or \$419,000/ mile

Using historical accident data collected before (1990-1996) and after (1999-2002), the cable median barrier and the societal costs shown in **Table 9**, this study estimated the total societal costs saved from the reduction of median related accidents. The total annual societal costs were calculated to be \$13.58 million before the installation of cable barrier and \$3.32 million after the installation, which results in a savings of \$10.26 million annually. (This results in a savings of \$420,000 per mile per year.)

Table 9: Accident Societal Costs⁶

PER FATAL COLLISION	\$3,760,000
PER DISABLING INJURY COLLISION	\$315,000
PER EVIDENT INJURY COLLISION	\$70,000
PER POSSIBLE INJURY COLLISION	\$35,000
PER PROPERTY DAMAGE ONLY COLLISION	\$6,500

THREE-STRAND CABLE MEDIAN BARRIER IN NORTH CAROLINA: IN-SERVICE EVALUATION

This TRB paper proposed several regression-type models that were developed to analytically estimate the effects of the installation of cable median barrier on crash rates for several crash types. The models take into account several other factors associated with variations in crash occurrences or crash rates such as weather conditions. The crash types included in the study are: Serious and fatal accidents, Ran-off-Road-Left, Hit-Fixed-Object Crashes, Rear-End Crashes, Ran of Road Left (RORL), Overturn Crashes, Sideswipe and Angle Crashes, and RORL Head-On Crashes. The models use the following basic equations to estimate the expected crashes:

$$\text{Expected crashes} = (\text{constant}) \times (\text{segment length}) \times (\text{other roadway factors}) \\ \times (\text{crash year factors}) \times (\text{treatment factors})$$

Then, the log of the expected crashes were formulated as a linear function of explanatory variables given below⁷:

$$\begin{aligned} \text{Log (Expected crashes)} = & \beta_0 + \log(\text{segment length}) + \beta_1 [\log(\text{AADT})]^2 + \beta_2 \\ & (\text{median width}) + \beta_3 (\text{median width})^2 + \dots + \text{other} \\ & \text{roadway terms} + \beta_k(Y_{90}) + \beta_{k+1}(Y_{91}) + \dots + \beta_r(T_1) + \beta_{r+1}(T_2) \\ & + \beta_{r+2}(T_3) \end{aligned}$$

Where, $Y_{90}, Y_{91}, \dots, Y_{96}$: crash year indicator variables,

T_1, T_2, T_3 : Treatment indicator variables (four different levels of treatments were evaluated).

⁶ Based on 1998 FHWA Recommendations and inflated to 2002 dollars.

⁷ For complete discussion of the model, refer to 'William W. Hunter, J. Richard Stewart, Kimberly A. Eccles, Herman F. Huang, Forrest M. Council, and David L. Harkey, 2001, Three-Strand Cable Median Barrier In North Carolina: In-Service Evaluation' published in transportation research board 2001'.

Table 10 shows the parameters calibrated using crashes collected from 6,111 segments of highway in the state of North Carolina.

Table 10: Accident Parameters

Parameter	DF	Estimate	χ^2	P-value
Intercept	1	-12.28	1525.08	< .0001
Year 90	1	3.11	5.75	.0165
Year 91	1	-.13	8.62	.0033
Year 92	1	-.06	1.89	.1689
Year 93	1	.04	.75	.3850
Year 94	1	.10	6.20	.0128
Year 95	1	.07	3.11	.0776
Year 96	1	.12	10.01	.0016
Log (ADT)	1	1.29	2858.21	< .0001
Narrow Median	1	.39	140.56	< .0001
Medium Median	1	.20	47.99	< .0001
< 6 Lanes	1	.19	15.13	.0001
6 Lanes	1	.29	33.56	< .0001
Right Shoulder Width	1	-.02	14.52	.0001
Reference Section	1	.33	8.04	.0046
Treatment Section (94)	1	.35	3.05	.0808
Treatment Section (95-97)	1	.34	5.92	.0150

The paper also presented the formula for Equivalent Property Damage Only (EPDO) and a Severity Index Calculation illustrated by the following equation:

$$EPDO \text{ index} = 76.8(A + K) + 8.4(B + C) + PDO$$

Where, K = number of fatal crashes,

A = number of A injury crashes (incapacitating injuries that will prevent normal activities for more than 24 h),

B = number of B injury crashes (incapacitating injuries that will not prevent daily activities for more than 24 h),

C = number of C injury crashes (complaint of pain or momentary unconsciousness), and

PDO = number of property-damage-only crashes.

The severity index (SI) averages the severity of all crashes at a location and is calculated in the following manner:

$$SI = EPDO \text{ number of crashes} = [76.8 (A + K) + 8.4 (B + C) + PDO] N$$

Where, N is the number of crashes at the location

Results from these analyses indicate that several types of crashes (e.g., ran-off-road-left, hit-fixed-object) increased on the sections where cable median barrier was installed. However, these sections showed improved overall safety through fewer serious and

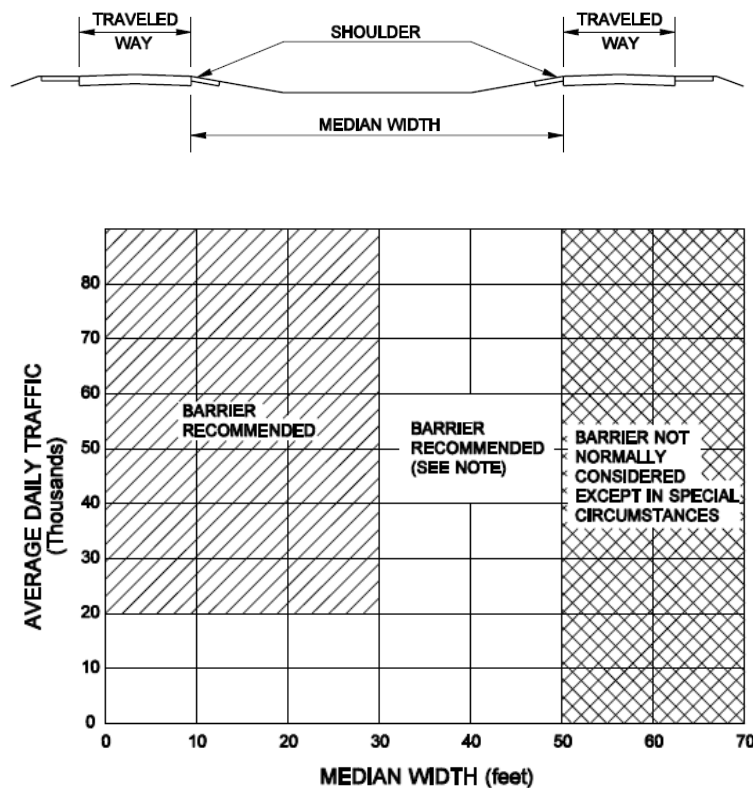
fatal crashes as well as fewer head-on crashes. Overall severity index values were greatly reduced after cable barrier installation. From our literature review point of view, this paper provides useful information about the procedure to test the cable median barrier after installation of truck-only lanes.

AASHTO REVISED CHAPTER 6: MEDIAN BARRIERS

This report provided recommended changes to Median Barrier Guidelines for chapter 6 of the AASHTO Design Guide. The main objective of this draft report is to reference the performance requirements for median barriers and to present guidelines for selecting and installing an appropriate barrier system. This report also presents the structural and safety characteristics of selected median barriers, including end treatments and transition sections in detail.

This report suggested a guideline for median barrier to be considered for high-speed fully controlled access roadways that have traversable medians as shown in **Figure 10**. The recommendations are as follow: 1) barrier is recommended for locations where the median is 15 m [50 ft] in width or less with more than 20,000 of the average daily traffic (ADT); 2) For locations with medians widths between 10 m [30 ft] and 15 m [50 ft] with the average daily traffic (ADT) less than 20,000, states are encouraged to conduct a benefit/cost analysis for the installation of the median barrier; and 3) a barrier is not normally considered for locations with median widths greater than 15 m [50 ft], except in special circumstances such as a location with a significant history of cross median crashes.

Figure 10: Suggested guideline to determine whether or not a barrier to be considered



The report included the selection and placement guidelines for new construction and also presented methods for identifying and upgrading existing systems that do not comply with current guidelines. Main conclusions and recommendations made were:

1. recommended that median barrier be considered for high-speed, fully controlled-access roadways that have traversable medians.
2. Factors responsible for selecting high performance cable barrier include: a) high percentage or large average daily number of heavy vehicles, b) adverse geometrics (horizontal curvature), and c) severe consequences of vehicular (or cargo) penetration into opposing traffic lanes.
3. Structural and safety characteristics of median barriers based on crash tested median barriers that passed the testing for level 3 compliance.
4. Major considerations in the selection of median barriers are: Barrier performance Capability, Barrier Deflection Characteristics, Compatibility, Costs, Maintenance, Aesthetic and Environmental Considerations, and Field Experience.

5. Recommendations for placements of median barriers are also made depending on terrain effects, fixed objects in medians. **Figures 11** and **12** illustrates the placement recommendations and layout of the median barriers

Figure 11: Recommended barrier section in non-level medians

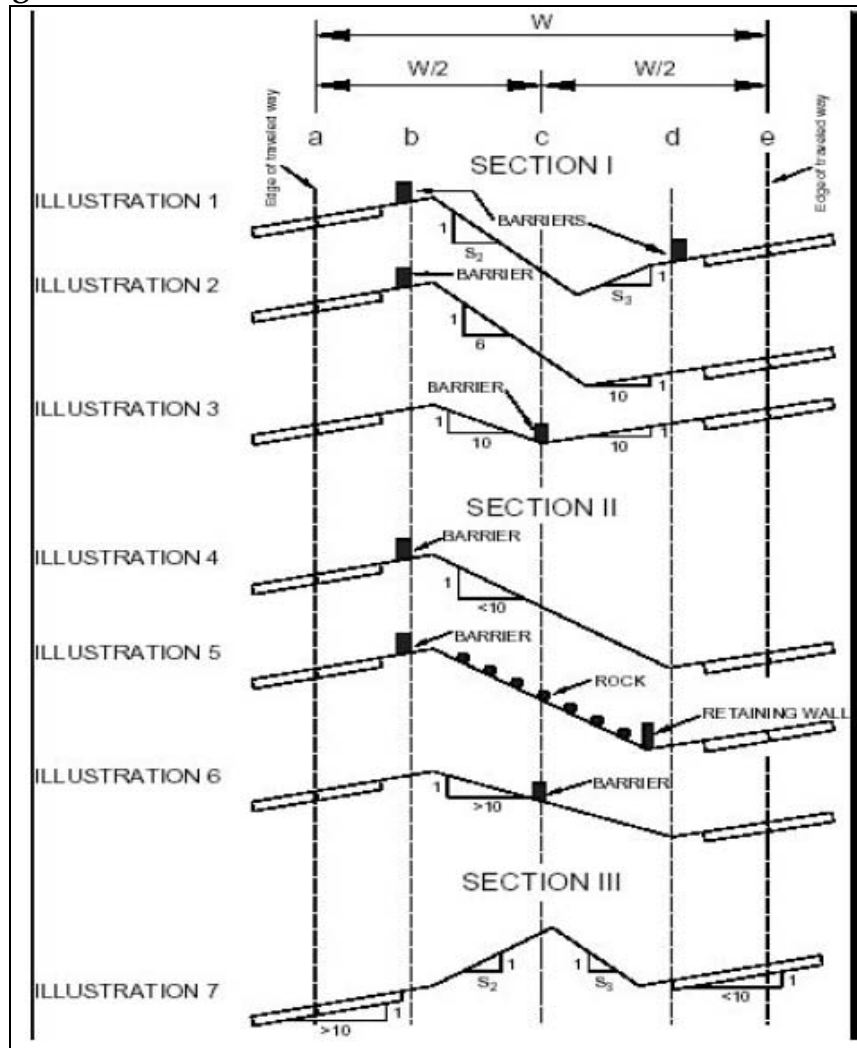
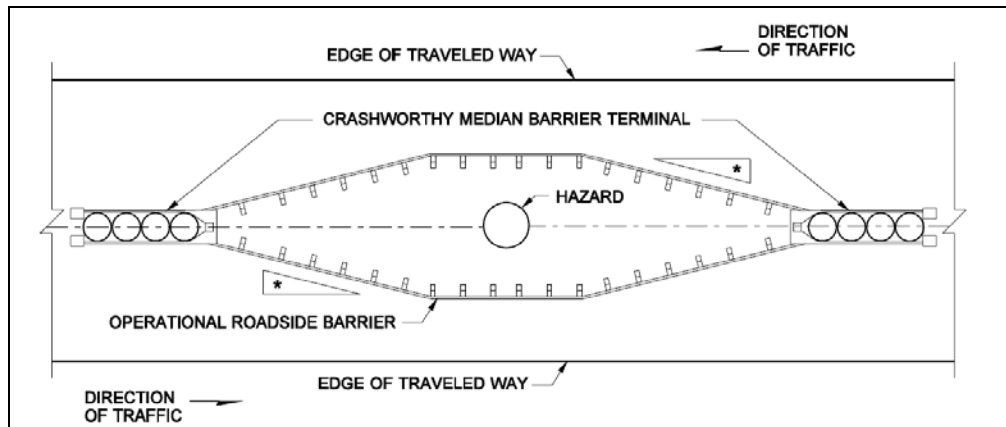


Figure 12: Recommended barrier placement in non-level medians

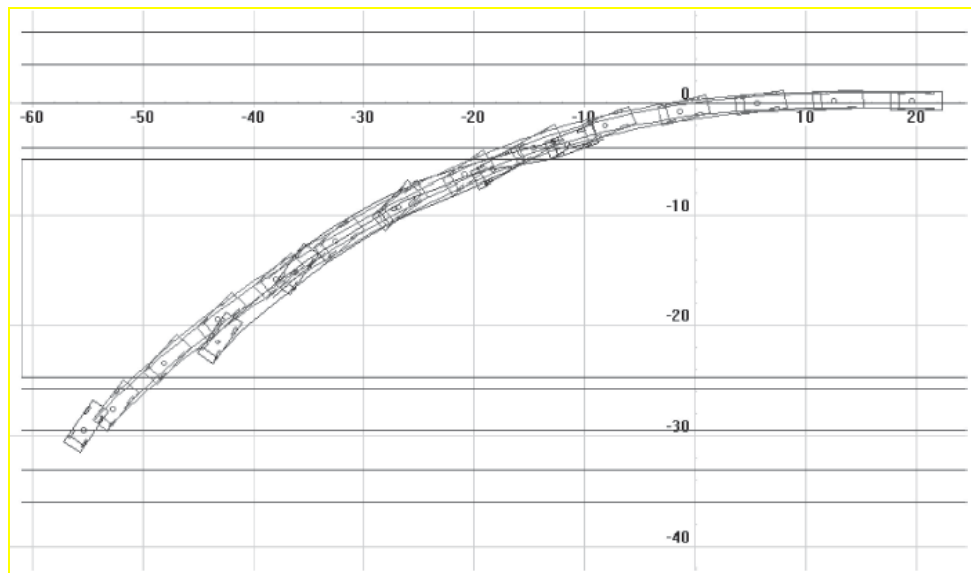


BAYESIAN RECONSTRUCTION OF MEDIAN-CROSSING CRASHES AND POTENTIAL EFFECTIVENESS OF CABLE BARRIERS

This TRB paper pointed out that the majority of cross median crashes occurred on sections with lower traffic volumes or wider medians than would warrant barriers according to the AASHTO guidelines. It also pointed out that placing a single barrier in the center of the median would cost less than two barriers but for a center-placed barrier there appears to be a greater probability that a vehicle will hit the barrier at an angle of greater than 25 degrees. This means the impact severity of the resulting collision may exceed the test level specified in NCHRP Report 350 and that the barrier may fail. Motivated by this fact, this paper reconstructed several fatal median-crossing events where the existing median exceeded 30 feet. For the analysis, a version of PC-Crash's trajectory model was developed by authors based on the technical manual of PC-Crash⁸.

The paper identified the issues that can be addressed through accident reconstruction. This includes initial location and vehicle velocity, and actions taken by the vehicles. After the crash parameters were identified, an assessment of the avoidance actions (or countermeasures) and causation analysis was carried out. (A sample of a reconstructed crash is shown in **Figure 13**)

Figure 13: An accident scene of median-crossing crash



⁸ Moser, A., H. Steffan, A. Spek, and W. Makkinga. Application of the Monte Carlo Methods for Stability Analysis Within the Accident Reconstruction Software PC-Crash. SAE Inc., Warrendale, Pa., 2003.

The developed simulation model is used to identify the causes of accident and included an analysis of roll over median crashes and their causes. The conclusions from the simulation analysis are as follow:

- Most median encroachment was triggered by a loss of control following a steering overcorrection.
- Few drivers regain control once their vehicle enters the median and unless they lack sufficient kinetic energy or are stopped by an obstacle will traverse the entire median.
- Impact severities indicated that the crashes were of lower intensity than that required by NCHRP Report 350's Test Level 3, so that a wide range of barrier designs could probably prevent crashes like the crossover and rollover crashes.

This report indicate that the computer based simulation techniques can be used for analyzing the causes of crash on truck-only lanes and that the road design standards can be extended to truck design.

DRIVING DOWN LANE DEPARTURE FATALITIES

Of the more than 42,000 people killed on our nation's highways annually, over 25,000 (about 60 percent) died in crashes caused when their vehicles veered from the lane. To address these devastated statistics, the American Association of State Highway and Transportation Officials (AASHTO) set a plan to cut the fatality by half in two decades. As the first step of this effort, this report focused on how state DOTs have made simple safety improvements programs intended to prevent roadway lane-departures, minimize the likelihood of a crash when a departure occurs and reduce the severity of the crashes. This report discussed the effectiveness of relevant safety programs in the following states:

1. Colorado's Hazard Elimination and Safety Program
2. South Dakota Statistics
3. Missouri's System-Wide Safety Solutions
4. Tennessee Statistics
5. Mississippi's Rumble "Stripes"
6. Delaware's Bicycle-Friendly Rumble Strips
7. North Carolina's "Ride Safe Corridors"
8. Centerline Rumble Strips
9. Washington State's Experience with Cable Median Barrier
10. Missouri's Experience with Guard Cable
11. Georgia's Pavement "Safety Edge"
12. Delaware's "Remove, Shield, Delineate" Program

For example, The Missouri's System-wide safety solutions resulting in a 25 percent reduction in lane-departure include: providing guardrail and median guard cable delineation on major roads; installing emergency reference markers every 0.2 miles on interstates; upgrading signs for better visibility; and installing emergency reference markers every 0.2 miles on interstates, etc. Besides guard cable, safety features discussed in this study included Rumble strips, Curve Delineation, Enhanced Pavement Markings, Skid Resistance, Horizontal Curves, Advanced Warning Signs for Horizontal Alignment, Sight Distance, Head-On Crashes, Centerline Rumble Strips, Raised Centerline Delineation, and "Buffer" Medians. This report provides useful information on the methods and safety programs, including guard cables that would enhance the safety of truck-only lanes.

A COMPREHENSIVE ANALYSIS OF AND DIRECTION FOR MODOT'S CABLE MEDIAN BARRIER PROGRAM

MoDOT analyzed the experience and the state of the practice for guard cable, and developed guidelines for MoDOT's future cable installation program. This study identified problems and recommended solutions in following five key areas: 1) systematic application of guard cable; 2) cable barrier type selection; 3) optimization of lateral placement; 4) routine maintenance and incident repair; and 5) emergency access issues.

The recommendations made for the key areas are summarized in **Table 11**.

Table 11: Recommendations for MoDOT Cable Median Barrier Program

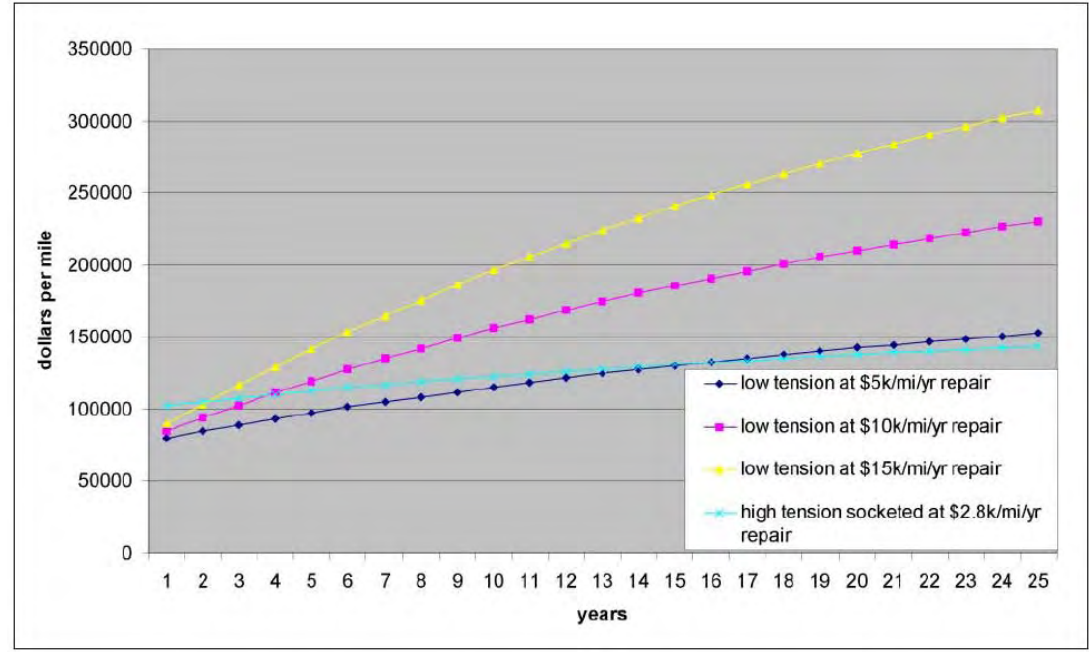
Systematic Application	<ol style="list-style-type: none"> 1. Prioritize cable median barrier installation locations based on traffic and safety data analysis, treating all divided highways equally. 2. Install new median cable median barrier on a corridor-wide basis, between logical termini. 3. Review traffic and safety data each year to validate current priorities and identify any emerging cross median safety concerns. 4. Identify and prioritize all remaining cable median barrier needs statewide.
Cable Barrier Type Selection	<ol style="list-style-type: none"> 1. High-tension, socketed systems should be employed on future large-scale installations. 2. Low-tension cable barriers may be used only for small installations, replacement work in current installations and sealing the gaps between current low-tension installations.
Optimization of Lateral Placement	<ol style="list-style-type: none"> 1. In medians 30 feet wide or wider, the cable barrier should be installed 4 feet down-slope of the edge of shoulder. 2. In medians narrower than 30 feet, the cable barrier should be installed at the vertex of either a V or flat-bottomed ditch. 3. Post spacing should not exceed 15 feet. 4. Discontinue the use of parallel installations (double runs) of cable median barrier, irrespective of median condition. 5. Ensure vegetation control measures are not omitted from cable installations as practical design or value engineering measures.

