NCHRP

REPORT 649

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

JOINT REPORT

NCFRP

REPORT 3

NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

Separation of Vehicles—CMV-Only Lanes

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 649

NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

NCFRP REPORT 3

Separation of Vehicles—CMV-Only Lanes

Cambridge Systematics, Inc.
Oakland, CA

Subscriber Categories

Construction • Design • Economics • Finance • Freight Transportation • Highways
Motor Carriers • Operations and Traffic Management • Policy

Research sponsored by the American Association of State Highway and Transportation Officials in cooperation with the Federal Highway Administration and by the Research and Innovative Technology Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2010
www.TRB.org

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Academies was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NCHRP REPORT 649

Project 3-73
ISSN 0077-5614
ISBN 978-0-309-15475-8
Library of Congress Control Number 2010928781

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at:

http://www.national-academies.org/trb/bookstore

Printed in the United States of America

NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

America's freight transportation system makes critical contributions to the nation's economy, security, and quality of life. The freight transportation system in the United States is a complex, decentralized, and dynamic network of private and public entities, involving all modes of transportation—trucking, rail, waterways, air, and pipelines. In recent years, the demand for freight transportation service has been increasing fueled by growth in international trade; however, bottlenecks or congestion points in the system are exposing the inadequacies of current infrastructure and operations to meet the growing demand for freight. Strategic operational and investment decisions by governments at all levels will be necessary to maintain freight system performance, and will in turn require sound technical guidance based on research.

The National Cooperative Freight Research Program (NCFRP) is a cooperative research program sponsored by the Research and Innovative Technology Administration (RITA) under Grant No. DTOS59-06-G-00039 and administered by the Transportation Research Board (TRB). The program was authorized in 2005 with the passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). On September 6, 2006, a contract to begin work was executed between RITA and The National Academies. The NCFRP will carry out applied research on problems facing the freight industry that are not being adequately addressed by existing research programs.

Program guidance is provided by an Oversight Committee comprised of a representative cross section of freight stakeholders appointed by the National Research Council of The National Academies. The NCFRP Oversight Committee meets annually to formulate the research program by identifying the highest priority projects and defining funding levels and expected products. Research problem statements recommending research needs for consideration by the Oversight Committee are solicited annually, but may be submitted to TRB at any time. Each selected project is assigned to a panel, appointed by TRB, which provides technical guidance and counsel throughout the life of the project. Heavy emphasis is placed on including members representing the intended users of the research products.

The NCFRP will produce a series of research reports and other products such as guidebooks for practitioners. Primary emphasis will be placed on disseminating NCFRP results to the intended end-users of the research: freight shippers and carriers, service providers, suppliers, and public officials.

NCFRP REPORT 3

Project NCFRP-10
ISSN 1947-5659
ISBN 978-0-309-15475-8
Library of Congress Control Number 2010928781

Published reports of the

NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at:

http://www.national-academies.org/trb/bookstore

Printed in the United States of America

C O O P E R A T I V E   R E S E A R C H   P R O G R A M S

CRP STAFF FOR NCHRP REPORT 649/NCFRP REPORT 3

Christopher W. Jenks, *Director, Cooperative Research Programs*
Crawford F. Jencks, *Deputy Director, Cooperative Research Programs*
William C. Rogers, *Senior Program Officer*
Charlotte Thomas, *Senior Program Assistant*
Eileen P. Delaney, *Director of Publications*
Hilary Freer, *Senior Editor*

NCHRP PROJECT 3-73 PANEL/NCFRP PROJECT 10 PANEL
Field of Traffic—Area of Operations and Control

Mary Lynn Tischer, *Federal Highway Administration, Washington, DC (formerly Virginia DOT, Richmond, VA)* (Chair)
Talvin Davis, *New Jersey DOT, Trenton, NJ*
Coty "Reggie" Dupré, *Dupré Transport LLC, Lafayette, LA*
John W. Fuller, *University of Iowa, Iowa City, IA*
James Gosnell, *Los Angeles, CA*
Douglas S. McLeod, *Florida DOT, Tallahassee, FL*
Charles E. Prestrud, *Washington State DOT, Seattle, WA*
Todd G. Trego, *American Transportation Research Institute, Smyrna, GA*
Arthur "Rey" Walker, *Maryland State Highway Administration, Hanover, MD*
Michael P. Onder, *FHWA Liaison*
Elaine King, *TRB Liaison*