Routine Maintenance and Incident Repair	<ol style="list-style-type: none"> 1. Lower the response time for non-priority cable repair to seven days. 2. Educate MoDOT personnel as well as external partners on the importance of a well-maintained cable median barrier system 3. Schedule regular visual inspections of the district's entire installation of cable barrier. 4. Continue to outsource the maintenance of low-tension cable barrier. 5. Maintain high-tension barrier with in-house maintenance forces as much as current workloads and efficiency allow. 6. Consider cable barrier maintenance on a corridor basis instead of only maintaining by district. 7. In addition to the cable barrier, ensure the surrounding median is restored to its pre-impact condition with each repair
Emergency Access Issues	<ol style="list-style-type: none"> 1. Emergency crossovers for freeways should be spaced approximately 2-½ miles apart. Additional crossovers in the vicinity of sparsely spaced interchanges may be required to facilitate snow removal. 2. Crossover spacing on expressways should mirror that of freeways. It is likely, however, that such spacing is already present on these routes. 3. The geometric design of the access should be in accordance with Standard Plan 606.41. 4. Emergency crossovers should be intentionally unattractive in order to discourage use by the general public. 5. MoDOT and the FHWA should enter into a programmatic Access Justification Report (AJR) in order to streamline future emergency crossover installations.

This report also estimated the life cycle costs⁹ for different types of median cable barriers. The estimated costs over years were converted to present values using 4~10% of interest rates. **Figure 14** shows the life cycle costs per mile over years.

⁹ Life cycle cost include installation costs, estimated yearly maintenance and repair costs.

Figure 14: Life cycle costs for three different types of cable median barriers



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Engineering Specification for Construction of Truck Only
and Passenger Only Travelways in Missouri – Phase 1.
RI 08 – 030.

Sub Document:

**Literature Review on
Safety Considerations
for Trucks and Truck-Only Lanes.**

Engineering Specifications for Construction of Truck Only and
Passenger Vehicle Only Travel ways in Missouri - Phase I: RI08-030
Literature Review on Safety Considerations for Trucks and Truck-only Lanes

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Literature Review on Safety Considerations for Trucks and Truck-only Lanes

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Engineering Specifications for Construction of Truck Only and
Passenger Vehicle Only Travel ways in Missouri - Phase I: RI08-030
Literature Review on Safety Considerations for Trucks and Truck-only Lanes

Introduction

To accommodate increasing truck traffic needs, enhanced safety, and reduced congestion, the Missouri Department of Transportation (MoDOT) is investigating proposed improvements along I-70 and I-44 business routes. As a part of developing engineering specifications for construction of truck only and passenger only travelways in Missouri, MoDOT contracted Wilbur Smith Associates and the Missouri University of Science and Technology to conduct a literature review to identify and summarize existing literatures on truck-only lane safety considerations. This review provides information about the safety issues of truck only lanes, safety considerations, road design upgrades and role of truck-only lanes as a solution for enhanced safety. As the concept of truck-only lanes is similar to managed lanes, safety findings on managed lanes are also added to this technical memorandum. **Figure 1** shows the typical layout of truck on lane highways.

Figure 1: Proposed Truck-Only Lane Layout¹



The purpose of this research is to gain understanding on safety issues that need to be considered while implementing the truck-only lanes. This memorandum, however, outlines the procedures and contents of the truck-only lane reports collected.

¹ Source : <http://www.transportation1.org/>

Dedicated Truck Lanes As A Solution To Capacity And Safety Issues On Interstate Highway Corridors (2007)

The goal of this report submitted to the Midwest Transportation Consortium is to address how the dedicated truck lanes can resolve capacity and safety issues on interstate highway corridors. Neil Burke, the author of this report, suggests the potential improvements for an interstate corridor that handles heavy freight traffic. The author expects these improvements to address the capacity issues and enhance safety within the state's interstate rehabilitation budget. Initial alternatives proposed for the improvement of I-80 corridor are:

- a) Construction of additional capacity,
- b) Restricted lane for heavy vehicles, and
- c) Truck only lanes.

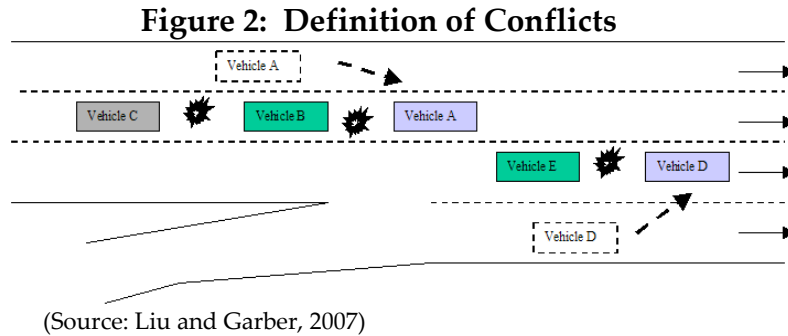
Even though the first two options may increase the capacity, they were found to be less effective than truck-only lanes in improving safety and operations. Truck-only lanes will enhance safety by reducing the conflicting movements. Also provision of Jersey barrier will be much more effective in reducing the cross over accidents. The recommendations from the study are as follow: 1) truck-only lanes are to be placed inside of the existing freeway and are to be separated by Jersey barrier, and 2) truck-only lanes are most cost-effective when the truck volumes are higher than 30 percent. In conclusion truck-only lanes will enhance safety by reducing the conflicting movements. Also provision of Jersey barrier will be much more effective in reducing the cross over accidents.

Identifying the Impact of Truck Lane Restriction Strategies on Traffic Flow and Safety Using Simulation (2007)

The objectives of this study undertaken by the Center for Transportation Studies at the University of Virginia for USDOT were as follows:

- Identify the effectiveness of different Truck Lane Restriction Strategies (TLRS) on traffic safety using surrogate measurements.
- Identify the effectiveness of TLRS on traffic operation.
- Identify the impacts of traffic and geometric factors on the safety and operational performance of TLRS.
- Prepare guidelines on the application of TLRS for traffic engineers.

For the analysis, the study conducts crash simulation runs using PARAMICS V3.0 with different scenarios for design features of truck restriction lanes (TRL). For example, 14,400 simulation runs were made with different traffic volumes, truck percentage, posted speed limits, the geometric conditions such as grade and density of interchanges. The study uses conflicts from the simulation runs as a measure of effectiveness (MOE) for safety analysis. **Figure 2** illustrates the definition of conflicts used in the analysis.



The data collected from simulation runs are analyzed using ANOVA, and tested whether truck restrictions have significant impacts on lane changing conflicts. The key findings of this study were: TRL have significant impact when main line traffic is greater than 1000 vehicles per hour per lane, and TLRS also have impact on average speed and density. **Table 1** summarizes the comprehensive recommendations. In the table, R n/N means restricting trucks from using the n leftmost lanes on N-lane (in each direction). For example, R2/3 denotes that trucks are restricted from truck using the two leftmost lanes on three-lanes.

Table 1: Truck Lane Restriction Recommendation

(a) 3-lane freeway section					
Volume (vphpl)	Truck Percentage (%)				
	5	15	25	40	50
<100	NA	NA	NA	NA	NA
100 - 500	NA	NA	NA	R2/3	R2/3
500 - 1000	R2/3	R2/3	R1/3	R1/3	R0/3
1000 - 1500	R2/3	R1/3	R0/3	R0/3	R0/3
1500 - 2000	R0/3	R0/3	R0/3	R0/3	R0/3

(b) 4-lane freeway section					
Volume (vphpl)	Truck Percentage (%)				
	5	15	25	40	50
<100	NA	NA	NA	NA	NA
100 - 500	NA	NA	NA	R3/4	R3/4
500 - 1000	R3/4	R3/4	R2/4	R1/4	R1/4
1000 - 1500	R1/4	R1/4	R0/4	R0/4	R0/4
1500 - 2000	R0/4	R0/4	R0/4	R0/4	R0/4

(c) 5-lane freeway section					
Volume (vphpl)	Truck Percentage (%)				
	5	15	25	40	50
<100	NA	NA	NA	NA	NA
100 - 500	NA	NA	NA	R3/5	R3/5
500 - 1000	R4/5	R3/5	R2/5	R2/5	R1/5
1000 - 1500	R1/5	R0/5	R0/5	R0/5	R0/5
1500 - 2000	R0/5	R0/5	R0/5	R0/5	R0/5

(Source: Liu and Garber, 2007)

Other engineering guidelines proposed in this study based on safety and operational analyses are as follows:

- The truck lane restriction should provide a traffic situation of level of service (LOS) C or better on a restricted lane, and LOS D or better on an unrestricted lane.
- If the LOS has been as low as E, no restriction should be applied.
- There should be no significant increase in frequency of merging conflict.
- There should be a significant decrease in lane-changing conflict or rear-end conflict.
- Reducing lane-changing conflicts has a higher priority than reducing rear-end conflicts in deciding the application of lane restrictions when there is a conflict between the influences of the lane restriction on them.
- Reducing truck-related conflicts has a higher priority than reducing car-car conflicts in deciding the application of lane restrictions when there is a conflict between the influences of the lane restriction on them.

Evaluation of the Potential Applicability and Impacts of Truck-Only Facilities (2007)

Exclusive truck facilities (ETFs) are considered as an alternative strategy to accommodate high truck volumes, reduce congestion, improve highway safety and enhance efficiency in freight movement. This study prepared by Battelle for the National Surface Transportation Policy and Revenue Study Commission reports evaluations of the potential applicability of exclusive truck facilities (ETFs). ETFs are classified into two types: 1) Exclusive Truck Lanes (ETL), and 2) Exclusive Truck Roadways (ETR). The key findings of the report were:

- A FHWA funded feasibility study has concluded that ETFs is feasible at locations where there is minimum traffic of 10,000 vehicles per day consisting of more than 25 percent truck traffic.
- Benefits of ETFs consists of reduced congestion, enhanced traffic safety, travel time savings, reduced vehicle operating cost, and improved freight movement.
- Estimated construction costs of ETFs, however, have discouraged the implementation of these lanes.
- Only 17 percent of highway agencies have considered ETLs for truck and busses, 20 percent highway agencies considered ETLs lanes for buses, and three percent highway agencies consider ETLs for heavy vehicles.

The implementation of ETFs has potential benefits such as increased access to freight facilities, improved system management which means reduced congestion and increased operational safety, highway freight system safety, and efficiency movements. The B/C analysis in the report quantifies following anticipated benefits:

- Reduced crash costs
- Travel time savings
- Vehicle operating costs savings
- Travel delay savings due to fewer crashes causing blockages

Recommended Procedures for the Safety Performance Evaluation of Highway Features (1993)

Unlike other truck safety studies investigated from the operational perspective, this National Cooperative Highway Research Program report (NCHRP 350) presents: 1) unified procedures for testing evaluating roadside safety devices, and 2) evaluation criteria to assess test results. Technically, this report updates the previous report

(NCHRP 230) by modifying the following key features including test vehicles, the number and impact conditions of the test matrices, adoption of the International System of Units (SI), etc.

Test articles considered for evaluation were longitudinal barriers, terminals, crash cushions, support structures, work zone traffic control devices, break utility poles, and Truck-Mounted Attenuators (TMAs). Highway Vehicle-Object-Simulation Model (HVOSM) computer program was used to simulate and identify the impact performance of geometric features. The resulting guidelines provide: 1) a basis on which researchers and user agencies can compare the impact performance merits of candidate safety features, 2) guidance for developers of new safety features, and 3) a basis on which user agencies can formulate performance specification for safety devices. Additionally, in-service evaluation was recommended to determine and document the procedure for which a safety feature performs during a broad range of collision, environmental, operational, and maintenance situations for typical site and traffic conditions. These guidelines are expected to enhance precision of the crash experiments conducted for both permanent and temporary highway safety features.

SR- 60 Truck Lane Feasibility Study - Final Report (2001)

This report submitted to Southern California Association of Governments (SCAG) evaluated the feasibility of dedicated truck-only lanes. The main purpose of this report was to evaluate the existing conditions of SR-60 lane and examine the feasibility of exclusive truck facilities, lane restrictions, and dedicated truck-only lanes. This report analyzed the crash data on SR-60 corridor to conclude that truck only lanes were feasible at truck traffic more than 30 percent of the total volume with peak hour volume exceeding 1,800 vehicles per lane and off peak exceeding 1,200 vehicles per lane. The following can be considered as key findings in this report

- Lane restrictions and non barrier separated exclusive truck facilities were the same.
- Due to reduction in congestion there will be positive impacts on noise and air pollution, fuel consumption, and other environmental issues.
- Dedicated truck lanes were found feasible at the three conditions listed below:
 - 1) Truck volume exceeding 30 percent of mix traffic
 - 2) Peak hour volumes exceeding 1,800 vehicles per hour per lane
 - 3) Off peak volumes exceed 1,200 vehicles per lane hour

Safety and Operational Aspects of Exclusive Truck Facilities (2005)

With an ambitious goal of 50 percent reduction of truck related fatalities by the end of this decade, USDOT have conducted research on improving performance of all elements of the systems- the driver, roadway and the system. Analyzing historical crash data on dual-dual lanes on the New Jersey Turnpike, the authors discuss the driver and roadway aspects. A typical section of dual-dual lanes on the New Jersey Turnpike is shown in **Figure 3**.

Figure 3: Separated lanes on the New Jersey Turnpike



(Source: Reich et al²)

In **Table 2**, crash rates on inner lanes exclusively used by passenger cars were compared with those on outer lanes used by trucks mixed with other vehicles. As seen in the table, it is observed that crashes are more in outer lanes compared to inner lanes.

Table 2: 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

PDO: property damage only

² Reich et al., The Potential for Reserved Truck Lanes and Truckways in Florida, Center for Urban Transportation Research, 2002.

Based on the statistical analysis, this study provides the following conclusions:

- Sideswipe collisions occupy the major percent of crashes than other types in both the inner and outer lanes. Sideswipe collisions were more prone to occur 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 were categorized as sideswipe collisions. This finding was similar to previous work on this subject. However, trucks were not over involved in rear-end collisions and run-off-the-road crashes, as reported in the referenced research.
- 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.
- Unstable speed variance may be a cause for rear-end collisions which were more in outer lanes comparatively.

The study used a VISSIM traffic simulation model to approximate the capacity of truck roadways. Depending on grades, interchange spacing, and proportion of exiting and entering truck traffic; the capacity of truck roadway is estimated to be between 1,025 to 1,475 trucks/hour/lane. For average annual daily truck traffic (AADTT) values of 50,000 trucks per day with level terrain and 10 percent trucks weaving at interchanges, the simulation results have shown that truck roadways with two lanes do not experience LOS values worse than LOS C.

Shoulder Rumble Strip Effectiveness (1997)

This paper presented at the 76 TRB Annual meeting, evaluated the effectiveness of the shoulder rumble strip called Sonic Nap Alert Pattern (SNAP) (**Figure 4**). Particularly, this paper answered questions raised on a previous study³ regarding traffic exposure, control segments for comparison, accident migration, and regression to the mean. To consider regression to the mean (i.e., improving by chance), for example, drifting-off-road (DOR) rates before SNAP were compared with those for similar roadway

³ Wood, N. E., "Shoulder Rumble Strips: a Method to Alert Drifting Drivers", presented at the 73rd Annual TRB Meeting, 1994.

segments. In order to consider accidents susceptible to SANP, the analysis eliminates accidents affected by weather conditions such as snow, ice, and slippery conditions.

Figure 4: Sonic Nap Alert Pattern (SNAP) Rumble Strip



Table 3 summarizes the trend of the single-vehicle accidents during the observation period. As seen in the table, the truck accidents drop drastically (in line 4) as the SNAP installation increases (in line 1) over six years of observation period.

Table 3: Single-Vehicle and SNAP Treatment⁴

	Year:	1990	1991	1992	1993	1994	1995
1	% Traffic Encountering SNAP	1 %	2 %	7 %	26 %	56%	82 %
2	All Single Vehicle Accidents Hit First Object Off Right Side	313	251	280	300	270	297
3	Not Treatable; & Affected by Weather, Variables, etc.	141	79	119	175	202	223
4	Susceptible to "SNAP:"	172	172	161	125	68	74
	● "Drowsy, Fatigue:"	(55)	(57)	(57)	(38)	(28)	(27)
	● Truck Accidents:	(19)	(11)	(14)	(14)	(4)	(8)
5	All single Vehicle Accidents:	1107	918	969	1033	1072	1186
	All Reported Accidents:	1620	1352	1390	1482	1675	1688
6	Traffic (in 100 MVM)	43.00	41.77	41.95	42.74	43.55	45.53

Before and after comparison of DOR crash rates clearly shows the effect of SNAP rumble strip. As seen in **Table 4**, DOR accident rates on segments with SNAP treatment reduced by 60 percent whereas those on segments without SNAP treatment reduce only by 31 percent.

⁴ John J. Hickey, Jr., (1997)

Table 4: DOR Rates Before and After SNAP/RRPM Treatment⁵

	BEFORE	AFTER	Reduction
53 Treated Segments (348 miles)	3.81 per 100MVM (421 Accidents/ 110.6 x 10 ⁸ VMT)	1.54 per 100MVM (105 Accidents/ 68.4 x 10 ⁸ VMT)	60 %
25 Segments Treated with only SNAP & RRPM (186 miles - no repaving)	3.84 per 100MVM (275 Accidents/ 71.7 x 10 ⁸ VMT)	1.41 per 100MVM (56 Accidents/ 39.8 x 10 ⁸ VMT)	63 %
13 Untreated Segments; 1990-92 vs 1993-95 (90 miles - interspersed)	3.97 per 100MVM (93 Accidents/ 23.4 x 10 ⁸ VMT)	2.74 per 100MVM (58 Accidents/ 21.2 x 10 ⁸ VMT)	31 %

In this study, it was also noted that some accidents are caused by drivers reaching for things such as cigarettes, lighters, cassette tapes, CDs, cellular phones, toll tickets, children, or reacting to other events in their vehicles while driving. They may not realize that they drifted, most often to the right. SNAP on right shoulders may alert some of these drivers before roadway departure has progressed too far to recover. SNAP can also be installed on left shoulders of divided highways where medians are wide enough for an appropriate reaction to the rumble strip warning.

Corridors of the Future (2007)

This project report undertaken by Wilbur Smith Associates (WSA) is intended to prepare methodology for making I-70 corridors safer, more efficient, and more effective in terms of freight movement for MoDOT. Missouri, Illinois, Indiana, and Ohio Departments of Transportation (DOTs) have shown interest in constructing dedicated truck-only lanes to reduce congestion and safety problems which will set new standards for interstates in future. The key concepts answered in this application are as follows:

- 1) Clear need of congestion reduction on the I-70 corridor.
The current system condition and identified threats are a) Recurring urban bottlenecks which undermine the efficiency of freight and personal transportation in major cities along the corridor; b) Crash-induced delays which undermine the reliable delivery of goods utilizing the corridor.
- 2) How are truck lanes solutions for congestion reduction and enhance safety.
The report identifies the solutions to mobility to congestion mitigation, safety, trade, and also provides the design guidelines and importance of ITS integration.
- 3) Actions that paves path to success.

⁵ John J. Hickey, Jr., (1997)

Issues leading to path of success such as Project Management, Planning and Feasibility Analysis, Public Information, participation, Environmental Stewardship Actions and Innovations for Streamlining, Planning Level Cost Estimates, Innovations in Project Delivery and Finance, Proposed Project Time-Line are discussed in this report.

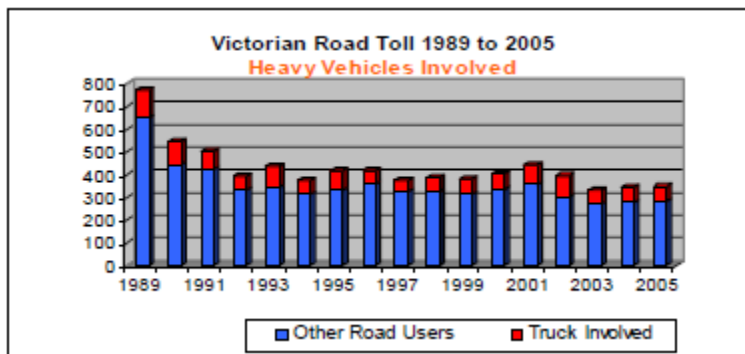
This application report concludes with information that the corridor project is designed to reduce congestion by providing improved mobility and the efficient flow of goods on the I-70 corridor. In view of our current literature review, this report gives the information design guidelines about safety features that need to be considered while constructing truck-only lanes. The following improvements will also add to the safety of truck-only lanes:

- Geometric upgrades
- Wider and brighter striping
- Median cable barriers
- Freeway reference markers
- Deployment of freeway service patrols, amongst others

Safer Roads for Trucks (2006)

Motivated by decrease in truck related deaths for six years (1999-2005, **Figure 5**), this Australian paper suggests safety initiatives that help local governments involving road safety, infrastructure, and planning to improve truck safety. This paper reports that observed reduction in accident rate was due to a combination of the following factors: 1) improved freeways and divided roads, 2) improvised safety systems such as Anti Braking System (ABS), Electronic Braking systems (EBS), front under run protection, 3) safety programs that focus on driver's education or training, 4) liaison with Victorian Roads transport safety services, 4) improved transport management, 5) TWU/VTA safety programs, and 6) targeted enforcement programs.

Figure 5: Truck related deaths have decreased from 124 in 1989 to 62 in 2005



This paper points out that driver fatigue was a contributing factor in about 30 percent of truck fatal crashes, and emphasizes that providing a diverse range of rest areas differing standards was important for truck safety. The types of rests areas include: 1) major rest areas that offer separate parking area for heavy and light vehicles and provide highest level of facility designed for long rest breaks, 2) minor rest areas designed for shorter rest breaks with sufficient parking space for both heavy and light vehicles, 3) truck parking bays designed primarily for heavy vehicle drivers to check tires and load security, and have a short break, and 4) freeway service center located adjacent to freeway in areas where towns have been bypassed. The author concludes that incorporation of safety features (like truck parking lots, barriers, educating drivers) and truck features (like EBS, ABS, front under run protection, integrate seatbelts, lane keeping technology) plays a prominent role in decreasing truck related accidents.

Truck Accommodation Design Guidance: Designer Workshop (2003)

This research performed by the Texas Transportation Institute (TTI) investigates the sensitivity of current Texas design practice to the unique operating characteristics of large commercial vehicles and determines threshold conditions under which design should reflect these larger vehicles. Findings in this report indicate that a serious consideration needs to be given on trucks when the Average Annual Daily Truck Traffic (AADTT) reaches 5,000 trucks per day during the design period. When the design AADTT reaches 25,000 trucks per day, it may be justified for considering separated truck roadways with a minimum of two lanes in each direction.

This research report also recommends that Texas DOT consider changes in the following design parameters in its Roadway Design Manual (and/or other appropriate documents): stopping sight distance, intersection and channelization, lane width,

shoulder width and composition, side slopes and drainage features, traffic barrier, passive signs, and acceleration lanes.

Highway/Heavy Vehicle Interaction (2003)

Based on a comprehensive literature review and a survey of highway agencies and trucking industry, this Commercial Truck and Bus Safety Synthesis Program (CTSSP) synthesis addresses the interactions of commercial trucks (and buses) with highway features and improvements that needs to be incorporated to enhance the safety operations of vehicles.

Firstly, the report identified the physical and performance characteristics of heavy vehicles that interact with highways like vehicle types and configurations, weights and dimensions, turning radius, off-tracking and swept path width, trailer swing out, braking distance, driver eye height, truck acceleration characteristics, rearward amplification, suspension characteristics, load transfer ratio, and rollover threshold.

Consequently, the report discussed the role of roadway geometric design in safely accommodating heavy vehicles. The design factors considered were: design vehicles, sight distance, grades, acceleration lanes, horizontal/vertical curves, intersections, interchange ramps, etc. It is also pointed out that current design criteria for acceleration lanes may not be long enough to accommodate the lowest performance trucks. This indicates that acceleration lanes were a major safety concerns at many locations. (More detailed discussion can be found in the report.)

The report also addressed roles of traffic control devices and traffic regulation designed for heavy vehicles. Citing Garber and Gadiraju's report⁶, it notes that differential speed limits for passenger car and heavy vehicles do not improve the accident rate significantly.

The report looked at differential speed limits and found they increased the interaction among vehicles in a traffic stream. This increased interaction slightly increased rear-end and side-swipe accidents on Interstates with traffic volumes under 50,000 vehicles per day, although the results were not statistically significant.

⁶ Garber, N.J., and R. Gadiraju, Speed Variance and Its Influence on Accidents, University of Virginia, Charlottesville, 1988.

Literature Review on Safety Considerations for Trucks and Truck-only Lanes

The study looked at agencies considering exclusive truck lanes but none had yet established design standards such as sight distance, grades, acceleration lanes, horizontal/vertical curves, intersections, interchange ramps, etc.

The study looked at restriction of heavy trucks from the left hand lanes and found little impact on safety, positive or negative.

The report also suggested other measures to improve truck safety and operations including the use of Intelligent Transportation Systems (ITS) and on-board vehicle technology for collision avoidance.

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Engineering Specification for Construction of Truck Only
and Passenger Only Travelways in Missouri – Phase 1.
RI 08 – 030.

Sub Document:

**Truck Only Lanes
Public Outreach Promotional Strategy.**

Truck-Only Lanes Promotional Strategy

Introduction

This memorandum identifies key audiences that the truck-only lanes promotional strategy should target, as well as existing promotional work that MoDOT could utilize; data that will need to be collected to have a successful promotion; and introduces the promotional tools. The promotional tools are discussed in further detail in the **Promotional Tools Memorandum**.

Key Audiences

A number of audiences with differing likely concerns and interests will be targeted by the truck-only lanes promotional strategy. Several of the overlapping audiences will have similar concerns and interests. Anticipated frequent concerns are listed and defined in the following table.

Concern	Definition
Safety	Fewer conflict points, feeling of safety, and fewer accidents.
Efficiency	Minimizing travel times and in turn costs.
Access	Number of access points and availability of services at those points.
Reliability	Consistency of travel time.
Direct Impacts	Caused by an action and occur at the same time and place as the action.
Indirect Impacts	Caused by an action, but are later in time or farther removed in distance.
Property Loss	The partial or total loss of property because of additional right of way needs caused by the construction of the truck-only lanes and the associated interchanges.
Noise	Increases in noise caused by additional truck traffic in an area and by speeds increasing due to less congestion on the interstates.
Air Quality	Decreases in air quality caused by additional truck traffic in an area.
Costs	The costs to construct truck-only lanes or the cost to ship goods and services.
Local Economic Impacts	Impacts to development potential, businesses and jobs, and to the local tax base.
Environmental Impacts	Impacts to threatened and endangered species, parks and recreation facilities, historic and archaeological resources, groundwater, drainage and surface water quality, floodplains, streams, stream crossings, wetlands, and farmlands.

In general, the key audiences include:

- **General Motorists** – motorists who may or may not live near I-70 or I-44 and use the routes infrequently.
 - Key Concerns: safety, access, efficiency

- Means of Reaching the Group: advertisement targeted at I-70 and I-44 and key locations along those routes
- **Regional Commuters** – motorists who may or may not live near I-70 or I-44 and use the routes daily.
 - Key Concerns: safety, access, efficiency
 - Means of Reaching the Group: advertisement targeted at I-70 and I-44 and key locations along those routes
- **Carriers** – companies that employ truck drivers to transport goods between locations; examples include Yellow Freight, United Parcel Service, Wal-Mart and Roadway Express.
 - Key Concerns: safety, efficiency, access, reliability, costs
 - Means of Reaching the Group: direct communication with the companies
- **Truck Drivers** – motorists that transport goods between locations of various distances, who may work for a carrier or are for-hire drivers.
 - Key Concerns: safety, efficiency, access, reliability
 - Means of Reaching the Group: advertisement targeted at I-70 and I-44 and key locations along those routes (e.g. truck stops) and through contact with the companies they work for
- **Shippers and Receivers** – companies or individuals that employ carriers to transport their materials, goods, or services. Companies or individuals can be both shippers and receivers. In some instances the shippers/receivers and the carriers will be the same (e.g. Wal-Mart).
 - Key Concerns: safety, efficiency, access, reliability, costs
 - Means of Reaching the Group: direct communication with the companies or individuals, based on conversations with the carriers on who their customers are
- **Industry Associations** – organizations that represent the interests of the freight industry, i.e. American Trucking Association (ATA), Intermodal Association of North America (IANA), and the World Shipping Council.
 - Key Concerns: safety, efficiency, access, reliability, costs
 - Means of Reaching the Group: direct communication with the associations and through contact with the companies they represent
- **Emergency Management Services** – police, fire, and ambulance services that serve I-70 and I-44.
 - Key Concerns: safety, access, law enforcement
 - Means of Reaching the Group: direct communication with these service operators

- **Potentially Impacted Landowners** – persons who own land around I-70 or I-44 which could be potentially impacted by the construction of truck-only lanes. Potentially impacted landowners include residential, commercial, and industrial landowners.
 - Key Concerns: potential impacts to their property
 - Means of Reaching the Group: advertisement targeted at the communities near I-70 and I-44 and direct communication with them
- **Residents** – persons who live near or in a community along I-70 or I-44. Residents include those who could be directly or indirectly impacted.
 - Key Concerns: potential impacts to their property and the community, i.e. property loss, noise, and air quality
 - Means of Reaching the Group: advertisement targeted at the communities near I-70 and I-44
- **Local Special Interests Groups** – organizations that represent and work to protect special interests that are specific to the areas surrounding I-70 and I-44, i.e. historic societies and neighborhood groups.
 - Key Concerns: potential impacts to the areas they represent, i.e. property loss, noise, and air quality
 - Means of Reaching the Group: advertisement targeted at the communities near I-70 and I-44
- **Business Owners** – persons who own businesses near or in communities along I-70 or I-44. Business owners include those who could be directly or indirectly impacted and may also be shippers/receivers.
 - Key Concerns: potential impacts to their businesses, i.e. property loss, noise, air quality, and the potential impact of reduced access points
 - Means of Reaching the Group: advertisement targeted at the communities near I-70 and I-44 and direct communication with them
- **Developers** – persons who have a vested financial interest in the land surrounding I-70 and I-44.
 - Key Concerns: how truck-only lanes will affect their development plans and the future development potential of their land
 - Means of Reaching the Group: advertisement targeted at the communities near I-70 and I-44 and direct communication with them
- **Local Public Officials** – elected and appointed officials at the local and county levels who represent the areas I-70 and I-44 run by.
 - Key Concerns: the potential impacts truck-only lanes will have on the areas they represent and on the constituents they represent
 - Means of Reaching the Group: direct communication with the officials

- **State and National Public Officials** – elected and appointed officials at the state and National levels who represent the areas I-70 and I-44 run by.
 - Key Concerns: the potential impacts truck-only lanes will have on the areas they represent and on their constituents and costs of implementation
 - Means of Reaching the Group: direct communication with the officials
- **Municipalities** – cities that I-70 and I-44 run by.
 - Key Concerns: safety, access, the potential impacts truck-only lanes will have on their communities
 - Means of Reaching the Group: direct communication with the cities
- **Economic Development Groups/Agencies** – organizations that represent groups of developers, business owners, and others who have a vested financial interest in the land surrounding I-70 and I-44, e.g. chambers of commerce.
 - Key Concerns: potential impacts to the local economies surrounding I-70 and I-44
 - Means of Reaching the Group: direct communication with the groups/agencies
- **Environmental Groups/Agencies** – organizations that protect the environmental quality of the land, water, air, and species near I-70 and I-44, e.g. the Department of Natural Resources, the Environmental Protection Agency, and the Sierra Club.
 - Key Concerns: potential impacts to the environment
 - Means of Reaching the Group: direct communication with the groups/agencies
- **Taxpayers** – all residents of Missouri and people who work in Missouri that pay Missouri taxes.
 - Key Concerns: cost of building truck-only lanes versus value of the benefits of truck-only lanes
 - Means of Reaching the Group: advertisement that can reach beyond geographic boundaries, e.g. websites and podcasts

Existing Promotional Work

MoDOT has numerous existing promotions that could be used and built upon to promote truck-only lanes. These promotions include:

- **Better Roads, Brighter Future** – The goal of the Better Roads, Brighter Future program is to improve the remainder of the state's 5,600 miles of major highways by 2011. These highways will receive wider stripes, rumble stripes, brighter signs, paved shoulders, and smooth pavement that will bring 85 percent of Missouri's major highway system up to good condition. The program targets highways carrying 80 percent of all travel on the state highway system—that's 103 million miles traveled a day. Approximately 95 percent of all Missourians live within 10 miles of one of these roads.
www.modot.mo.gov/betterroads/

- Improve I-70 – I-70 connects the two largest cities in Missouri and carries more rural daily traffic than any other route. The interstate has been an engine for nearly 50 years of economic growth and prosperity. The safety and economic prosperity of Missourians depends, in part, on I-70 growing along with the state and the nation. That's why MoDOT is currently working to develop a plan for the future of I-70. Improve I-70 is the MoDOT effort to develop such a plan. www.improvei70.org
- I-44 Planning for Progress – The goal of the I-44 Planning for Progress initiative is to gather information on I-44 and set out a plan for the future of the highway. The first step in the initiative, the I-44 Purpose and Need Study has been completed. www.modot.org/i44planningforprogress/index/htm

Data Needs

In order for the promotional strategy to be successful data will need to be collected. This data includes:

- Traffic counts on I-70 and I-44, including passenger vehicle and truck counts. This data will be used to highlight how traffic and congestion on I-70 and I-44 is growing and the percent of truck versus passenger vehicles.
- Crash data on I-70 and I-44. This data will be used to highlight safety concerns and the percent of trucks involved in crashes.
- Mailing lists for homes and businesses near I-70 and I-44.
- Community facilities in the communities near I-70 and I-44.
- Radio and television stations in the communities near I-70 and I-44.
- Newspapers available in the communities near I-70 and I-44 and readership rates.
- Current and future land use and development plans along I-70 and I-44. This data will be used to understand concerns that might arise in regards to the impacts truck-only lanes will have to communities.

Promotional Tools

Numerous tools could be used to reach out to key audiences and promote the concept of truck-only lanes. The key goal is to promote the safety benefits of truck-only lanes. These promotional tools include:

- Website
- Billboards
- Interactive Kiosks
- Bulletin Boards
- Brochures
- Mailers
- Public Meetings

- Podcasts
- Radio Advertisements
- Newspaper Advertisements
- Video Clips
- Presentations
- Television Advertisements

The following table groups these tools into two categories: 1) promotional tools that are targeted at a particular audience and 2) general information for a wide audience.

Category	Promotional Tools
General information for a wide audience	Website, Billboards, Interactive Kiosks, Bulletin Boards, Brochures, Podcasts, Radio Advertisements, Newspaper Advertisements, Video Clips, Television Advertisements
Targeted information at a particular audience	Mailers, Public Meetings, Presentations

These promotional tools are discussed in detail in the **Promotional Tools Memorandum**.

Engineering Specification for Construction of Truck Only
and Passenger Only Travelways in Missouri – Phase 1.
RI 08 – 030.

Sub Document:

**Truck Only Lanes
Promotional Tools.**

Truck-Only Lanes Promotional Tools

Introduction

This memorandum outlines the promotional tools that could be used promote the benefits of truck-only lanes. Each promotional tool includes a description, goal(s), approximate cost, target audience, when and how the tool should be used, advantages, and disadvantages.

I. Website

- A. **Description:** An online tool used to provide information.
- B. **Goal:** Provide information to a large number of people.
- C. **Approximate Cost:** \$18,000 – set-up. \$10,000 per year – maintenance.
- D. **Target:** All audiences
- E. **When and How the Tool could be used:** The website could be used throughout the life of the project, as a source where all the marketing information available on truck-only lanes is available.
- F. **Advantages:** Reaches an unlimited geographic area, people who wouldn't otherwise take the time to attend a meeting, stop at a kiosk, or sign-up on a mailing list, might look at a website, easy to update, accessible 24-hours a day, and people can go directly to the information they are interested in.
- G. **Disadvantages:** Not everyone has access to a computer or to the internet, not everyone knows how to use the internet, and cost.

II. Billboards

- A. **Description:** Large information signs along the side of highways.
- B. **Goal:** To get motorist interested in truck-only lanes and direct them to further information.
- C. **Approximate Cost:** \$1,600 per month rental (cost based on billboard being 14'x48', illuminated, and in the Kansas City Metro Area)
- D. **Target:** General motorists, regional commuters, and truck drivers.
- E. **When and How the Tool could be used:** Billboards could be used throughout the life of the project, as a means of providing a brief introduction to the concept of truck-only lanes and letting motorists know where additional information can be found, i.e. website and interactive kiosks. The billboards could be placed along I-70 and I-44.
- F. **Advantages:** Eye catching, can use both text and graphics, and specifically targeted at motorists using I-70 and I-44 (those who will be most affected by truck-only lanes).
- G. **Disadvantages:** Cost, not easily updated, can't provide detail information, susceptible to weather.

III. Interactive Kiosks

- A. **Description:** A walkup booth with a touch screen used to navigate through information.
- B. **Goal:** Provide detailed information to motorists traveling on I-70 and I-44.

C. Approximate Cost: Equipment - \$3,500 to \$8,000 (touch screen LCD, standard enclosure, printer and standard software). Installation - \$250 to \$500. Monitoring service - \$20 to \$800 per month.

D. Target: General motorists, regional commuters, and truck drivers.

E. When and How the Tool could be used: Interactive kiosks could be used throughout the life of the project, as a means of accessing information on truck-only lanes at locations along I-70 and I-44. The interactive kiosks could be placed at popular rest areas, visitors' centers and truck stops along I-70 and I-44.

F. Advantages: Can be placed at locations along I-70 and I-44, provides information on truck-only lanes to people who may not otherwise have access to other marketing tools, reaches people who periodically use I-70 and I-44 to travel thru or visit Missouri.

G. Disadvantages: Cost, susceptible to damage, and maintenance may be needed.

IV. Bulletin Boards

A. Description: A board with information affixed to it.

B. Goal: Provide information to motorists traveling on I-70 and I-44.

C. Approximate Cost: Development of materials - \$1000. Assumes materials for the bulletin boards will be distributed and set-up by MoDOT staff.

D. Target: General motorists, regional commuters, and truck drivers.

E. When and How the Tool could be used: Bulletin boards could be used throughout the life of the project, as a means of providing information on truck-only lanes at locations along I-70 and I-44. The bulletin boards could be placed at rest areas, visitors' centers and truck stops along I-70 and I-44 where the interactive kiosks are not.

F. Advantages: Cost, can be placed at locations along I-70 and I-44, provides information on truck-only lanes to people who may not otherwise have access to other marketing tools, reaches people who periodically use I-70 and I-44 to travel thru or visit Missouri.

G. Disadvantages: The information is static unless someone physically goes to the site is located and updates it, susceptible to damage, and maintenance may be needed.

V. Brochures

A. Description: An informational pamphlet.

B. Goal: Provide detailed information available at key locations near I-70 and I-44.

C. Approximate Cost: \$440 (cost based on brochures being 2 colors, 4 pages, 11x17, and 1000 copies)

D. Target: General motorists, regional commuters, truck drivers, potentially impacted landowners, and residents.

E. When and How the Tool could be used: Brochures could be available throughout the life of the project as a means of provided information on truck-only lanes. The brochures could be available at locations such as libraries, post offices, rest areas, visitors' centers, truck stops, and with the interactive kiosks. Brochures could also be available to hand out at public meetings and presentations.

F. Advantages: Cost, a large volume can be produced, detailed information can be provided, both text and graphics can be utilized, different versions can be produced for different audiences, and interested persons can take them home with them.

G. Disadvantages: Can easily be overlooked at locations, can easily be thrown away without being read, and not environmentally-friendly.

VI. Mailers

A. Description: An information pamphlet sent to homes and businesses through the mail.

B. Goal: Provide detail information to the immediate areas around I-70 and I-44.

C. Approximate Cost: \$720 (cost based on mailers being 2 color, 4 pages, 11x17, 1000 copies, and \$0.28 stamps)

D. Target: Potentially impacted landowners, residents, neighborhood groups, and business owners.

E. When and How the Tool could be used: Mailers could be used at the beginning of the project to reach out directly to those living and working in the immediate area around I-70 and I-44.

F. Advantages: Cost, a large volume can be produced, detailed information can be provided, both text and graphics can be utilized, different versions can be produced for different audiences, and easily track who and who has not received information on truck-only lanes.

G. Disadvantages: Can easily be thrown away without being read, not environmentally-friendly, and inevitable a number of mailers will be returned to sender.

VII. Public Meetings

A. Description: Organized and coordinated informational meetings for the public.

B. Goal: Provide detailed information and give the public the opportunity to ask questions.

C. Approximate Cost: \$16,000 (per meeting including staff preparation)

D. Target: General motorists, potentially impacted landowners, residents, neighborhood groups, business owners, developers, public officials, and municipalities.

E. When and How the Tool could be used: Public meetings could be held after other marketing tools have been initiated and people are aware of the project and might have questions. It could be used as an informational meeting for a large audience and maybe used in conjunction with other marketing tools, i.e. brochures, advertisements, and PowerPoint presentations.

F. Advantages: Provides an opportunity for two-way interaction, a large audience can be reached, multi-media can be used such as print, video, graphics, and audio and provides a set time for people to learn about truck-only lanes.

G. Disadvantages: People have to make time to come and it involves a lot of manpower and advance planning by the agency running the meeting.

VIII. Podcasts

- A. Description:** An audio broadcast available on the internet and downloadable to some cell phones, PDAs, and IPODs.
- B. Goal:** Provide detailed information on truck-only lanes to a new generation who rely heavily on the internet and personal devices to receive information.
- C. Approximate Cost:** Equipment – approximately \$100 (Alesis USB Mic Podcast Kit). Podcast Development - \$850 to \$900.
- D. Target:** Regional commuters and truck drivers.
- E. When and How the Tool could be used:** Podcasts could be available on the project website to listen and/or download throughout the life of the project. The podcasts could be used to provide detailed information on truck-only lanes in short, easy to listen to segments. The different segments could include an introduction, safety benefits, costs, traffic benefits, etc.
- F. Advantages:** Cost, reaches unlimited geographic area, people who wouldn't otherwise take the time to attend a meeting, stop at a kiosk, or sign-up on a mailing list, might look at a website, easy to update, accessible 24-hours a day, and people can go directly to the segment(s) they are interested in.
- G. Disadvantages:** Not everyone has access to a computer or to the internet, not everyone knows how to use the internet, and requires special equipment to record a podcast.