FOREWORD

By William C. Rogers
Staff Officer
Transportation Research Board

NCHRP Report 649/NCFRP Report 3: Separation of Vehicles—CMV-Only Lanes presents an extensive compendium of information about CMV-only lanes and examines major issues and concepts that should be understood in developing new applications of CMV-only lane concepts as a potential method for both easing congestion and reducing the number of traffic accidents on highways. Appendices to this report, including an annotated literature review, performance evaluation criteria, benefits monetization factors and unit costs, and net present value calculations for benefit-cost analysis, are available on the TRB website. This report and the supplemental information can be used by public agencies that may be considering CMV-only lane concepts in corridor studies or other planning applications. The report provides data such agencies can use to support their own evaluations of CMV-only lane projects.

Because of the continued growth in both automobile and truck traffic, there is considerable interest in building CMV-only lanes as one solution to ever-increasing highway congestion. System reliability is especially important in the movement of high-value, time-sensitive commodities; the assumed reliability of CMV-only lanes with the resulting improvements in truck productivity and operational efficiency may provide sufficient added value that truckers and shippers would be willing to pay to build and operate the highway lanes.

Under NCHRP Project 03-73/NCFRP Project 10, the research team was asked to

- Review and discuss the literature on existing and proposed CMV-only facilities,
- Describe associated planning process issues,
- Describe major CMV-only configurations and analyze key design issues,
- Discuss opportunities to apply Intelligent Transportation System technologies,
- Examine the feasibility of increased size and weight standards on such roads,
- Examine factors related to the success of truck-only lane projects,
- Examine the suitability of tolling and privatization of such roads, and
- Suggest areas of future research to improve the understanding of the performance of CMV-only lanes.

The research contained in this report was conducted by Cambridge Systematics.

CONTENTS

CHAPTER 1

Introduction

This report provides the final results of research on NCHRP Project 03-73, "Separation of Vehicles—Commercial Motor Vehicle (CMV)-Only Lanes." It presents a review and discussion of a wide range of issues relevant to planning, designing, and evaluating CMV-only lanes that should be useful to planners and policy-makers in the public and private sectors. It also presents results of a comparative evaluation of the performance of different CMV-only lane concepts, and potential benefits and costs of these concepts. Finally, it concludes with a discussion of potential areas of further research on promising CMV-only lane concepts.

1.1 Project Overview

For a number of years, there has been growing interest in CMV-only lanes, and several notable proposals for CMV-only lane systems/projects have appeared in the planning and traffic engineering literature. To a large extent, this growth in interest has been related to the growth in truck traffic relative to automobile traffic and the contribution of truck traffic to congestion.

Heavy trucks (standard trucks as well as longer combination vehicles [LCVs]) have a greater impact on capacity than their sheer volume would suggest, especially when mixed with automobiles. Separation of autos and trucks may be a beneficial way of building more system capacity in certain circumstances. A number of studies also have suggested that CMV-only lanes that are tolled may present a viable means of financing system capacity improvements. The argument has been made that trucks have a higher value of time than autos, and may therefore be willing to pay a higher price for congestion relief. In addition to congestion relief, truckers might also be willing to pay tolls on CMV-only lanes that facilitate operations of LCVs and other oversize/overweight (OS/OW) trucks, in order to be able to engage in these operations to improve trucking productivity and operational efficiency.

A number of studies have shown that system reliability is especially critical in the movement of high-value, time-sensitive commodities, and that the reliability benefits of CMV-only lanes (due to the combination of less overall congestion and the incident-reduction potential of truck-auto separation) may provide added value for which truckers/shippers would be willing to pay. It also has been suggested that separation of autos and trucks may have significant safety benefits. Autos are far more maneuverable than heavy trucks, yet auto drivers often do not take this into account when making certain fast response driving maneuvers and this can lead to increased crashes. Further, when trucks and autos are involved in crashes, they are far more likely to be fatal crashes than when crashes involve only autos.