IX. Radio Advertisements

- A. Description:** An audio broadcast on the radio.
- B. Goal:** To get motorist interested in truck-only lanes and direct them to further information.
- C. Approximate Cost:** Ad Development - \$850 to \$900 (single-voice ad). Ad Placement - \$20 in Springfield to \$106 in St. Louis (30-second ad).
- D. Target:** General motorists, regional commuters, and truck drivers.
- E. When and How the Tool could be used:** Radio advertisements could be used throughout the life of the project, as a means of providing a brief introduction to the concept of truck-only lanes and letting motorists know where additional information can be found, i.e. website and interactive kiosks. Radio advertisements could be bought at radio stations that broadcast to the communities surrounding I-70 and I-44 and they could be scheduled to broadcast at peak travel times in both the a.m. and p.m.
- F. Advantages:** Reaches a large audience and reaches motorists while they are driving and thinking about it.
- G. Disadvantages:** Cost, only allotted a short amount of time, and it is easy to change the radio station during commercials.

X. Newspaper Advertisements

- A. Description:** A printed article in a newspaper.
- B. Goal:** Provide information to the immediate communities around I-70 and I-44.

C. Approximate Cost: Ad Development - \$100 to \$200. Ad Placement - \$13 in the Jefferson City News-Tribune to \$562 in the St. Louis Dispatch (Column inch black and white ad).

D. Target: Potentially impacted landowners, residents, neighborhood groups, business owners, and developers.

E. When and How the Tool could be used: Newspaper advertisements could be used throughout the life of the project, as a means of providing a brief introduction to the concept of truck-only lanes and letting persons know where additional information can be found, i.e. website and public meetings. Newspaper advertisements could be bought at newspapers that are distributed in the communities surrounding I-70 and I-44 and they could be run on peak readership days, i.e. Sundays.

F. Advantages: Can use text and graphics and can vary the size and detail of information provided.

G. Disadvantages: Cost, newspapers are a declining media, and advertisements can easily be overlooked in not the appropriate size or in the appropriate location.

XI. Video Clips

A. Description: A recorded visual presentation.

B. Goal: To visually described what truck-only lanes are and what their benefits are.

C. Approximate Cost: Development - \$3,400. Voice-over - \$40/hour.

D. Target: All audiences.

E. When and How the Tool could be used: This tool could be used throughout the project to provide an introduction to what truck-only lanes are and their benefits. Video clips could be used in conjunction with other tools, i.e. websites, kiosks, public meetings, and television advertisements.

F. Advantages: People are used to getting most of their information from television and video and readily accept this way of presenting information. However, this can also be a disadvantage because you have to compete in quality with the commercial productions that your audience is used to.

G. Disadvantages: Cost, time, and very few agencies can produce their own video and therefore must hire an outside firm.

XII. PowerPoint Presentations

A. Description: A computer projected slide show that could be narrated and made available on-line.

B. Goal: Provide detail information to a large audience.

C. Approximate Cost: \$3,400 (per presentation plus staff time to present)

D. Target: All audiences.

E. When and How the Tool could be used: PowerPoint presentations could be given at the beginning of the life of the project and by request throughout to groups such as public officials, neighborhood organizations, economic development groups, etc. and can be used in conjunction with public meetings.

F. Advantages: Suitable for all sizes of audiences, but especially large audiences.

G. Disadvantages: Very easy to turn a good presentation into a bad presentation with too many words, redundant information, boring images, and too long of a presentation, best shown in a slightly darken room, however, this invites the audience to doze, and you have to get people to the presentation (if live).

XIII. Small Promotional Items

A. Description: Small items to hand out that direct people to the website, i.e. business cards, paycheck stuffers, coffee cup sleeves, stress balls.

B. Goal: To introduce the project and direct people to the website.

C. Approximate Cost: Business cards/Pay check stuffers - \$100 per 1000 copies. Promotional items - \$0.50 to \$3.00 each depending on the item.

D. Target: All audiences.

E. When and How the Tool could be used: Small promotional items could be used throughout the life of the project, as a means of introducing the project and directing people to the website. Small promotional items could be handed out or left at key locations throughout the communities surrounding I-70 and I-44, such as provided local coffee shops with the promotional coffee cup sleeves.

F. Advantages: Cost, a large volume can be produced, different items can be used to target different audiences

G. Disadvantages: Easily discarded, not environmentally-friendly, only directs people to the detail information,

XIV. Earned Media

A. Description: Free promotion of the project that is earned by getting people interested in it, i.e. op-ed articles, letters to the editors, stories on the local news.

B. Goals: Provide detailed information to the immediate communities around I-70 and I-44.

C. Approximate Cost: Free/staff time.

D. Target: Potentially impacted landowners, residents, neighborhood groups, business owners, and developers.

E. When and How the Tool could be used: Earned media could be used throughout the life of the project whenever the opportunity presents itself.

F. Advantages: Cost, reaches a large audience.

G. Disadvantages: Isn't a given that the project will get earned media, facts can get distorted and reported wrong.

XV. Television Advertisements

Television advertisements were investigated, however after consultation with MoDOT public relations personnel television advertisements were deemed too costly and are not recommended for use during this promotional strategy.

Engineering Specification for Construction of Truck Only
and Passenger Only Travelways in Missouri – Phase 1.
RI 08 – 030.

Sub Document:

**Truck Only Lanes
EMS Survey.**

Truck-Only Lanes EMS Survey

Introduction

This memorandum summarizes the results of the Emergency Management Services (EMS) survey conducted as part of the MoDOT Engineering Specifications for Truck-Only Lanes project.

The Study Team developed the survey questions based on emergency service issues related to truck-only lanes identified during the project. The survey consisted of ten questions, four multiple choice and six open ended. Prior to distribution the survey and the contact list of EMS providers were reviewed by Captain Londell Jamerson of the Missouri Highway Patrol. Captain Jamerson indicated that he believed the questions would generate a response beneficial to the project.

The survey was distributed with a letter explaining the project and the purpose of the survey, and a copy of the **Truck-Only Lanes Talking Points**. The survey was distributed on Friday, April 3, 2009. The deadline for returning the survey was Friday, April 24, 2009 or three weeks from the distribution date. A copy of the letter, the survey, and the talking points is in **Appendix A**.

The survey was mailed to 132 state, county, city, and private EMS providers, who serve areas located along the I-70 and I-44 corridors. The contact list of EMS providers is located in **Appendix B**.

Survey Response

Of the 132 surveys sent out, 43 surveys (or 33 percent) were returned by the deadline. The following paragraphs provide a summary of the most common answers to each of the ten questions. All of the completed surveys are in **Appendix C**.

Question 1: How do you think truck-only lanes will affect safety along interstate highways?

- A. Truck-only lanes will not affect safety along interstate highways.
- B. Truck-only lanes will improve safety on interstate highways.
- C. Truck-only lanes will decrease safety on interstate highways.

The most common response to Question 1 was "B". Eighty-eight percent thought truck-only lanes would improve safety on interstate highways. Most of the EMS providers indicated they chose "B" because separating trucks and cars would improve safety. Of the three that chose "A" they explained that they felt truck-only lanes would not help avoid accidents, either because of

Question 1		
	Responses	Percent
A	3	7%
B	38	88%
C	0	0%
Three did not respond.		

an existing lack of accidents, because trucks would still have to merge to exit and enter, or because truck-only lanes would cause driver confusion.

Question 2: How do you think truck-only lanes will affect emergency management?

- A. Truck-only lanes will not affect emergency management.**
- B. Truck-only lanes will help emergency management.**
- C. Truck-only lanes will hinder emergency management.**

In response to the affects on emergency management, 60 percent of the EMS providers thought truck-only lanes would help emergency management. The most common reason for choosing “B” was that having additional truck-only lanes could allow traffic to be diverted during an incident or provide room to work during an incident, both would help emergency management efforts. Most EMS providers who chose “A” were simply unsure if or how truck-only lanes would impact emergency management or they felt that once the initial introduction period was over, things would remain unchanged. Of the nine percent of EMS providers that felt truck-only lanes would hinder emergency management, most indicated they had concerns with having enough access to efficiently respond to an incident.

Question 2

	Responses	Percent
A	11	26%
B	26	60%
C	4	9%
Two did not respond.		

Question 3: What specialized equipment or services do you need to assist with incidents involving trucks?

The most common response to Question 3 was that large, heavy duty equipment able to handle trucks, including tow trucks, extrication equipment, and cranes are needed to assist with incidents involving trucks. The second most common response was hazardous material equipment. Other responses included properly trained personnel, barricades, traffic cones, and other equipment to alert and divert traffic.

Question 4: What improvements on the interstate system would you like to see regarding emergency access to assist you in responding to incidents in general and anything additional for those incidents involving trucks?

The most common response to Question 4 was that wider shoulders or emergency vehicle only lanes and more median crossovers were needed along the interstate system. Other responses included more emergency message boards and quicker placement of messages on signs, better interaction between MoDOT and EMS providers, emergency response staging areas, and more traffic control devices.

Question 5: What potential problems do you see regarding emergency access to truck-only lanes? Do you have any suggestions to address these potential problems?

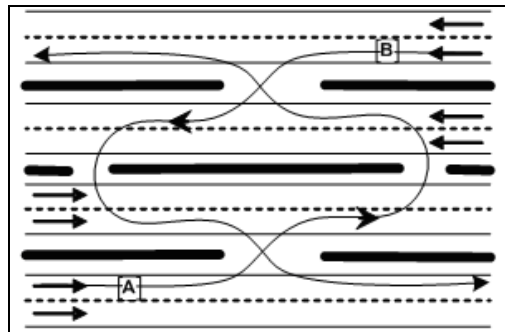
By far the most common potential problem indicated was making sure there are enough access points to the truck-only lanes and that the access points are wide enough for a fire truck to turn through.

Question 6: What are the current emergency services issues on the interstate system? How would truck-only lanes impact these issues?

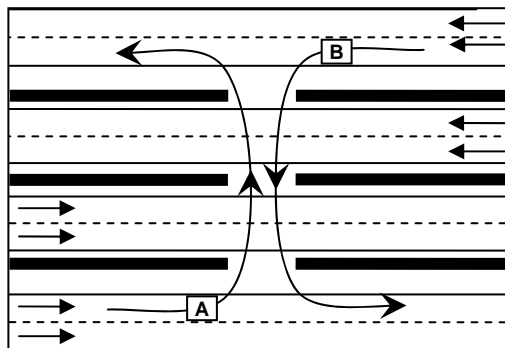
The most common response to Question 6 was access and getting to incidents efficiently. Other responses included proper identification of incident locations, secondary incidents caused by back-ups, having enough space for EMS providers to work during an incident, and the personal safety of EMS providers when responding to incidents.

Question 7: Which crossover scenario do you prefer from the two exhibits shown below?

A. Offset barrier openings showing Movements A and B flowing with traffic.



B. Parallel barrier openings showing both Movements A and B crossing traffic in the inner lanes.



The majority, 53 percent, of the EMS providers chose crossover scenario “A”, while 37 percent chose crossover scenario “B”. In addition, two EMS providers indicated that they did not prefer either one.

Question 7

	Responses	Percent
A	23	53%
B	16	37%
Two did not respond.		

Question 8: What do you consider a reasonable distance between access points to the truck-only lanes?

- A. 1 mile
- B. 2.5 miles
- C. 5 miles
- D. 10 miles

Question 8

	Responses	Percent
A	20	47%
B	13	30%
C	7	16%
D	0	0%
Three did not respond.		

The most common response to Question 8 was response “A”, 47 percent of the EMS providers consider one mile a reasonable distance between access points to truck-only lanes. The second most common response was 2.5 miles between access points, “B”, with 30 percent and 16 percent chose “C”. None of the EMS providers that responded to the survey chose 10 miles as a reasonable distance between access points.

Question 9: If truck-only lanes are constructed, what new specialized training would be needed for emergency service providers, if any?

The majority of EMS providers indicated that they would like training on how to access the truck-only lanes, how to divert traffic if there was an incident, and simple familiarization with the location of access points and slip ramps. The second most common response was additional hazardous material training. Other responses included understanding the engineering philosophy behind truck-only lanes, traffic flow expectations, updates during the construction process, new laws to be enforced, and common emergency response plans.

Question 10: In the space provided below please identify any additional concerns or questions you have regarding truck-only lanes on the interstate system.

Question 10 provided respondents an opportunity to identify any additional concerns or questions. Forty percent of the respondents used this space. Some of the identified concerns were education of the public and the trucking industry, what the ultimate cross section will be, enforcement, and continued communication between MoDOT and EMS providers. Please see **Appendix C** for all the responses in their entirety.

Conclusion

The results of the survey indicated that, at least among EMS providers, there is no real opposition to truck-only lanes along I-70 and I-44. The most common concern from EMS providers is how and where access to truck-only lanes will be gained. Overall, the survey

indicated that with continued communication and education, EMS providers felt that truck-only lanes would be beneficial to the interstate system.

Engineering Specification for Construction of Truck Only
and Passenger Only Travelways in Missouri – Phase 1.
RI 08 – 030.

Sub Document:

**I-70 Truck-Only EIS Freight
White Paper – Literature Review.**

Evaluating Options for Truck Productivity and the Feasibility of Truck-Only Facilities: Literature Review

February 29, 2008

Prepared for:
HNTB

Prepared by:
Wilbur Smith Associates

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Introduction

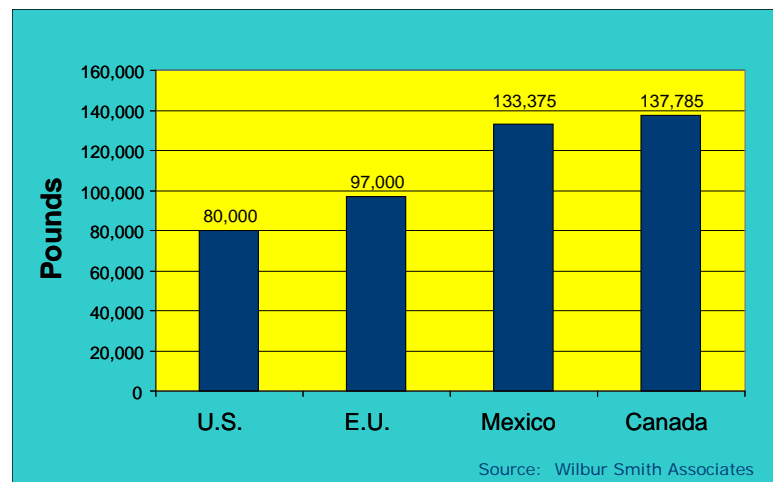
In the words of Thomas Friedman we now live in a *flat world* - a globalized economy moving at an increasingly faster pace. "*Supply Chaining*" is attributed as one of the major forces leveling the playing field in our global economy:

*"Supply-chaining is a method of collaborating horizontally - among suppliers, retailers, and customers - to create value. Supply-chaining is both enabled by the flattening of the world and a hugely important flattener itself, because the more they grow and proliferate, the more they force the adoption of common standards between companies (so that every link of every supply chain can interface with the next), the more they eliminate friction at borders, the more they encourage global collaboration."*¹

One of the driving forces behind global supply-chaining is *intermodalism*; the ability to smoothly transition freight shipments from one mode to another. Intermodalism has become the linchpin of U.S. transport policy since Congress passed the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991. Yet there are indications that the federal highway system is dragging down the potential of intermodalism because federal policy has stifled highway productivity as compared to other nations, and to other modes.

Exhibit 1 compares the national weight limit policies for commercial vehicles in regular operations. As the graph indicates, currently U.S. federal weight limits on the Interstate and Nation Network Highway systems are among the lowest of any industrialized nation in the world. More than half of the states in the U.S. also allow some commercial vehicle operations on state roads to exceed the gross vehicle weight (GVW) or axle load limits imposed on federal highways. The implication is that to remain competitive in a global economy requires the adoption of common standards.

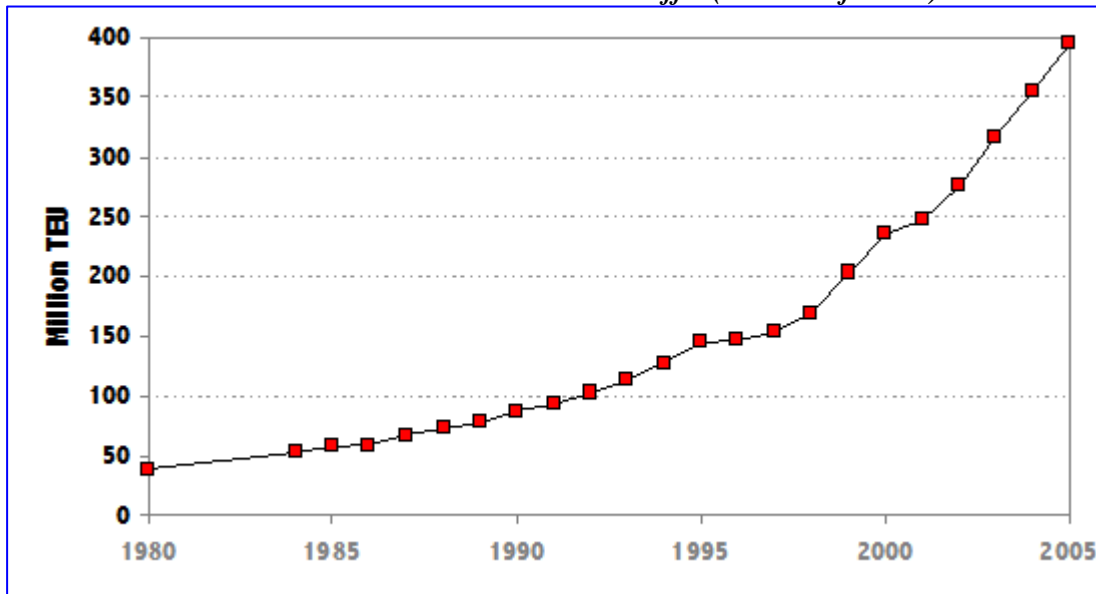
Exhibit 1: Comparison of Federal Truck Weight Policy



Another way to view the lagging productivity of the U.S. federal highway system is to compare the growth in operating assets across the modes of the national intermodal/multi-modal goods movement system. Containerization has undoubtedly been the most significant development in the ability to seamlessly integrate the various modes of freight transport. Containerized freight first emerged in the late 1950's but since 1990 world container volumes - measured in twenty foot equivalent units (TEUs) have quadrupled (**Exhibit 2**).

¹ Friedman, Thomas L., *The World is Flat: A Brief History of the Twenty-First Century*; Farrar, Straus and Giroux, New York. 2005. pp.129.

Exhibit 2: World Container Traffic (millions of TEUs)



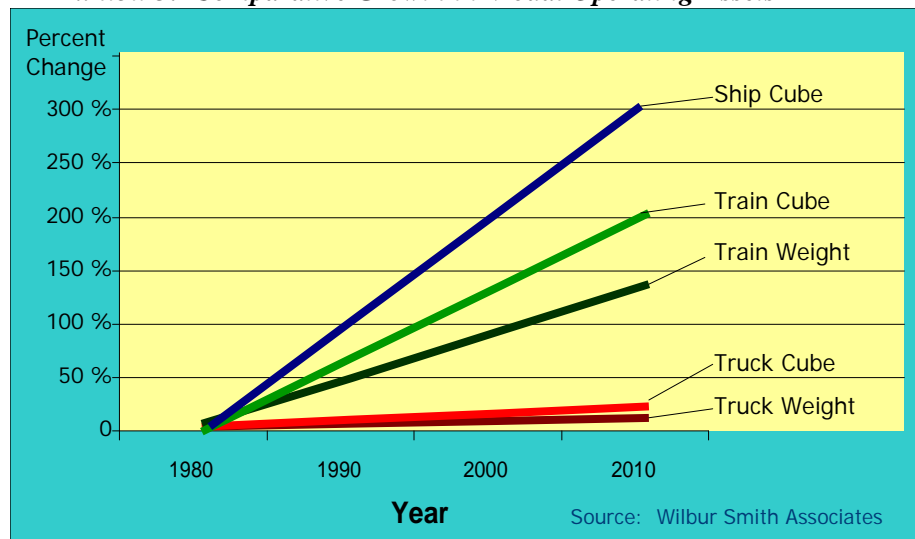
Source: Drewry Shipping Consultants

Accessed at: <http://people.hofstra.edu/geotrans/eng/ch3en/conc3en/ch3c5en.html>

Given the U.S. position as a dominate world competitor, the U.S. has a significant hand in the growth of world container traffic. To respond to this growth some modes of freight transport have become significantly more productive (**Exhibit 3**).

Exhibit 3: Comparative Growth in Modal Operating Assets

For instance, in 1980 the average size of an ocean going container ship was 4,000 TEUs. Today, shipping lines are operating ships that accommodate 14,000 TEUs, and ships carrying 16,000 TEUs are under construction - an increase in cubic carrying capacity of 300. In 1980, just prior to federal deregulation the average length of a Class I unit train was 75-80 cars. The first



Source: Wilbur Smith Associates

double stack container trains began operating in 1984, and today the typical container unit train is double stacked and 120 cars in length - an increase of 200 in cubic capacity. Class 1 railroads have also seen significant, yet less dramatic growth, in productivity from a weight standpoint, as trains have grown longer and hopper car weight standards have gone from 236,000 pounds common in 1980, to 286,000 pounds common today, and 315,000 pound hopper cars becoming more common.

By comparison the federal weight and capacity standards for commerce vehicles have flat-lined. The federal GVW in 1980 was 72,380 pounds, versus 80,000 today, just a 9% change. From a cubic stand point trucks have fared slight better as commercial vehicle operators have gradually replace 48 foot semitrailer with 53 foot semitrailers, resulting in a modest cubic capacity growth of approximately 18 percent over nearly 30 years.

Given the need to remain competitive in a global economy, U.S. agencies charged with constructing, maintaining and operating highways are struggling with how to arrest the growth in severely congested segments of the network. During the 1980s and 1990s several prominent research efforts were undertake to examine increasing regulatory limits on the operating assets of the trucking industry, however objections from competing modes and public concerns about safety prevented larger truck size and weight proposals from gaining traction with Congress. Much of the focus for increasing highway productivity in recent years has focused improving operations through better facility management and technology. More recently the topic of “truck-only lanes” or “truckways” as a new design concept has emerged as one possible response in the search for new paradigms to ease congestion and meet the road network demands of the modern global economy.