The objectives of the Separation of Vehicles—CMV-Only Lanes Project are to compile data from actual applications and studies of emerging concepts and use these data to present a profile of the benefits and costs of CMV-only lanes. This information will serve as a reference guide for planners who may be considering CMV-only lane concepts in corridor studies or other planning applications. The analyses in the project also will provide data that practitioners can use to support their own evaluations of CMV-only lane projects.

The research was comprised of the following 10 tasks for meeting the objectives of the project:

- Task 1—Conduct a literature review of existing CMV-only facilities as well as proposed concepts, which will provide information for subsequent tasks.
- Task 2—Describe planning process issues associated with the development of CMV-only lanes.
- Task 3—Describe major CMV-only configurations and identify and analyze key design issues.
- Task 4—Discuss opportunities to apply Intelligent Transportation Systems (ITS)/Commercial Vehicle Operations (CVO) technology to CMV-only lanes and the benefits that can accrue from these deployments.
- Task 5—Examine opportunities to operate LCVs and heavy-weight trucks on CMV-only lanes.
- Task 6—Explore issues and opportunities associated with tolling and privatization of CMV-only lanes.
- Task 7—Prepare an interim report that summarizes the findings and data collected in the first six tasks. The interim report was completed in August 2008 and an edited version of the report that responds to panel comments is presented as Appendix A (available on the TRB website at www.TRB.org by searching for NCHRP Report 649/NCFRP Report 3).
- Task 8—Compile available field and modeling data into a performance evaluation of different CMV-only lane concepts.
- Task 9—Evaluate CMV-only lanes in terms of relative costs and benefits.
- Task 10—Prepare a final report that summarizes the results of the analyses conducted in the project. This report includes a summary of existing CMV-only facilities, a description of different configurations and the factors that influence the feasibility of each configuration, a discussion of performance data, and a summary of the benefits and costs of different CMV-only lane systems.

1.2 Definition of Commercial Motor Vehicle

A commercial motor vehicle (CMV) can be defined in a variety of ways. In response to a request from the project's Technical Panel, a working definition of a CMV was developed for this project.

FMCSA, under the Code of Federal Regulations—Title 49 (49 CFR) Part 390 (Rulemaking Procedures—Federal Motor Carrier Safety Regulations), defines commercial motor vehicles for U.S. Department of Transportation vehicle registration purposes as follows:

- Vehicles having a gross vehicle weight rating or gross combination weight rating (in the case of combination vehicles) of at least 10,001 lbs; or
- Vehicles designed or used to transport more than eight passengers (including the driver) for compensation; or
- Vehicles designed or used to transport more than 15 passengers (including the driver), but not for compensation; or
- Vehicles used in transporting material found by the Secretary of Transportation as being hazardous under 49 U.S.C. 5103, and transported in a quantity requiring placarding under 49 CFR, Subtitle B, Chapter 1, Subchapter C.

This standard federal definition for CMVs includes not only trucks categorized according to weight and commodity (i.e., hazardous cargo), but also includes passenger vehicles such as buses. Another, more restrictive federal definition is based on commercial driver licensing (CDL) requirements (Part 383: Commercial Driver's License Standards; Requirements, and Penalties).

This definition includes trucks with a gross vehicle weight or gross combination weight rating of at least 26,001 lbs, trucks carrying hazardous materials requiring placarding (same as Part 390), and vehicles carrying 16 or more passengers, including the driver.

Finally, FHWA classifies nonpassenger vehicles by the number of axles and number of units, as opposed to the FMCSA's definition based on weight or commodity. Single- and multi-trailer trucks (i.e., not single unit trucks), for example, fall within Classes 8 to 13 in FHWA's scheme.

The Technical Panel agreed with the project team's recommendation that the types of vehicles included in the CMV definition for this project will be directly dependent on the types of vehicles best served by various CMV-only lane configurations and not tied to any of the federal definitions.