The purpose of this literature review is to look at potential options for increasing the productivity for goods movement on interstate highway corridors. The review of literature is organized around several perspectives:

1. Facility management for improving truck operations
2. Vehicle design and capacity research
3. New facility truck-only design concepts
4. Research on advanced technologies applying to truckways

1. Facility Management for Improving Truck Operations

There is a growing trend in the U.S. to employ "*managed lane*" concepts into freeway operations. Managed lanes mean different things to different people, and at this time there is no universally recognized definition of managed lanes.

"However, two states have developed definitions, in one instance to guide implementation of projects, and in another to serve as a starting point for discussion of the concept. The Texas Department of Transportation (TxDOT) has developed the following definition for managed lanes as part of its managed lanes research program, and it serves as the official definition of the concept for TxDOT: A managed lane facility is one that increases freeway efficiency by packaging various operational and design actions. Lane management operations may be adjusted at any time to better match regional goals."

The Washington State Department of Transportation also developed a definition of managed lanes through a workshop held in June 2001: "Managed Lane facilities include any roadway lane that can be managed to prevent congestion from occurring. In managed lanes, one or more of these techniques is used to control the number of vehicles using the lane or roadway:

- Limiting access -- providing infrequent on-ramps, as on the I-5 and I-90 express lanes*
- User eligibility requirements -- such as HOV-only, truck-only, permit-only, etc.*
- Pricing -- tolls can be varied by time of day to control traffic volumes.*

*By considering these as different forms of traffic management, it is possible to plan the best combination of tools to keep a roadway from becoming congested over time, and to optimize traffic to achieve the best person and vehicle throughput."*²

Given the Washington State definition for managed lane techniques, *truck-only* lanes can be discussed as a managed lane technique. However, for this literature review, truck-only lanes are examined in a separate section under New Facility Design Concepts, however lane restrictions for trucks appear in this section.

A great overall resource for learning more about managed lane concepts and current research can be found at the Managed Lane website maintained by the Texas Transportation Institute: <http://managed-lanes.tamu.edu/>

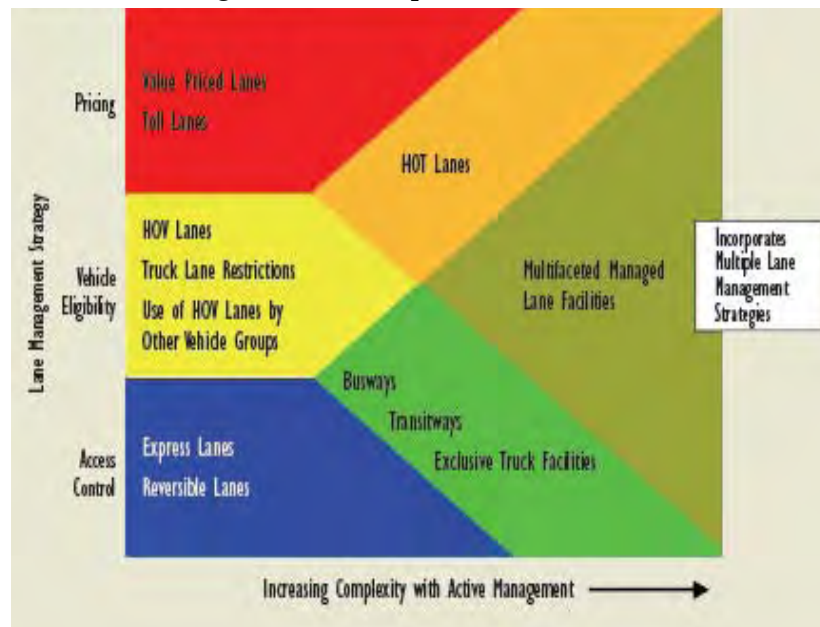
² **Managed Lanes: Strategies Related to HOV/HOT**, A Draft White Paper prepared by the TRB HOV Systems Committee (A3A06), September 2003. Accessed at: http://managed-lanes.tamu.edu/related_work/TRB/TRB-MLJS-Managed_Lanes_White_Paper-Sep2003-Final.pdf

A. Managed Lanes: A Primer¹ (undated)

Exhibit 4: Managed Lane Concepts

Published by FHWA, the report is designed for community leaders, key policy makers, transportation agency managers, and those working to find solutions to today's transportation challenges. The purpose is to provide information on managed lanes as a mobility strategy, and to give the reader a starting point for exploring managed lanes in their own community. Topics covered in the primer include the following:

- Defining managed lanes,
- Managed lane success stories,
- Issues and challenges unique to managed lanes projects, and
- The future of managed lanes.



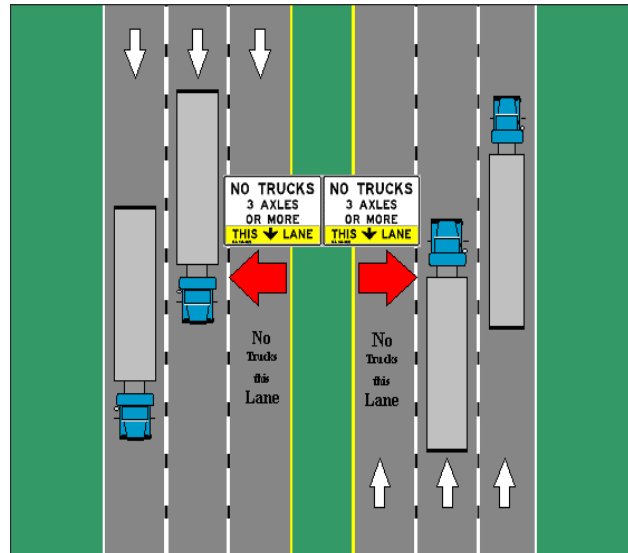
B. Evaluation of Truck Lane Restrictions in Virginia² (2007)

A number of states have implemented truck lane restrictions in an attempt to improve safety and mobility on freeways. These restrictions typically prohibit trucks from traveling in the median lane, potentially increasing passing opportunities and reducing negative interactions between slow-moving trucks and other vehicles. Virginia currently has two forms of truck restrictions in place. The first type of restriction prohibits trucks from the median lane of interstates that have three or more lanes by direction, provided certain criteria on speed limit and location are satisfied. The second type of restriction prohibits trucks from traveling more than 15 mph below the posted speed limit in the left lane of two-lane directional interstate segments. This report documents the results of a safety and operational evaluation of Virginia's truck lane restrictions. Crash data were examined at a total of 43 sites with restrictions and 16 similar sites without restrictions. Likewise, operational data were collected at sites with restrictions and similar sites without restrictions. The results of the analysis showed that the restrictions on two-lane sites appeared to be having a positive impact on operations and safety. At these sites, crashes were reduced by 23 percent, and speeds were estimated to have increased by 5.5 mph. At the three-lane sites, no statistically significant increase in speed was observed. A breakpoint in crash performance appeared to occur at approximately 10,000 vehicles per day per lane. Roads below this threshold experienced significantly fewer crashes than anticipated, whereas roads above this level had significantly more crashes than expected.

C. Monitoring of Texas Vehicle Lane Restrictions³ (2004)

The goal of this study undertaken for TxDOT and FHWA by TTI, was to develop guidelines for truck lane restrictions in Texas. Among the study key findings:

- Implementing truck lane restrictions during peak traffic periods have had a long-term impact on reducing crashes on the I-10 East Freeway in Houston.
- Based upon the study of enforcement levels and crashes, it is not conclusive if increased enforcement activities have direct impacts to improved safety to freeway operations.
- The truck restrictions in Houston have not had a detrimental impact on freeway speeds or operations.
- Based upon recent surveys of opinions on the I-10 East restriction, the general public continues to see a need for and benefit of the truck restrictions on freeways in Texas.



D. Managed Lanes: A Cross Cutting Study⁴ (2004)

In 2004, the Federal Highway Administration published a study on managed lanes with the intent of reviewing the state-of-the-art in managed lanes in order to increase the understanding of (1) what managed lanes are, (2) how to plan for implementation, (3) what operational and design issues are considered, and (4) how active management of the lanes over the life of the facility affect its implementation. The report also examined the operational aspects of implementing different types of designated truck lanes with and without tolls. The study considered not only tolled truck facilities, but also reversible and express lanes for trucks. The study included three case studies from California.

E. Safety and Operational Evaluation of Truck Lane Restriction on I-75⁵ (2004)

This study evaluated safety and operating characteristics of the I-75 corridor in north Florida where trucks restricted throughout the day from using the inside lane. The study included an operational and crash simulation model. Results found that relaxing the lane restrictions on trucks would not significantly improve travel times or reduce delays, but would increase the level of lane switching behavior by trucks, hence increasing lateral conflicts and truck-car collisions. In a review of truck-car crashes in the state, it was found that improper lane change was one of the major contributing causes of heavy truck-passenger car crash involvement. The findings of this study supported the hypothesis that lateral separation of truck and car traffic could yield safety benefits without significant losses in travel time or cost.

F. Another View of Truck Lane Restrictions (2003)⁶

As truck volumes on US highways continue to increase, both elected officials and members of the general public often look to the use of lane restrictions for large trucks as a means to increase operating efficiency and highway safety. In the past, research has offered little evidence that either safety or efficiency is positively impacted by widespread use of this practice. This paper offers another view of truck lane use restrictions on high-speed, limited access facilities. To determine the effects of lane use restrictions, scenarios which varied traffic characteristics such as volume, grade, percentage of trucks, and the presence of entrance and exit ramps, were developed using the VISSIM model. In each scenario traffic along the model freeway segment was monitored to determine the effect of the lane use restrictions by comparing values of various traffic measures from a model run first without and then again with truck lane restrictions.

As in past research efforts, the implementation of truck lane restrictions in a variety of scenarios is shown to have little effect on a number of traditional measures, including average speed, speed differential between cars and large trucks, and level of service. However, further examination of data resulting from the simulation process shows that significant gains in the area of safety and driver comfort may be realized through the reduction of lane-changing maneuvers by all vehicle types, lending support to past drivers surveys indicating strong support for this practice among drivers of passenger vehicles.

G. State and Federal Legislative Issues for Managed Lanes⁷ (2003)

This 2003 TTI study assessed federal and state legislative needs necessary for Texas to successfully implement managed lane facilities, including truck-only lanes and the legislative actions necessary to support deployment.

H. Marketing the Managed Lanes Concept⁸ (2003)

This study performed by TTI examined pricing issues associated with managed lanes, including truck-only facilities with an emphasis on public perception and public interaction when a new and complex managed or truck-only project was introduced.

I. Managed and Priced Lane Workshop⁹ (2003)

In a 2003 workshop, FHWA with TRB hosted a workshop in Biscayne, Florida, to address key issues in the area of managed and priced lanes. In the workshop, truck-only lanes were identified as a key potential for managed and road pricing policy and research.

J. Using Narrow Freeway Lanes to Mitigate Transportation Related Problems¹⁰ (2003)

In a 2003 study, the American Public Works Association (APWA) published a study (Murphy) in which the concept of lateral separation of trucks and cars was addressed through the concept of dedicated passenger lanes, or Small-Vehicle Commuter Lanes (SVCL's). The APWA study emphasized the relative safety of separating passenger vehicles from trucks, and the lower cost, design, and operational requirements of dedicated lanes when they are focused on passenger instead of truck traffic.

K. Truck Accommodation Design Guidance: Final Report¹¹ (2003)

In a 2003 report by Texas A&M (Middleton), the increasing volume of truck traffic associated with supply chain management strategies (such as JIT) as well as North American Foreign Trade Agreement traffic were cited as issues driving research into Truck-Only facilities. Consequently, Texas A&M published this study of unique operating characteristics of large commercial vehicles and design thresholds for these vehicles. The findings of the study suggested that special design warrants may be met with Average Annual Daily Truck Traffic (AADTT) at or exceeding 5000 trucks, and dedicated truck lanes may be warranted on segments with AADTT at or exceeding 25,000 trucks. This study also included a review of the TxDOT “Roadway Design Manual” to account for unique truck requirements with regard to stopping sight distance, intersection and channelization control, lane width, shoulder width and composition, side-slopes, drainage features, passive signs, and acceleration lanes

L. Interim Manual For Managed Lanes¹² (2003)

In 2003, the Texas Transportation Institute (TTI) (Khun et. al) compiled three years of design, operational, and planning research on managed lanes into an Interim Manual for Managed Lanes. The manual included an introduction to the design and implementation of different types of managed lanes facilities, including truck-only lanes.

M. Operational Performance Models for Freeway Truck-Lane Restrictions¹³ (2003)

In this 2003 study, the Florida Department of Transportation (Gan and Jo) conducted a study to develop operational performance models to identify the most efficient truck-lane restriction alternatives for freeways. Performance measures included average speed, throughput, speed differentials and lane changes. This study used the VISSIM simulation model on various scenarios under prevailing conditions. The modeling indicated that:

- Truck restriction alternatives increased the average speed, except in cases where the corridor was highly congested with trucks and multiple truck lanes in operation
- Overall throughput for trucks is greater when one truck lane is provided, increasing the truck capacity of a roadway segment
- Speed differentials between restricted and non-restricted lane groups are significant, which can be expected to increase both free-flow speeds and induce truck travel demand on truck-only facilities
- Lateral movement (lane switching) actions with potential conflicts between trucks and passenger cars were significantly reduced by dedicated truck facilities
- One-lane truck restriction was beneficial for 3, 4, and 5-lane highways, whereas two-lane truck facilities were only appropriate for 4 and 5-lane highways

N. Enforcement Issues on Managed Lanes¹⁴ (2003)

This 2003 Texas study provided an overview of enforcement issues for operating freeways with managed lanes, including truck lanes. The importance of technologies, such as automated

vehicle identification (AVI), license plate recognition (LPR), and electronic toll collection (ETC), was emphasized as critical to the effectiveness of facilities of this type.

O. Current State-of-The-Practice for Managed Lanes¹⁵ (2002)

A managed lane facility is one that increases freeway efficiency by packaging various operational and design actions. Operating agencies may adjust lane management operations at any time to better match regional goals. Managed lanes are intended to provide peak period free flow travel to certain user groups.

A review of literature concerning the various operational strategies for managed lanes revealed that numerous studies are being conducted and numerous strategies are being tested in an attempt to improve freeway efficiency. Strategies, terms, and acronyms are often used interchangeably to describe a particular action or variation of a design without strict adherence to definitions. For example, what may be described by one jurisdiction or study as a high occupancy toll (HOT) lane is described by another jurisdiction as a value express lane. Meanwhile, a third entity uses the term value express lane for a totally different strategy. An effort has been made to distinguish the various strategies. However, in some instances definitions by authors of reports reviewed may seem to conflict traditional definitions of a particular strategy.

P. Evaluation of Houston Lane Restrictions¹⁶ (2002)

Lane restrictions on a portion of I-10 near Houston were implemented in 1998 in an effort to reduce the number of crashes involving trucks between Houston and Beaumont. The Houston City Council called on TxDOT to test truck lane restrictions. TxDOT contracted with the Texas Transportation Institute to conduct a 36-month evaluation of the restrictions to measure their effectiveness.



The results of the evaluation determined that truck compliance with the lane restrictions was in the “70 to 80 percent range.”

Q. Investigating Large Truck-Passenger Vehicle Interactions (2007)¹⁷

An analysis of truck-passenger car interactions was performed for Missouri urban and rural freeways. In an analysis of mean speeds, trucks were found to travel approximately 2 mph slower than other vehicles on urban interstates and 3.5 mph slower on rural interstates. These speed differences between trucks and passenger vehicles were not very large. Thus, there was no evidence that, on the average, trucks were traveling much faster than passenger cars. The result was statistically significant for rural but not for urban interstates. One reason for the lower speed differences in urban areas could be due to the higher traffic volumes and lower speeds.

There was no significant difference in speed differentials between daytime and nighttime on rural freeways.

In terms of lane usage, trucks concentrated mainly in the middle lanes and avoided the right-most and left-most (median) lanes in situations with 5 and 6 lanes. With 3 lanes present, trucks tended to use the middle and right-most lanes. The 4-lane scenario seemed to be anomalous as trucks tended to travel in the two left-most lanes. The application of truck lane restrictions could alter the current truck lane usage significantly and increase the truck usage in the right-most lane.

In terms of number of crashes, trucks accounted for a smaller percentage of crashes as compared to passenger vehicles. In particular, trucks accounted for 19.9% and passenger vehicles for 68.2% of fatal crashes. However, an analysis of truck at-fault crash rates versus passenger vehicle at-fault crash rates, named RSEC ratios, showed that on urban freeways, the percentage of truck crashes is disproportionately larger when considering the volume or exposure of trucks.

Even though the reasons for the disproportionately higher RSEC ratios (urban) for trucks are not clear, the following are presented as possible issues in consideration, both for and against:

- performance characteristics of trucks: braking, acceleration, driver visibility
- length of trucks leading to greater number of interactions per physical space
- formal training of commercial drivers
- the length of commercial truck trips
- behavior of passenger vehicles near trucks
- the different nature of rural versus urban truck-passenger vehicle interactions

In contrast, the rural data in general shows that truck crashes are not as disproportional to the crash rates of passenger vehicles. These results point to a greater safety concern in truck passenger vehicle interactions on urban freeways.

2. Vehicle Design and Capacity Studies

A. Commercial Truck and Bus Synthesis Report # 3¹⁸ (2003)

The objective of this TRB Synthesis report was to summarize state-of-the-practice information regarding safety implications from operating commercial trucks and buses on highways, and present options for highway design improvements that could enhance the safe operation of commercial vehicles. The report describes its purpose as follows: "The synthesis describes current highway design features, operational practices, and other initiatives of importance to commercial truck and bus safety." The results presented in the synthesis report include operational characteristics that may be affected by the operation of LCVs on Interstate 70. In summarizing the findings of the synthesis, the authors present conclusions, and seven recommendations. The recommendations from the report are:

1. The marking of passing and no-passing zones on two-lane highways should be evaluated to ensure that heavy vehicles use them properly. The sight distance criteria in the MUTCD

used for marking passing and no-passing zones are appropriate for passenger cars, but do not explicitly consider heavy vehicles. Research to confirm that this does not lead to poor safety performance in passing zones would be desirable.

2. The current AASHTO *Green Book* criteria for acceleration lane lengths at entrance ramps to major highways appear appropriate to accommodate average trucks, but do not appear to accommodate the lowest performance trucks. Research is needed to determine whether this leads to poor safety performance and whether the design criteria for acceleration lane length can be changed in a cost-effective manner.
3. Offset left-turn lanes have been found to be effective in reducing the potential for opposing left-turn vehicles to restrict their drivers' view of potentially conflicting traffic. Such sight restrictions are of greatest concern when one or more of the opposing left-turn vehicles is a large truck or bus. However, the frequency of accidents related to such sight restrictions and the benefits of providing offset left-turn lanes to remove such sight restrictions has not been documented.
4. More research on the issue of differential speed limits is needed. The belief that lower heavy vehicle speeds will reduce accident rates is widespread but unproven. By contrast, fundamental traffic engineering principles suggest that accident rates increase as the variance of vehicle speeds on a facility increases. Highway agencies need better information on the safety effects of differential speed limits.
5. A recent limited test of left-lane truck restrictions in Houston showed positive results for safety. However, all previous research on truck lane restriction has found no effect on safety. Further research based on field trials would be desirable to establish whether lane restrictions have safety benefits.
6. Highway agencies are facing decisions about whether to reduce traffic congestion by building exclusive truck lanes or exclusive truck roadways. Research is needed to provide safety performance measures to assist highway agencies in such decisions.
7. Evaluations of ITS systems that use new technology to improve heavy vehicle safety should continue. New and innovative systems should be developed and the safety effectiveness of both existing and new systems should be evaluated and documented.

B. Exempting Maine Interstate Highways from Federal Weight Limits¹⁹ (2004)

The Study of Impacts Caused by Exempting Currently Non-Exempt Maine Interstate Highways from Federal Truck Weight Limits and a companion study, *The Study of Impacts Caused by Exempting the Maine Turnpike and the New Hampshire Turnpike from Federal Weight Limits*, were conducted to support a request from the State of Maine to the Congress, that federal weight limits in the state be raised. In 1998, The Transportation Equity Act for the 21st Century (TEA-21) provided an exemption from the federal gross weight limit on the Maine Turnpike and the New Hampshire Turnpike. The remaining Interstate routes in Maine, I-295, I-395 and large portions of I-95 remain subject to the federal GVW limit of 80,000. The analysis modeled commodity flows across Maine's state and federal highway systems under two weight policy

scenarios. The analysis examined the safety, pavement, bridge and traffic impacts resulting from the adoption of a truck weight policy based Maine's state truck weight limits, as compared to the existing federal truck weight policy imposed by Congress on the Interstate Highway System.

Exhibit 5: Exemption Impact Summary

The study concluded that extending the existing federal truck weight exemption on the Maine Turnpike to include currently non-exempt Interstate Highways in Maine would divert five and six axle TST combinations over 80,000 lbs. from the many state highways and some portions of the Maine Turnpike. Overall this traffic diversion from

Impacts are rounded to nearest \$1,000	
Safety Economic Impacts	\$356,000
Pavement (Low)	\$1,002,000
Pavement (High)	\$1,651,000
Bridge	\$317,000
Annual Savings - Low	\$1,675,000
Annual Savings - High	\$2,324,000

state to federal highway facilities would have positive impacts on safety and infrastructure costs. **Exhibit 5** summarizes the economic impacts that would result from the contemplated policy change. The economic benefit to Maine resulting from exempting currently non-exempt Interstate Highways in Maine from federal truck weight limits was an estimated \$1.7 to \$2.3 million per year.

C. The Comprehensive Truck Size and Weight Study²⁰ (2000):

The report authors emphasize that the purpose of the study was to develop “a policy architecture” that could be used to analyze changes to truck size and weight at a sub-national level. As a result, the study presented in four volumes provides no definitive conclusion regarding national truck size and weight policy. Volume III of the study however, does present the results that were achieved when the tools developed were applied to several policy scenarios. Five different scenarios were compared to a “base case” scenario representing the current regulatory scheme. One of the illustrative scenarios, the North American Trade Scenario – is presented with two options. The first option examines a series of vehicle configurations using a tridem axle group loaded to a maximum weight of 44,000 pounds. The second option examines the same vehicle configurations with the tridem axle group loaded to a maximum of 51,000 pounds. A six axle tractor semitrailer (TST) with a 51,000 load on the rear tridem can attain a gross vehicle weight of 97,000 pounds. **Exhibit 6** illustrates that bridge and geometric costs were estimated to increase significantly with heavier tridem axle loads. However, bridge and geometric costs will be highly sensitive to the networks to which a scenario is applied and bridge analysis remains one of the more contested areas of the TS&W policy debate. Rail freight diversion also posts significant numbers, but again the extent of rail diversion in a particular region will be dependent on factors such as length of haul and access to rail services. The North American Scenarios posted positive results (reductions in cost) in the area of pavement, congestion, energy and savings to shippers.

Exhibit 6: Estimated Impacts of Truck Size& Weight Scenarios (% Change from Base Case)

	Uniformity	N.A. Trade (1)	N.A. Trade (2)	LCV Nationwide	H.R. 551	Triples
Pavement Costs	-0.3	-1.6	-1.2	-0.2	0	0
Bridge Costs	-13.0	+33.1	+42.2	+34.4	0	+10.4
Geometric Costs	0	+13.3	+13.3	+965.0	0	0
Congestion Costs	+0.6	-1.2	-1.2	-2.9	0	-7.6
Energy Costs	+2.1	-6.2	-6.3	-13.8	0	-12.8
Shipper Costs	+3.0	-5.1	-7.0	-11.4	0	-8.65
Rail Contribution*	na	-42.8	-49.7	-55.8	na	-38.2
N.A. Trade (1) -- 44,000 pound tridem axles; N.A. Trade (2) -- 51,000 pound tridem axles.						
*The amount of rail revenue available to pay fixed costs after freight service (variable) costs have been covered.						

D. Impacts of Changes in Truck Weight Regulations in Montana²¹ (1999)

The full title of this study was *Infrastructure and Economic Impacts of Changes in Truck Weight Regulations in Montana* and continued an earlier investigation into potential truck weight changes in Montana. (Also see: *Impact on Montana's Highways of Adopting Canadian Interprovincial and Canamex Limits on Vehicle Size and Weight*; 1997 – Transportation Research Record #1602): These studies examine the impact of truck size and weight changes to Montana's highway infrastructure and state economy. Montana currently allows several vehicle combinations with up to 9-axes that can attain weight of 123,000 GVW. These studies analyze the impacts of several alternative size and weight policies. Overall, the studies found that lowering existing weight limits would have detrimental effects to both the state's economy and infrastructure:

“Changes in transportation costs of 4 to 54 percent were predicted under the 36,000 kg (80,000 lb) scenario, which were estimated to be 0.2 to 4.1 percent of the value of the goods produced. Changes in transportation costs typically were at least an order of magnitude larger than the changes in infrastructure costs. Statewide economic impacts in terms of forgone gross state product amounted to -0.4 percent and, in the first year alone, were 2 to 20 times the infrastructure impacts, depending on the scenario.”

E. Truck Weight Limits: Issues and Options²² (1990):

Requested by Congress in Section 158 of the Surface Transportation and Uniform Relocation Assistance Act of 1987. “As requested, the committee analyzed the effects of a number of specific proposals for changes to existing federal weight limits and regulations and developed recommendations that we believe will serve the public interest.” The study concluded that eliminating state's grandfathered weight limits would cost the nation about \$8 billion annually (1990 \$'s). The study made five recommendations to Congress: 1) Replace the current federal bridge formula for vehicles of 80,000 pounds or less, 2) Establish a broad special permit program to make it easier for states to allow vehicles in excess of 80,000 pounds without the necessity of

states grandfather rights, 3) Take no action to restrict grandfather rights that had already been claimed, 4) Increase weight enforcement, especially off interstate highways, and 5) States should pursue regional cooperation in standardizing weight limits and permit practices. In general, the report concluded: “It has been found that increasing truck weights can significantly reduce the cost of goods movement and that cost savings due to more efficient trucks generally exceed the additional pavement and bridge costs incurred by highway agencies.”

F. New Trucks for Greater Productivity and Less Road Wear²³ (1990):

New Trucks for Greater Productivity and Less Road Wear: An Evaluation of the Turner Proposal, was undertaken at the request of AASHTO, to specifically examine a new approach to truck size and weight regulation that had been advocated by Francis C. Turner, a former administrator for FHWA. In a nutshell, the “Turner Proposal” as it became known, would allow additional weight on more axles. The proposed Turner configurations included a 7-axle tractor-semi-trailer (TST) combination, and several double trailer configurations. The overall evaluation of these heavier vehicles was stated as such: “The availability and use of Turner trucks on U.S. roads, operating according to the procedures recommended by this study, would benefit the country by reducing the cost of shipping freight and the cost of maintaining and preserving the road system.”

3. Longer Combination Vehicle (LCV) Studies

There are many factors influencing the safe operation of LCVs on our nation’s highways. Vehicle design factors are the principle factors influencing vehicle behavior on the road network. The following subsection investigates performance measures influencing LCV safety, the varying LCV configurations (as well as the characteristics for each), and their implications for LCV safety.

G. Long Combination Vehicle (LCV) Safety Performance in Alberta²⁴ (2007)

To assist in improving the understanding about the safety impact of large vehicles in the province, Alberta Infrastructure and Transportation (AIT) Policy and Corporate Services Division commissioned a study to analyze the safety performance of long combination vehicles (LCVs) operating on Alberta’s LCV network, relative to the safety performance of other vehicle types operating on the same network. This study was intended to help define future truck size and weight policy for Alberta highways, and provide information to policy makers in Alberta and its trading partners concerning LCV safety. The safety performance analysis of LCV operations in Alberta relative to other vehicle types operating on the LCV network and urban areas resulted in the following key findings:

- There were 106 LCVs involved in 106 reported collisions on the Alberta LCV network and in urban areas over the study period. These accounted for 0.02 percent of all collisions in the study area (106 of 490,956). Sixty percent of these (65 of 106) took place on the LCV network and 40 percent (41 of 106) in urban areas.
- Over the study period (1999 to 2005), LCVs maintained a steady percentage of vehicles involved in collisions from year to year. Other vehicle types, except for straight trucks and bobtails, showed decreasing percentages of vehicles involved in collisions.

- The severity outcome of LCV collisions on the LCV network was lower than that of other vehicle types. LCVs accounted for one percent of all trucks in fatal collisions, one percent of all trucks in injury collisions, and one percent of all trucks in property damage only (PDO) collisions. Other combination vehicles accounted for nearly two-thirds of trucks in fatal collisions, 57 percent of trucks in injury collisions, and 43 percent of trucks in PDO collisions. Taking traffic exposure into consideration, LCVs have a lower fatality, injury, and PDO rate per 100 million VKT than other vehicle types.
- Over one-half of LCV collisions on the LCV network were single-vehicle collisions. Most of these were attributed to night-time driving and wildlife intervention. Single-vehicle collisions accounted for only 37 percent of collisions involving other articulated combinations.
- LCVs were over-represented in collisions on the LCV network in winter (December, January and February) and spring (March, April and May), relative to the corresponding seasonal traffic volume distribution.
- Driver action and environmental condition were the main contributing factors listed for LCVs involved in collisions on the LCV network and in urban areas. Driver action was particularly associated with Turnpike doubles operating in urban areas. Improper turning and improper lane change were cited as contributing factors in 40 percent of turnpike double collisions in urban areas.
- Adverse road surface conditions (wet, slush, snow, or ice) were cited as contributing factors for about 40 percent of all LCVs involved in collisions on the LCV network. This proportion was similar for other truck types but smaller for passenger vehicles. Comparatively, adverse road surface conditions were cited as contributing factors for one-quarter of all LCVs involved in collisions in urban areas. The same proportion was experienced by all other vehicle types.

H. Safety Review of Rocky Mountain Double Operations²⁵ (2006)

Safety Review of Rocky Mountain Double Operations on Two-Lane, Undivided Rural Roads examined the operational safety review of an undivided, two-lane rural road in Manitoba. It outlined special permitting requirements designed to enhance safety compliance and operational transparency. Some of the design and implementation considerations for special LCV operating permits included:

- Issuing a permit for a given time period
- Developing clear and precise conditions specific to the proposed operation of LCVs ensuring that conditions are strictly and continuously met
- Specifying the required special equipment, time of operation, record keeping, driver qualification standards

Additionally, the study identified four infrastructure-related remediation priorities:

- Pavement repairs in the vicinity of hazards located adjacent to the roadway edge
- Resurvey of passing sight lines and a remarking of passing restrictions to match the passing sight distance requirements of LCVs
- Remediation of severe pavement rutting, and

- Provision of edge line painting through all horizontal curves

I. Western Uniformity Scenario Analysis²⁶ (2004):

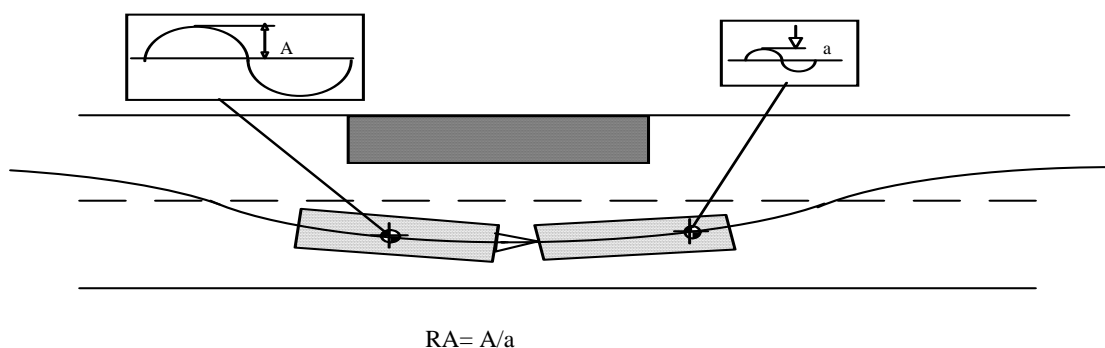
The Western Uniformity Scenario Analysis study was requested by the Western Governor's Association (WGA) to analyze a truck size and weight scenario that would lift the LCV freeze and allow uniform LCV weights, dimensions, and routes in 13 western U.S. states. States included in the analysis are: Washington, Oregon, Nevada, Idaho, Utah, Montana, Wyoming, Colorado, North Dakota, South Dakota, Nebraska, Kansas, and Oklahoma. Detailed analyses were conducted to effectively estimate 2010 forecasts of vehicle miles traveled (VMT) for several LCV vehicle configurations using state reported traffic counts and vehicle classifications derived from weigh-in-motion data. The analysis was conducted as an extension of the *USDOT Comprehensive Truck Size and Weight Study* previously cited.

The study also identified significant reductions in travel by conventional semitrailers if scenario weights and dimensions were adopted. Among these reductions were a 76 percent reduction in 5-axle semitrailers, a 44 percent reduction in STAA doubles, and a 25 percent reduction in total heavy truck travel. These reductions, the study concluded, would be attributable to a twenty fold increase in LCVs on the roads of the western states and the resulting increase in freight per vehicle. However, truck crash reductions would not be expected to be as significant as reductions in truck travel because the traffic reductions are projected for rural interstate roads whereas many truck crashes take place on rural arterial connectors.

The Western Uniformity Analysis summarizes previous attempts to analyze crash databases, noting that previous analyses tend to contradict each other and to date results have not been statistically significant. The study goes on to identify three performance metrics that are key vehicle dynamics and handling as proxies that indicate truck safety risks: 1) Static rollover threshold; 2) Rearward amplification, and 3) load transfer ratio.

Static rollover threshold affects overall vehicle stability and is the minimum amount of lateral acceleration needed to result in wheel lift from the ground. It is most important, when evaluating rollover threshold to consider how payloads are distributed throughout the semitrailer of the LCV. In general, the lower the center of gravity and the more uniformly distributed the payload the more stable the vehicle. According to the study, most of the LCV designs that it analyzed “have good to excellent rating for static rollover threshold.”

Exhibit 7: Schematic Representation of Rearward Amplification (RA) in LCVs



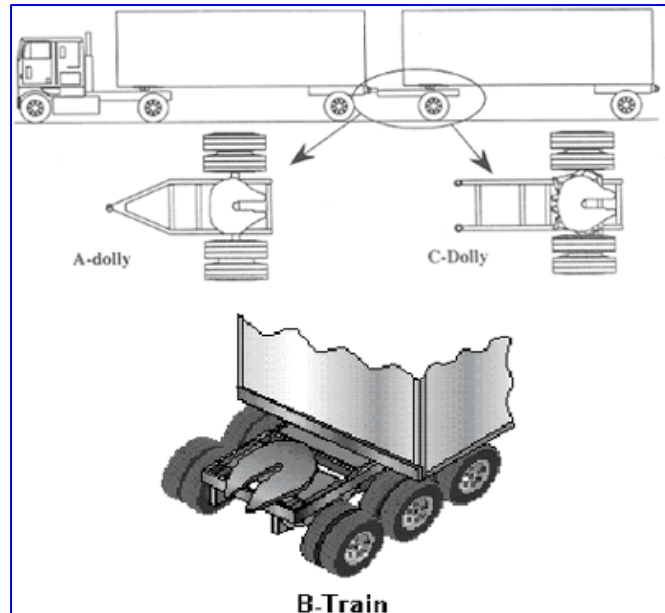
Rearward amplification consists of the steering effects that are transferred from the cab to articulated semi-trailers. Rapid steering can have major effects on trailer movements and is often influenced by axle groupings, center of gravity, wheelbase dimensions and suspension characteristics. Particularly important is the way trailers are connected. These connections can either be characterized as an A-train, B-train or C-train. According to the report, “certain configurations of LCVs are more prone than typical tractor-semitrailers to rearward amplification. For example, rearward amplification is 1.73 times greater for trucks with twin 28-foot trailers than for typical tractor semi-trailers, but can be 2.18 times worse for triple-trailers (with their five points of articulation) than it is for typical tractor semi-trailers.” An ‘A-train’ or ‘A’ converter dolly has a single connection point to the lead trailer and is the most common type in the United States. This type allows more rearward amplification than does the ‘B-train’ or ‘C-train’. Typical tractor-semitrailer combinations have a rearward amplification of 1.24. Under current design standards, STAA doubles (two 28-foot trailers) have rearward amplifications of 2.15. Also, the rocky mountain double (RMD), with an allowable gross vehicle weight of 105,500 pounds would be considered to have poor dynamic performance. The Triple-trailer A-train, at a value of 2.72, has the highest rearward amplification of all vehicles examined in the *Western Uniformity Analysis*. When the triple-trailer combination is fitted with C-dollies, dynamic activity is reduced by 39 percent and is in line with doubles and other LCV configurations. The most stable vehicle examined is the B-train tanker at 117,000 pounds and a trailer width of 102 inches. It performs even better than the single-trailer combination.

Load transfer ratio is the proportion of load transferred to one side of the vehicle in a transient steering maneuver. Essentially, the load transfer ratio is a combination of rollover and rearward amplification into one performance category. According to the study, “The load transfer ratio performance of the triple A-train and the STAA double is very poor.” The load transfer characteristics would tend to improve with trailer length and ‘B’ and ‘C-Train’ configurations.

Exhibit 8: Combination Vehicle Dolly Hitch Designs

‘B’ and ‘C-Train’ configurations improve stability through “roll couplings.” These couplings take advantage of the fact that two adjacent units in a multi-trailer combination roll in different directions during a dynamic lane change maneuver. By making the coupling or hitch more rigid along the roll axis, each unit in the combination “helps” the other counteract excessive roll forces.

Roll coupling is a special attribute of ‘B-train’ and ‘C-dolly’ connections (**Exhibit 8**). In a ‘B-train’ connection between two trailers in a twin configuration a standard “fifth-wheel” connection is used to couple the two trailers together, thereby providing significant counter-roll forces between the two trailers.



A ‘C-dolly’ connection also provides roll and coupling stiffness through the use of two drawbars between trailers. One of the axles of a ‘C-dolly’ is self-steerable to prevent tire scrubbing. ‘A-dollies,’ which are used today, have one drawbar. Both B-train and C-dolly connections between two trailers effectively eliminate an articulation point and provide a large counter-roll force for each of the two trailers when dynamic forces act in opposing directions during an evasive lane change maneuver.

Some researchers believe the same effect can be accomplished through the use of such advanced technology as electronically controlled braking systems (currently the subject of a field operational test), which employ load and speed sensitive differential braking to maintain the direction of the individual units in combination vehicles making evasive maneuvers. This could reduce the “crack-the-whip” phenomenon and dynamic roll instability especially inherent in multi-trailer vehicles.

J. Long Combination Vehicle Safety Performance in Alberta²⁷ (2001)

In 2001, Alberta’s branch of Infrastructure Transportation Policy and Economic Analysis conducted a review of LCV road safety performance and commercial truck collision factors along a 3,000 km stretch of the LCV network that accounted for nearly 20 percent of the province’s primary highway network. The study investigated three LCV types involved in traffic collisions. The study investigated: rocky mountain doubles, turnpike doubles, and triples. Once the collisions were classified the project team divided the number of vehicles of a given type involved in a collision by the total distance traveled by that vehicle type. The findings are given in Exhibit 9.

Exhibit 9: Collision Rates by Vehicle Type (1995-1998)

Vehicle Type	Estimated Error	Collision Rate Per 100 million km traveled
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		Low	Calculated Rate	High
Unit Truck	$\pm 10\%$	168	187	206
Tractor Semi	$\pm 10\%$	72	80	87
Multi Trailer	$\pm 10\%$	93	104	114
Rocky Mountain	$\pm 10\%$	9	10	11
Turnpike Doubles	$\pm 10\%$	18	20	22
Triples	$\pm 10\%$	15	17	19
Personal Vehicles	$\pm 10\%$	84	88	93
Total Number of Vehicles	$\pm 10\%$	84	89	93
All LCV	$\pm 10\%$	14	16	17

The Alberta Vehicle Road Safety Performance Study found that:

- LCVs have the lowest collision rate of all vehicle classes, including personal vehicles.
- Rocky mountain doubles had the best safety performance of all LCV configurations.
- Triples, when configured as A-trains, were slightly better than tractor semi-trailers. The study concluded that triple combination vehicle performance could be improved if they were configured as B or C-trains.
- Adverse weather and road surface conditions were present in 42 percent of all LCV collisions. These conditions accounted for 67 percent of rocky mountain double collisions, 43 percent of turnpike double collisions, and 27 percent of triple combination collisions.
- LCV permit operations were identified as the most vital factor influencing LCV safety. These included selective routing, speed restrictions, time of operation, operator qualification requirements and operating restrictions. Using these special permit requirements for LCV operations would effectively mitigate safety risks associated with these heavier vehicles. Operating restrictions would additionally improve the seamless operation of LCVs and enforcement of these restrictions would ensure carrier compliance with operating requirements.

K. Special Haul Programs Safety Review – Saskatchewan²⁸ (2000).

The *Special Haul Programs Safety Review* was conducted in Saskatchewan, Canada in 2000 to assess the current and on-going level of safety of the special haul programs in relation to the normal truck fleet. Special haul programs are those that require the explicit use of LCVs to move special products that would otherwise be unable to be transported. The study compared collision statistics using special haul permit records and the Saskatchewan Government Insurance (SGI) collision database. Once collision rates were identified, project participants calculated the amount of travel by trucks in special haul programs by compiling truck travel records from participating companies. This process required all companies participating in the special haul program to provide information on the number of vehicle-kilometers traveled in Saskatchewan. According to their analysis, trucks in special haul programs in 1999 accounted for 4 percent of the truck fleet, but less than 1 percent of large truck collisions in the province.

Additionally, the study assessed the safety implications of reduced truck exposure due to the allowance of heavy vehicles in special haul programs. Special haul programs in Saskatchewan totaled approximately 47 million vehicle-kilometers, which represented a travel reduction of nearly one-third in the amount of truck travel that would have otherwise been required to haul the same amount of product. The study estimated that special haul programs could reduce annual truck collisions by 18 crashes per year. This crash reduction was estimated to save the province \$1.2 million in property damage and injury costs.

L. Tractor-Trailer Crashes in Indiana: A Case-Control Study²⁹ (1997).

Tractor-Trailer Crashes in Indiana: A Case-Control Study of the Role of Truck Configuration, attempted to determine whether multiple-trailer combination vehicles were over-involved in crashes on interstate highways in Indiana relative to their proportion in the traffic stream. The study authors concluded that there was “no overall increase in crash risk among tractors pulling two trailers relative to tractors pulling one trailer, but the crash risk of double-trailer vehicles might be greater under less favorable operating conditions and road environments” such as snow, ice, and slush. The study authors compared double-trailer vehicle crash risks with those of single-trailer vehicles using a Standardized Crash Ratio (SCR) to identify whether vehicles were over or under involved in crashes. The study results showed that “among all crashes combined, no excess involvement of double-trailer vehicles in crashes was observed relative to what was expected; double-trailer vehicles actually were under-involved, albeit non-significantly, in crashes.” Double-trailer vehicles were under-involved in multiple vehicle crashes (SCR=74), dry surface road crashes (SCR=61), wet (excluding snow, ice, and slush) road crashes (SCR=54), fatality or serious injury crashes (SCR=66), curved road crashes (SCR=86), and in crashes on roads with a grade (SCR=89). Additionally, the study identified “close to half (45 percent) of double-trailer crashes occurred on snow, ice, or slush covered roads, compared with 21 percent of single-vehicle crashes.” The study authors also suggested a need for more research on the impacts that different truck configurations might have on crash rates. The authors cited a major limitation regarding the lack of control data for variables within the relationship between truck configuration and crash risk, such as driver age, vehicle ownership, and vehicle condition. The study concluded that “the relatively safe operation of doubles in Indiana may have been attributable to their driver and carrier characteristics rather than their inherent properties” indicating that the study findings were only attributable to Indiana, and may not be true of operations in other states.

4. New Facility Concepts: Planning and Policy Studies of Truck Only Lanes

During the past decade the transportation community has studied potential methods for deploying truck-only facilities from policy, design, and operational perspectives. The goal of this section is to provide a synopsis of those efforts, as well as case studies for those few, limited deployments of truck-only facilities that exist.

The following is a summary of developments in the research and deployment of truck-only facilities. The citations are listed from most recent under several topic headings.

A. Dedicated Truck Facilities as a Solution to Capacity and Safety Issues on Rural Interstate Highway Corridors³⁰ (2007)

This paper identifies the safety and operational benefits of constructing dedicated truck facilities on a rural Interstate corridor. The Interstate highway segment in the case study is a 164-mi section of I-80 from the Iowa-Illinois border to Altoona, Iowa (an eastern suburb of Des Moines, Iowa). Although many studies have considered constructing an additional lane on freeways and designating it for trucks only, this paper considers the construction of a separate four-lane, limited-access facility for trucks. The I-80 corridor was analyzed with the Highway Economic Requirements Software-state edition (HERS-ST) to measure the performance before and after trucks were removed from the general purpose lanes. Several benefit-to-cost ratios were calculated outside of HERS-ST to determine the economic feasibility (but not the financial feasibility) of constructing dedicated truck lanes. Since there are no similar truck-only facilities in the United States, it is unknown what proportion of motor carriers would choose to use a truck-only facility rather than the mixed traffic lanes (general purpose lanes), and future policy may or may not require trucks to use parallel truck-only facilities. Therefore, a sensitivity analysis was conducted within the benefit-to-cost analysis to determine the benefits of diverting 100 percent, 75 percent, 50 percent, and 25 percent of trucks to a dedicated truck facility. At all levels of diversion, the benefits exceed the costs. Although the analysis shows that a truck-only facility is desirable, the policy framework to make such a facility physically and financially feasible does not exist in federal or Iowa policy.

B. Issues in the Financing of Truck-Only Lanes³¹ (2005)

Adding truck-only lanes to existing highways would be expensive enough that State and local DOT's are unlikely to find sufficient resources to fund them using traditional sources, such as a State's road-use tax fund. Therefore, tolls would likely be assessed on users of the improved facility. In terms of financing, the central policy questions are who should pay these tolls and how high the tolls should be. For each potential truck lane project, a feasibility analysis could be carried out that takes into account the following:

- Current traffic volume by time of day, flow speed, safety record, and percentage of traffic due to heavy trucks
- Potential for trucking productivity gains if the truck-only lanes were added, including an assessment of whether the State would want to pursue the possibility of allowing LCVs to operate on the new lanes
- Potential offsets to productivity gains that could result from diversion of truck traffic to other lower order roads or diversion rail traffic to highways.
- Potential environmental, community, and other social costs associated with the operation of truck-only lanes.
- Cost of adding the lanes with a suitable number of entry and exit points and design features to minimize interactions between trucks and other traffic as trucks are moving on and off the truck-only lanes.

The analysis suggests that truck operators would receive the majority of benefits from truck-only lanes and ideally should pay the preponderance of costs. Unless the traffic stream contained a sufficient number of heavy trucks, the toll levels for these special-purpose lanes

may be high enough to prompt significant diversion of truck traffic to non-tolled facilities. Allowing LCVs to use the truck-only lanes, could enable public- or private-sector operators to charge higher tolls while limiting the diversion of truck travel to alternative roads. There are many obstacles, however, including legislative and environmental issues, to allowing LCV use, even if those vehicles were limited to dedicated truck lanes.

C. Corridors for Toll Truckways: Suggested Locations for Pilot Projects³² (2004)

This paper published by the Reason Foundation addresses possible locations for a pilot project to add truck tollways on interstate highways. Key elements of this study included an overview of the issue of toll finance for truck lanes, background information on tolling policies, and issues that may be relevant to piloting truck-only lanes:

- Road pricing or value pricing – tolls
- Dynamic pricing – San Diego introduced dynamic pricing. Every six minutes tolls are recalculated, taking into account upstream traffic flows.
- Variable pricing in France – France charges higher tolls during the weekend hours when people travel back to Paris.
- Build-Operate-Transfer (BOT) model – award long-term concessions to private companies. In 1999, Canada, Italy, and Portugal sold the existing state owned toll facilities plus a long-term franchise to operate them (ranging from 33 to 99 years).
- Double taxation – Fuel taxes and tolls. Rebates of fuel taxes for miles driven on toll roads could address this issue.
- Misconception – A popular U.S. misconception that tolls should pay for the large up-front cost of building a road should be removed once the initial investment is recovered. This misconception ignores the substantial costs of property maintaining and rebuilding highways.

This research focused heavily on the idea of private or toll-financed implementation strategies for dedicated truck lanes, but does not focus specific operational, capacity, or safety aspects of truck-only lanes independent of finance.

D. Washington Commerce Corridor Feasibility Study³³ (2004)

This study conducted by Wilbur Smith Associates and HNTB for the Washington DOT examined the feasibility of a dedicated 102 mile north-south toll truck-way from I-90 near the foothills of the Cascades southeast to Chehalis and possibly another 60 miles south to Oregon. The study found that such a corridor is feasible, but the truck-way cost for the full 270 mile route is about \$14.7 billion (\$54.4 million/mile or \$18 million/lane-mile) and exceeds the financial resources of the state DOT at this time. If built for the full complement of passenger cars, rail, energy, and recreational trails, the total costs could be \$42 billion to \$50 billion - the higher figure is based on environmental considerations that would require considerable tunneling.

E. National I-10 Corridor Study³⁴ (2003)

The National I-10 Freight Corridor Study completed by WSA and HNTB, examined seven congestion relief scenarios, including one for corridor management entailing the development of truck-only segments. Candidates for separated truck lane application were evaluated by considering three principal criteria - daily truck volume, volume/capacity ratios, and overall vehicle volume. Secondary consideration was given to two “service sensitivity” factors:

numbers of trucks carrying high service freight, and numbers of trucks making deliveries within miles (typically two to three hours) of the observed point. Four candidate sections were produced by this method and then subjected to scenario analysis.

- *Los Angeles to Inland Empire:* This approximately 50-mile passage in the Los Angeles basin runs from the San Pedro Bay ports on I-710 east to Ontario on SR 60, and ends at the intersection with I-15.
- *Phoenix to Tucson:* This 153-mile section of I-10 lies between the intersection with SR 85 west of Phoenix and Davis Air Force Base below Tucson.
- *Houston West:* This is a 101-mile passage between San Antonio and Houston, beginning where SR 71 connects from I-10 toward Austin, and ending east of Houston where SR 146 enters I-10 from the Port.
- *Gulf Coast:* This long section of I-10 extends 172 miles from the intersection of I-10 and I-12 at Slidell, LA, along the coast of Mississippi and Alabama to Pensacola, FL.

Modeling of a scenario with these improvements demonstrated that of 203 deficient miles (volume exceeding capacity) in the year 2000 along the segments analyzed, a total 137 miles would improve to sufficient levels of service, a 67percent improvement. By the year 2008, of the total 313 deficient miles along the segments analyzed, a total 174 miles would improve to sufficient levels of service, a 55percent improvement. By 2013, of the total deficient miles, almost 200 miles will improve to sufficient levels of service, a 55percent improvement. However, by 2025, the impact drops down to a 185 mile (41 percent) improvement.

The reduction in capacity deficiencies are expected to be reflected in better operating speeds along affected segments over the forecast period, translating into significant reduction in delay for freight and passengers. It was concluded that with these improvements, passenger speeds may be expected to increase by over 18 percent, and as much as 37 percent during peak hours, resulting in an equivalent **savings in delay of 103 million annual vehicle hours**, an annual cost savings of **\$1.8 billion**.

The study concluded that further research into the feasibility of these projects was warranted. Given the potential identified benefits of truck-only facilities on these segments, the locations identified in the I-10 study may at some time develop into truck-only projects.

F. Economic and Financial Feasibility of Truck Toll Lanes³⁵ (2003)

This study examines the economic and financial feasibility of heavy-truck toll lanes. Implementation was studied from the standpoint of productivity changes, toll-lane fees and revenues, and travel time and operating cost. The economic benefits of toll-lane scenarios were estimated using Highway Design and Maintenance Standards model developed by the World Bank. The results of the modeling indicated that there are economically and financially viable potentials for truck-only lanes.

G. Florida: Potential for Reserved Truck Lanes and Truckways³⁶ (2002)

The Florida Center for Urban Transportation Research (CUTR) performed a study identifying candidate corridors for truck-only facilities in the state. A methodology using GIS models was developed to identify potential sites for truck-only lanes based on crashes, truck volume, and level of service. Corridors identified include:

- I-95 Miami to Titusville
- I-95 Daytona to Jacksonville
- I-75 Naples to Ft. Meyers
- I-4 Tampa through Orlando to Daytona
- I-75 Venice north to the Florida state line
- Lake City to Jacksonville

The study also solicited input from state and local officials, highway safety professionals, planners, enforcement agencies, and truck drivers regarding the sites. At identified sites, a review of public agency information about the site was conducted as were key project attributes for a truck-only facility. It was concluded that separated facilities should provide:

- Ease of passing
- Adequate Shoulders
- Adequate right of way
- Situated in the median
- Interchanges far enough apart to avoid long weave sections
- Sufficient lateral and longitudinal separation to support safe access into and out of the facility.

H. Toll Truckways: A New Path Toward Safer and More Efficient Freight Transportation³⁷ (2002)

This policy paper from the Reason Foundation, sets forth self-financing toll truckways as an alternative method of approaching long-distance inter-city trucking. In this pre-cursor to the 2004 study referenced above, Poole described the truckway concept as a concrete barrier separated lane dedicated to heavy trucks. Potential advantages suggested in this study included lower costs for permitting longer combination vehicles (LCV's) and potential reductions in lateral and longitudinal conflicts between vehicles. Electronically collected toll finance is recommended as opposed to fuel taxes, state taxes, or other user fees. The paper is the foundation for Poole's subsequent work on the subject in 2004.

I. Planning Truck-Only Lanes: Emerging Lessons from the Southern California Experience³⁸ (2003)

This TRB paper examined research documenting recent efforts to develop truck-only facilities in the United States. The focus was on the truck lanes program of the Southern California Association of Governments, which was one of the most ambitious of its type in the United States. Specific California facilities analyzed included SR-60 and I-710.

SR-60 is an east-west corridor from Downtown Los Angeles to the San Gabriel Valley, and I-710 is the major access route to ports in Los Angeles and Long Beach. Both freeways had very high truck volumes and were the subject of feasibility analyses for truck-only lanes. The research focused primarily on traffic patterns and operational aspects of truck traffic on these corridors, with suggestions regarding facility design, demand analysis, and toll analysis.

J. Dedicated Lanes for Automated Freight Traffic³⁹ (2000)

Delft University of the Netherlands has several advanced technology research program themes, including: a) *Automated-Vehicle Design & Versatile Traffic Control* which is developing automated concepts for transport of persons and goods, including adapted design of dedicated vehicles, including concepts for vehicle control and fleet control. b) *Design & Management of Reliable Multimodal Networks* is the development of design concepts for robust multimodal transport infrastructures and service networks, guaranteeing reliable transport services. Under these themes, university researchers have published several papers contributing to the knowledge base for operating exclusive truck facilities: The aim of the research effort was to develop standard design modules for the accommodation of freight-only lanes on roads and motorways. The initial paper examines several scenarios under which dedicated freight lanes could be implemented and discusses issues that must be examined in future research relating to safety, traffic management, cost and legal implications. The next two papers cited in this review are publications that were elements of the larger examination of automated truck lane concepts.

K. A Microscopic Simulation of Freight Lanes Near Merging Areas⁴⁰ (2001)

Published by ITS America, this paper is an engineering simulation that examines how the growth in freight transport would affect the traffic characteristics of motorways near connections to local road networks. The efficiency and safety of merging zones where dedicated lanes flowed into mixed-use lanes was modeled in several scenarios using the Simone model. The results showed the positive impact of flow-control measurements as the truck traffic proportion grew. Gains in travel time, energy, efficiency, and safety were found with traffic control customized to handling truck volumes, and potential extensions of the scenarios to microscopic modeling of dedicated truck lanes were recommended as potential follow-up projects.

L. Buffer Area for Dedicated Lanes of Automated Freight Traffic⁴¹ (no date)

This paper investigated the impact of various strategies for automatically controlled trucks for improving the throughput of existing roadways. The research also examined the concept of dedicated trucks lanes at on-ramps – assuming the shoulder lane would be a dedicated freight lane. The simulation performed examined various strategies for automated truck platooning, and found that platoons could drastically increase average truck speeds under some strategies.

“Truck Only” or Separated Truck/Passenger Facilities: Case Studies

To date, existing “truck-only” facilities have been limited to short distance routes and ramps. In fact, there are many more examples of “passenger only” facilities where trucks are excluded from general purpose lanes either entirely or during peak demand periods. Consequently, the research conducted for this study found only modest case studies where the operational and system-wide characteristics of truck-only



facilities can be examined; however, some examples of truck exclusions have been included here as they may offer insights about the safety and operation of facilities when commercial and passenger traffic streams are separated.

A. California: I-5

Northbound and southbound lanes of I-5 in Los Angeles County have reserved truck lanes at the State Route 14 split. The total length of the segments are 2.426 miles on the northbound (NB) lanes and 2.452 miles on the southbound lanes (SB). The purpose of these truck lanes is to separate slower moving trucks from the faster general traffic on the grade. After constructing the new I-5 alignment, the original alignment was used for the truck-only lanes. This truck-only facility has been in place for about 30 years.

Also, SB I-5 in Kern County at the State Route 99 junction near the “Grapevine” has a truck lane that begins on Route 99 at Kern County mile-post L000.629 (the equivalent of I-5 mile-post R015.838) and ends on I-5 at mile-post R015.492. The total length is 0.346 miles. The purpose of this design is to place merging trucks further downstream of merging automobile traffic. While these facilities are designated as exclusive truck lanes, there are some segments where passenger cars are permitted to facilitate specific movements.

B. New Jersey Turnpike Dual-Dual Section⁴²

The New Jersey Turnpike is a limited access toll facility that employs several managed lane techniques to optimize flow. A 35 mile segment of the facility was expanded into two separate roadways in the 1970s. This dual-dual roadway segment of the turnpike separates passenger traffic and heavy commercial vehicles. The six inside lanes of the dual-dual section are auto-only; the six outer lanes accommodate all vehicle types, including heavy trucks. The auto-only and multi-purpose lanes are separated by concrete barriers, and each part of the roadway has its own entrance and exit ramps.



C. The South Boston By-Pass Road

The South Boston Bypass Road was converted from a dilapidated four-track urban railroad corridor into an urban freight corridor consisting of a refurbished railroad track and a two-lane dedicated truck roadway that is more than 1-mile long.



The route was initiated in the 1800 when it provided railroad access to Boston from the south side of the city. It later became a two-track, depressed route with 12 overhead bridges. The route was expanded to four-tracks in the 1920's. In the later half of the 20th Century as freight service declined, maintenance on the facilities was deferred. In the 1980's the corridor was suggested as a dedicated freight corridor as part of the Central Artery/Tunnel Project (The Big Dig). A feasibility study of the project was approved in 1987. Hurdles in completing the project included property acquisition and hazardous materials clean-up. Following more than a year of construction the South By-Pass Road opened to commercial and emergency vehicle traffic in 1993. The route was later extended south to a frontage road system at Interstate Route 93. The north end of the corridor was also modified to provide direct truck access to the new Third Harbor Tunnel.⁴³

D. The Clarence Henry Truckway – New Orleans

The Clarence Henry Truckway, an east bank wharf road used solely by cargo trucks in the Port of New Orleans. The Clarence Henry Truckway gives truckers speedy and dedicated access to the Port's Mississippi River terminals. Constructed at a cost of \$17 million the, 5.5 mile truckway is the main transportation artery for New Orleans' uptown docks.

E. Covington, Virginia – I-64 Truck Ramp

MEAD/Westvaco, a large paper manufacturer located in Covington, maintains its own container pool and truck yard which has a dedicated truck access ramp to I-64. Primarily, finished products are drayed by truck to inter-modal facilities outside the Roanoke, Virginia, region.

F. Minneapolis/St. Paul – Bus Only Shoulders

Since 1991, the Metropolitan Transit Service in the Twin Cities Metropolitan Area has been implementing a “bus-only shoulders” initiative to provide transit buses an advantage in rush-hour traffic. As of 2005, the system of bus-only shoulder lanes totaled 220 miles, with an additional 36 miles identified for expansion of the policy. Planners have expanded the system over the years by an average of about 15 miles per year.



Before adding new sections to the “bus-only shoulders network,” highway shoulders are prepared to handle 40- and 60-foot buses loaded with five tons of passengers. Some shoulders are rebuilt or restored, and most storm sewer drains are raised to grade-level to smooth out the ride. New signs advising commuters that only buses are allowed to travel on the shoulder are also erected.

Preparing shoulders for buses costs about \$100,000 per mile, and the region has invested about \$2 million per year to date — pennies on the dollar compared to building new lanes for traffic, or the cost of congestion in terms of lost time, income, and the environment.

Over the 14-year history of the policy, no major accidents have occurred as a result of using bus-only shoulders. Support for the policy has been broad, as it has been a low cost method of providing more reliable commute times. Other metropolitan areas such as Atlanta, Miami and San Diego are now considering pilot studies of similar policies.

City buses currently have access to shoulders on virtually every major highway across the Twin Cities Metropolitan Area, including some freeways and county roads. Buses are permitted to use shoulders around the clock, but the primary use is during rush hour when congestion is highest. Shoulders have also been used during traffic slowdowns caused by wet weather, snow, accidents, or road construction. Planners anticipate that the program will grow for about five more years. By then, most essential highway shoulders will be incorporated into the system.⁴⁴

Truckway Projects under Development

G. I-4/Crosstown Connector; Tampa Bay, FL

Currently access between the Port of Tampa and Interstate 4 is provided by a pair of one-way streets: 21st and 22nd Streets. The Florida Department of Transportation has proposed a connector roadway that will improve access to the Port between I-4 and the Lee Roy Selman Crosstown Expressway. The proposed "Crosstown Connector" will provide both general purpose lanes, as well as Eastbound and Westbound truck-only lanes from I-4 to and from the Port of Tampa.

H. SR-60 California

In February, 2001, the Southern California Association of Governments (SCAG) completed a feasibility study report (FSR) on exclusive lanes for commercial trucks. "Trucks" were defined as vehicles having three or more axles. The study focused on State Route 60, from I-710 to I-15, a distance of approximately 38 miles. SR-60 was evaluated for number of lanes, cross-sections, adjacent land use, over- and undercrossings, and their clearances, and right-of-way. Based on the above characteristics, three main strategies were considered: (1) allowing trucks to share the HOV lanes at limited time periods, (2) adding truck lanes to the freeway at grade, and (3) adding lanes above the freeway grade. The HOV lane option was dropped due to a number of barriers, including legal and funding obstacles.

I. I-710 Truck-way: Los Angeles -

In 2004, the SCAG concluded that user supported, dedicated truck-ways offered a viable and self-financing way to mitigate congestion and reduce vehicle emissions in southern California. SCAG proposed 142 miles (229km) of 2x2 lane truck-way from the San Pedro Bay ports (LA and Long Beach), northeast through the greater Los Angeles area, through the San Gabriel mountains, to Barstow on I-15 on the edge of the Mojave Desert.

J. New Jersey Portway

The New Jersey Department of Transportation's (NJDOT) Portway International Intermodal Corridor is a billion dollar, decade-long program that includes the phased development of various projects designed to improve truck access and road safety. The projects aim to relieve

highway congestion near and around marine terminals and other intermodal service centers within a 17-mile corridor that runs from Union and Essex counties to Hudson and Bergen counties. Planned improvements include construction of a new, dedicated truck roadway to relieve a highly congested portion of the Corridor's route.

Truck-Only-Toll Projects (Proposed or Considered)

Recent projects for truck only facilities are currently under study and development in a number of states. The following areas have conducted studies and are known to be considering or in the process of implementing truck-only-toll projects at this time:

K. HOT Lanes & TOT Facilities: Potential in the Atlanta Region

Traffic congestion and delays caused by crashes involving commercial vehicles have become almost a daily occurrence in Atlanta, one of the nation's most congested cities. In seeking solutions to Atlanta's traffic tie-ups, the State Road and Tollway Authority undertook a study to examine the feasibility of High Occupancy Toll (HOT) lanes and Truck Only Toll (TOT) lanes as viable options for Atlanta's traffic problems.

TOT lanes for this study were toll lanes reserved for the use of commercial vehicles, including trucks and buses. Under the study assumptions use of the TOT lanes by trucks would be an option. In other words, truck drivers would have to make a choice as to whether they would pay a toll for a faster, more reliable route, or remain in general traffic lanes. The study examined three options:

1. Two TOT lanes in each direction between the corridors of I-75 South and North, using I-285 West and I-75 North and I-85 North, using I-285 North.
2. Option 1, plus HOV lanes inside I-285 would be open for a toll to commercial vehicles from 10 a.m. – 3 p.m.
3. All existing and proposed HOV lanes would become TOT lanes, except inside I-285, which would still prohibit through truck trips.

Table ES-2 Comparison of General Purpose and TOT Lane Trip Times during 2030 PM Peak Period under Scenarios 1 and 3

Sample Trip and Destinations	Scenario 1 TOT Lane versus Scenario 1 GP Lane	Scenario 3 TOT Lane versus Scenario 3 GP Lane
I-75 north to I-285 west to I-75 south		
I-75 at I-285	6 minutes saved	14 minutes saved
I-285 E at I-75 S	32 minutes saved	45 minutes saved
I-75 S at end	51 minutes saved	70 minutes saved
I-75 north to I-285 east to I-85 north		
I-75 at I-285	6 minutes saved	14 minutes saved
I-285 E at I-85 N	27 minutes saved	39 minutes saved
I-85 N at end	68 minutes saved	80 minutes saved

Note:
Time savings are cumulative from origin at region's limits.
GP: General Purpose highway lanes

Using regional traffic models the study examined the potential costs and benefits associated with faster more reliable transportation.

The table to the above provides a sample of time savings found when comparing the options considered.⁴⁵ The study found that TOT lane options would reduce the percentage of congested directional miles in general purpose lanes in the Atlanta Region by 17% - 24%. The study

further predicted that the implementation of TOT lanes could save trucking companies up to a billion dollars in time savings.⁴⁶

L. Virginia – I-81

In 2004, a study panel for the Virginia Department of Transportation recommended that the state negotiate an agreement with a builders' consortium to widen I-81 to eight lanes. Separate truck lanes, with tolls, are in that proposal. An analysis performed for the project anticipates safety and capacity improvements in highway performance with minimal environmental cost.

Key drivers inducing Virginia to implement the toll financed truck lanes on I-81 include:

- Implementation of a long-term solution for I-81 in 15 years
- Separation of cars and heavy commercial vehicles using Safe and Freight-Efficient (SAFE) Lanes
- A high-quality pavement to reduce the number of future delays and lane closures for repairs
- A 20-year pavement warranty for all new mainline/collector-distributor lanes and shoulders, which will lower VDOT's future maintenance costs and free up funds for other road projects
- Six dual interchanges and eight truck-only flyovers, as well as other interchange improvements
- Project cost of \$6.3 billion, including the pavement warranty, with no finance gap
- Inter-modal freight movement: Numerous elements included, with a rail plan that would encourage trucked cargo to move to rail
- True public-private partnership – shared responsibilities and assumption of risk by private sector
- Opportunities for VDOT to use the low-bid procurement process for elements of the project
- Minimal environmental impact, based on reducing right-of-way needs (vs. previous proposals)
-

M. The Trans-Texas Corridor

“The proposed 4,000 mile multi-modal corridor embodies the vision of future infrastructure provision in Texas. It will include separate lanes for trucks and passenger vehicles, high-speed passenger rail, commuter and freight rail, and utility lines (for water, electricity, natural gas, petroleum, fiber optic cables and telecommunication lines). It will be built in partnership with the private sector and will facilitate economic development while providing congestion relief and increased safety.”⁴⁷



N. Texas: I-35 NAFTA Corridor

In the I-35 Duluth to Laredo study, the utilization of truck-only lanes from Dallas-Ft. Worth to Laredo was suggested. To accommodate truck traffic, the Trade Focus Strategy provides special features for trucks from the Dallas-Ft. Worth area south to Laredo. This involves about 785 km (490 miles). Options to consider include provisions for larger truck sizes and weights as well as the option of special lanes for trucks. The location for these lanes can be a separate facility near I-35 or special truck lanes within the I-35 right-of-way.

O. Chicago CVHAS Freight Movement Study

In 2004, an assessment of the Applicability of Cooperative Vehicle-Highway Automation Systems (CVHAS) to Freight Movement in dedicated lanes in Chicago, models and economic impact analysis were performed for truckways in the Chicago area. The results indicated that each of several dedicated truck lane alternatives were analyzed to be cost effective, with benefit/cost ratios between 2.61 and 5.32.

P. Niagara Falls, New York to Ontario

Investors have purchased selected parcels of land and the Michigan Central Bridge over the Niagara River from the Canadian Pacific railroad for a truck-only facility connecting Ontario to New York. Truck traffic crossing the river in 2004 was estimated at 50,000 daily, including an average annual daily truck volume of approximately 7,000 trucks. The project is expected to reduce bottlenecks on the existing bridges attributable to border-crossing truck inspections.

5. Research on Advanced Technologies Applying to Truckways

Truck Platooning (TP) is a mass flow concept of maximizing the through-put of commercial vehicles on a highway asset using physical and/or electronic connections that allow the entire platoon to be controlled as a single unit. The concept offers the benefit of dramatically reducing fuel consumption, eliminating delays caused by congestion on mixed vehicle facilities, and potentially reducing the cost of labor inputs. Most truck platoon concepts being advanced include a dedicated road infrastructure separated from normal traffic, primarily due to current safety concerns of mixing the traffic. Following are some of the commonly recognized potential benefits of truck platooning on dedicated truckways

- **Vehicle Operational Cost Savings** – More than 50 percent of the fuel consumed by a typical five axle tractor-semi-trailer combination is the result of aerodynamic drag. Current research estimates that truck platoon can result in fuel saving of 10-20 percent. Additional research to verify estimates and better understand both energy saving and some potential off-setting costs associated with brake components is needed.
- **Driver Cost Savings** – In the long term, major cost savings could result from driverless trailing vehicles. This would require both significantly improved control technologies and major regulatory changes. In the short term, operational cost savings are possible if drivers in trailing units are placed in a “non-duty status” under hours of service regulations.

- Infrastructure Savings – In the short term, dedicated truck-only facilities could accommodate significantly higher capacity and greater time reliably using mass flow platoons. Limited truck platooning using existing mixed traffic lanes might also be feasible. Use during commuter off-peak periods could be used to offset restrictions in truck traffic during peak commuter timeslots.

Current U.S. University Research Programs for Advanced Truck Technologies

Enabling mass flow truck platooning is an area of Intelligent Transportation Systems (ITS) referred to as “intelligent vehicle initiatives” (IVI). The reports discussed under Section B of this bibliography discussed research on advanced truck technologies that has occurred in The Netherlands. In the U.S. there are three universities considered to be the hotbeds of IVI research: The University of California – Berkeley, the University of Minnesota, and Virginia Tech. Following is a brief summary of the work occurring at each of these institutions:

A. University of California – Berkeley:

- PATH – Partners for Advanced Transit and Highways (www.path.berkeley.edu/) California PATH was established in 1986. It is administered by University of California, Berkeley, in collaboration with Caltrans. PATH is a multi-disciplinary program with staff, faculty, and students from universities statewide, and cooperative projects with private industry, state and local agencies, and non-profit institutions. Caltrans provides one-half of PATH funding; the remaining funding comes from US Department of Transportation, other state and local agencies, and private industry.
- Demo 2003 (www.highway-to-automation.org/demo2003/overview.htm) was a demonstration of truck and bus automation that took place on the interstate Highway 15 reversible express lanes located just north of San Diego, over a two-day period during October, 2003. A “convoy” of three automated trucks and a “platoon” of three automated buses demonstrated the technical feasibility of cooperative heavy vehicle automation. The message conveyed to the key decision-makers in attendance was be that the technologies necessary to make cooperative heavy vehicle automation feasible are closer to reality than some thought. The event was intended to raise awareness and see vehicle automation as a potential solution to some of the traffic congestion and safety challenges that impact our surface transportation system today.

Papers published by researchers in the PATH program include:

Showcasing the Benefits of Automated Driving of Transit Buses and Heavy Trucks

In 2001, ITS America (Shladover) held a conference in which the California Department of Transportation (CALTRANS) and the University of California PATH program demonstrated the development of applications in Advanced Vehicle Control and Safety (AVCSS) technologies to improve transportation operations. The demonstration addressed AVCSS systems for both transit buses and heavy duty trucks operating in a reserved truck lane.

Opportunities in Truck Automation

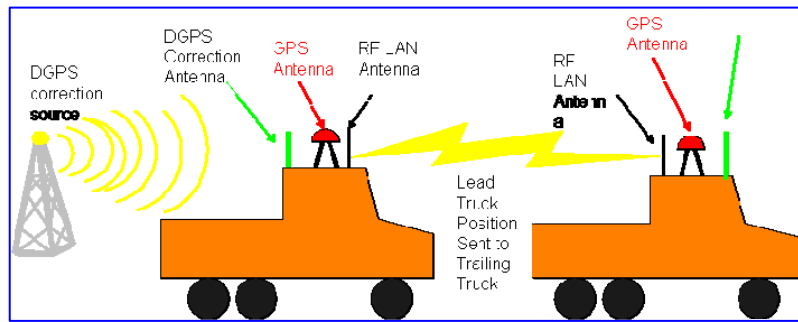
In 2001, ITS America (Shladover) held a conference devoted to trucks in ITS. At the conference, the substantially greater benefits of automation technologies beyond existing ITS

applications was explored. Presentations included research on the benefits of truck lanes themselves, and went on to present benefits in terms of vehicle operating, fuel and emission savings as well as benefits in driver performance. Key drivers of the level of benefit from automated truck systems in dedicated lanes were found to be driving conditions, freight movement logistics patterns, and truck vehicle designs in areas where such solutions might be deployed.

B. University of Minnesota – ITS Institute

ITS Institute (University of Minnesota) (www.its.umn.edu/about/index.html) - The Institute's activities are guided by its theme of enhancing the safety and mobility of road- and transit-based transportation through a focus on human-centered technology. The center brings together technologists in the core ITS areas of computing, sensing, communications, and control systems to approach significant safety and mobility problems with a fresh perspective. Among its IVI projects in progress:

- **SMART Plow:** To clear multilane highways in a single pass, Mn/DOT routinely employs a technique known as "gang plowing" in which three or more plows operate in a staggered formation. The



lead plow throws its snow into the path of the second plow, which throws that snow, along with the snow from its own lane, off into the path of the next plow in the formation. Gang plowing requires a group of highly skilled drivers operating as a team. The snow thrown up by multiple plow blades can reduce visibility to near white-out conditions, leaving the plow operators with nothing but the running lights of the vehicle ahead to steer by. These difficult conditions can force plow operators to increase the spacing between their vehicles, thereby increasing the risk that a motorist will attempt to pass through the slow-moving platoon. This risky behavior can lead to serious accidents, as the car hits the unplowed pavement ahead of the platoon and the cloud of snow thrown up by the lead plows, then loses control or slows down so suddenly that it is struck by the next plow in the gang. Recently the ITS Institute demonstrated the use of GPS technology in maintaining spacing between automated plows traveling in a gang. The test plow (left) maintained a selected spacing and lateral offset. Enabling plows to operate safely in close formation is the goal of the current research project, says principal investigator Craig Shankwitz, director of the ITS Institute's Intelligent Vehicles program. The system under development is based on GPS navigation and wireless communication between all vehicles in the plowing platoon, and includes both lateral and longitudinal controllers to maintain desired vehicle spacing and offset between plows operating in different lanes.

- **Adaptive Cruise Control (ACC):** ACC is an in-vehicle technology that could increase the carrying capacity of existing urban highways. ACC systems use radar sensors to monitor the

gap between the ACC-equipped vehicle and the vehicle ahead. In theory, ACC has the capacity to "squeeze" more vehicles onto a roadway by enabling them to operate closer together than they could using human control alone.

C. Virginia Tech Transportation Institute (VTTI) (www.ctr.vt.edu/)

VTTI was established in August, 1988, in response to the U.S. DOT's University Transportation Centers Program, and in cooperation with the Virginia DOT. VTTI is housed in a 30,000 square-foot building in Blacksburg at the western end of Virginia's Smart Road, a road designed specifically for testing new transportation technology. The building accommodates the Smart Road Control Center, where researchers monitor and control data collection, weather-generation, lighting, power grids, and roadway surveillance cameras. VTTI enjoys several focused in-house laboratories where researchers collect, distill, and analyze transportation research data. The Safety and Human Factors Laboratory is equipped with data reduction systems comprised of monitors, video recorders, and high-speed computers. Similarly outfitted, the Advanced Product Test and Evaluation Laboratory is specifically designed to secure confidential data collected for proprietary research.



- Virginia Smart Road - a unique, state-of-the-art, full-scale research facility for pavement research and evaluation of Intelligent Transportation Systems (ITS) concepts, technologies, and products; the first facility of its kind to be built from the ground up with its infrastructure incorporated into the roadway. It is currently a 2.2-mile two-lane road with a banked turn-around at one end and a slower speed turn-around at the other end. The latest phase of construction was completed in May 2001, and includes a 2,000-foot bridge and several hundred yards more of concrete pavement. When the entire 5.7-mile project is completed, the Smart Road will be a four-lane, limited access highway between Blacksburg and Interstate 81 in southwest Virginia, with the first 3.2-km designated as a controlled test facility. This connection will serve an important role in the I-81/I-73 transportation corridor. After construction, provisions will be made to route traffic around controlled test zones on the Smart Road to allow for ongoing testing.
- Instrumented Trucks - a semi-tractor and trailer that have been modified and instrumented to test and evaluate ITS technologies under real-world driving conditions.
- Automated Highway System (AHS) is a concept consisting of a guideway constructed in the rights-of-way of the Interstate Highway System which would utilize magnetic levitation ("maglev") to propel closely-spaced, individual vehicles at high speeds.

European Truck Technology Research Initiatives:

D. STARDUST

A research project supported by the European Commission, with an objective to assess the extent to which ADAS (Advanced Driver Assistance Systems) and AVG (Automated Vehicle Guidance) systems can contribute to a sustainable urban development not only in terms of direct impacts on traffic conditions and environment but also in terms of impacts on social life, economic viability, safety, etc. STARDUST attempts to integrate end user potential acceptance analysis (by means of stated preference surveys), investigation of the human factors issues (using data from instrumented vehicles, driving simulators, and microscopic modelling) and larger scale assessment of the impacts, at city-level (using semi-dynamic traffic assignment models). Finally, STARDUST will also carry out a review and synthesis of the existing analysis on the legal and institutional aspects of the deployment of the selected ADAS and AVG systems.

E. CHAUFFEUR

This project is developing truck platooning capability for commercial freight movement. The program, funded largely by the European Commission, is led by DaimlerChrysler; the lengthy roster of partners includes Renault Research, Renault Trucks, and Italian truck manufacturer IVACO. The multiyear CHAUFFEUR I program was completed in 1999 and culminated with demonstrations of a manually-driven truck followed by a truck in automated mode at close headways on public highways in Germany. CHAUFFEUR II has been underway since January, 2000, with current activities focusing on specifying functions, systems, and components, and doing some preliminary evaluation work. Renault Recherche and Renault Vehicle Industriale are new partners, joining the team for CHAUFFEUR II. The key aim in this second phase is to realize a truck platoon -- multiple full-size trucks following one another at close headway, with only the lead truck driven by a human. (<http://www.chauffeur2.net/>)



Dedicated freight corridors using “hybrid” approaches

Deserving of brief mention are a number of futuristic approaches to dedicated freightways that involve conceptual modes or “dual-mode” concepts. Much of the research that has occurred regarding futuristic concepts has taken place in Europe and Asia. A web site maintained by a retired University of Washington Professor is a good resource for many of these innovative approaches: <http://faculty.washington.edu/~jbs/itrans/afreight.htm>

F. CargoMover

CargoMover[®] by Siemens Transportation Systems of Germany is a “completely new type of rail freight transport system combining all the advantages of a truck and a freight train.” This technology is similar to what is some times referred to in the U.S. as “open



platform” intermodal rail service. At the heart of the CargoMover is its innovative control system. Instead of a driver, a central computer directs the vehicle from one siding to the next using a special wireless network – without blocking the path of any other train, without breaks or restrictions on night movement, and without tolls or traffic jams.

<http://www.transportation.siemens.com/ts/en/pub/home.htm>

G. Bladerunner

“BladeRunner” is another dual-mode vehicle that looks like a giant, articulated truck. A key feature of the concept is the ability for the front and rear motive units to precisely track each other so that if the front goes around the corner so will the back in exactly the same track. The concept for this hybrid system is to run the Bladerunner vehicles on rail lines without the junctions and stations of the railways, but with the braking performance and flexibility of road vehicles. Narrow designated lanes, with rail lines embedded into the pavement, would run down the centre of every trunk road in the country and form the basic infrastructure for a very efficient transport alternative.



H. Japanese Automated Freight Transport System

This dual mode concept was presented by the Public Works Research Institute, Advanced Transportation Division in the 1990's. This dual mode truck would operate as an electric vehicle on ordinary roads. Both innercity and intercity dedicated guideways would be built. It would be operated at about 45 km/hr on dedicated guideways in urban areas and at about 100 km/hr on the intercity guideway. A synchronous control system is being tested for merging and demerging the DMT's. An advanced vehicle control system is being developed at the Public Works Research Institute so that the DMT's can be operated at headways as low as 1-3 seconds.



The Public Works Research Institute has built a 760 meter dedicated track for testing the DMT's. The track is used for experiments which test, among other factors, computer-controlled operation, the communication system, automatic traffic divergence, automatic vehicle spacing and merge actions. The design speed for this test track is 40 km/hr and it includes grades of +6% and -6% and curves with a radius of 65 meters.

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Engineering Specification for Construction of Truck Only
and Passenger Only Travelways in Missouri – Phase 1.
RI 08 – 030.

Sub Document:

**Appendix
Truck Only Lanes
EMS Survey Package.**



April 3, 2009

«Contact», «Contact_Title»

«Service»

«Address_1»

«Address_2»

«City», MO «Zip»

RE: Missouri Truck-only Lanes

MoDOT is conducting an analysis of the potential use of truck-only lanes on interstates in Missouri. As part of this analysis, MoDOT has hired Wilbur Smith Associates to complete an examination of the engineering issues with truck-only lanes. Key issues regarding the implementation of truck-only lanes include provisions for emergency access, emergency response, and effects on emergency service providers.

As an emergency service provider who provides service close to a major interstate corridor, we request that you complete the enclosed survey regarding the effects of truck-only lanes on emergency access and response. The enclosed survey should only take a few minutes to complete and your responses will greatly help the Study Team to understand the key emergency access and response related issues.

To help you better understand the truck-only lane concept proposed and better respond to the survey we have enclosed a series of talking points on truck-only lanes and their potential use in Missouri.

If you have any questions about the survey or the project, please contact me at 816-942-3570 or at shamadi@wilbursmith.com.

To help us complete the study in a timely manner we require your responses no later than April 24, 2009. Please mail your responses to:

Gina Hershberger
Wilbur Smith Associates
10401 Holmes Road, Suite 210
Kansas City, MO 64131

Your assistance with this important research project is greatly appreciated.

Sincerely,

Steve Hamadi, PE
Senior Project Manager

As part of the **MoDOT Engineering Specifications for Truck-Only Lanes** project, the project team is evaluating the safety and emergency access concerns related to truck-only lanes. Please answer the following questions about safety and emergency access to truck-only lanes.

1. How do you think truck-only lanes will affect safety along interstate highways?

(Please Circle your Answer)

- A. Truck-only lanes will not affect safety along interstate highways.
- B. Truck-only lanes will improve safety on interstate highways.
- C. Truck-only lanes will decrease safety on interstate highways.

Please Explain your Answer: _____

2. How do you think truck-only lanes will affect emergency management?

(Please Circle your Answer)

- A. Truck-only lanes will not affect emergency management.
- B. Truck-only lanes will help emergency management.
- C. Truck-only lanes will hinder emergency management.

Please Explain your Answer: _____

3. What specialized equipment or services do you need to assist with incidents involving trucks?

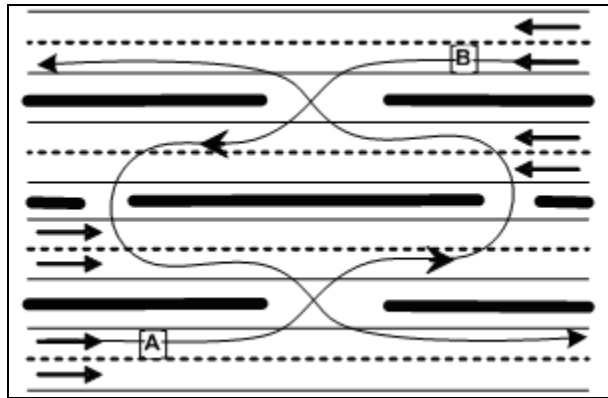
4. What improvements on the interstate system would you like to see regarding emergency access to assist you in responding to incidents in general and anything additional for those incidents involving trucks?

5. What potential problems do you see regarding emergency access to truck-only lanes? Do you have any suggestions to address these potential problems?

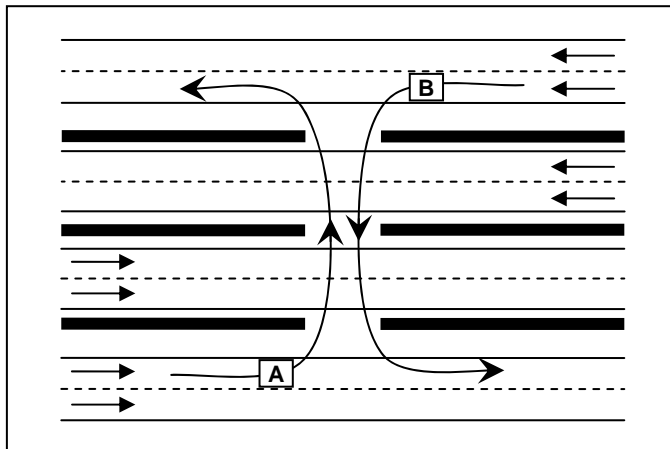
6. What are the current emergency services issues on the interstate system? How would truck-only lanes impact these issues?

7. Which crossover scenario do you prefer from the two exhibits shown below?
(Please Circle your Answer)

A. Offset barrier openings showing Movements A and B flowing with traffic.



B. Parallel barrier openings showing both Movements A and B crossing traffic in the inner lanes.



8. What do you consider a reasonable distance between access points to the truck-only lanes?
(Please Circle your Answer)

- A. 1 mile
- B. 2.5 miles
- C. 5 miles
- D. 10 miles

9. If truck-only lanes are constructed, what new specialized training would be needed for emergency service providers, if any?

10. In the space provided below please identify any additional concerns or questions you have regarding truck-only lanes on the interstate system.

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Name: _____

Address: _____

City: _____ State: _____ ZIP: _____

Phone: _____



Missouri Department of Transportation
Organizational Results
P. O. Box 270
Jefferson City, MO 65102

573.526.4335
1 888 ASK MODOT
innovation@modot.mo.gov