Consequently, as trucks are implicitly the focus of this research, passenger vehicles falling under the CMV classifications under federal regulations (discussed previously) will not be included as CMVs. Since the work approach for this project involves analyzing different types of truck-only lane configurations, flexibility in the CMV definition has been adopted to accommodate different types of trucks, based on the type of application of truck-only lanes (note that the terms "CMV-only" and "truck-only" generally will be used interchangeably in this report).

1.3 Overview of the Report

The interim report presented an extensive compendium of information about CMV-only lanes and identifies major issues and concepts that should be understood in developing new applications of CMV-only lane concepts. Since this compendium will be a useful planning reference for practitioners, it is reproduced in its entirety as Appendix A of this final report. The appendices of the interim report, which are also included as appendices to this final report, provide a detailed bibliography of references including an evaluation of the types of information available from major sources, and a compilation of data tables developed from the major sources. These data tables provide additional material that practitioners can use to support their own analyses of CMV-only lanes.

In order to provide background on key concepts and to introduce some of the primary data sources that can be used in evaluating CMV-only lane concepts, Chapter 2 of this final report provides a summary of the interim report. This sets the stage for the analytical elements of the final report, which are contained in Chapter 3, Performance Evaluation, and Chapter 4, Benefit-Cost Analysis. Chapters 3 and 4 draw data from other studies and provide a consistent framework for comparing various CMV-only lane configurations with each other and with other types of roadway capacity improvements. The general approach used in these evaluations was to define two primary scenarios—long-haul intercity corridors and congested urban corridors—to develop a series of relevant alternatives for each scenario, and then to conduct sensitivity tests for the impact of other features (such as tolling). The performance evaluations examine measures of effectiveness related to congestion, reliability, and safety impacts. In Chapter 4, the benefits of the alternatives described in the performance evaluations are monetized and benefit-cost (B-C) comparisons are conducted. Chapter 5 presents the conclusions and recommendations of this study effort. Since the data used in the performance evaluations and B-C comparisons are drawn from various studies using different assumptions, traffic conditions, and analytical procedures, much of the analytical effort was associated with adjusting the results to provide comparability. Wherever appropriate, results are provided in ranges.

A main finding of the background review of existing literature that was conducted for the interim report is that while there is a substantial body of information on CMV-only lanes from planning and feasibility studies, there are very few real-world applications of the concept. Actual applications of concepts that are in some way related to CMV-only lane concepts fall into the following categories:

- Dual-dual[1] roadways that provide separated lanes for autos only (an example of which is the New Jersey Turnpike);
- Lane restrictions for trucks in right-hand lanes;
- Interchange by-passes for trucks (examples of which are found on I-5 outside of Portland, Oregon, and on I-5 in California at the SR 14/I-5 interchange, the I-5/I-405 interchanges in both the north [San Fernando Valley] and south [Orange County]);
- Truck climbing lanes on high grades (an example of which is found on I-10 in San Bernardino County, California, between Redlands and Yucaipa); and
- Short connectors from major port/intermodal facilities to freeways (an example of which is found on the A-20 motorway connecting the Port of Rotterdam with the A-16 motorway).

These applications are quite limited, and they do not correspond to the types of approaches of most interest in the various feasibility and planning studies that have been conducted in North America and Europe over the last 20 years, which have focused more on long-haul multistate corridors or major urban freight corridors. The limited data available from these real-world applications makes it difficult to conclusively evaluate certain performance features of CMV-only lanes, particularly the safety and reliability benefits. Nonetheless, where these data are available they have been used in this study to validate certain conclusions about anticipated performance benefits of CMV-only lanes.

Although there is limited real-world application of CMV-only lanes, the literature review conducted for the interim report shows that there is a substantial number of references to CMV-only lane topics. The preponderance of information was found in planning, policy, and feasibility studies with limited real-world application of the truck-only lane concept. It also was noted in the interim report that there is limited information in the areas of ITS applications and LCVs. Thus, much of the source data on these configurations of CMV-only lanes draw heavily on the work of a limited number of researchers.

[1]As noted, dual-dual roadways are comprised of dedicated lanes for autos, along with general purpose (mixed-flow) lanes with auto and truck traffic (trucks are restricted to the general purpose lanes and are not allowed to operate on the auto-only lanes). The terminology "dual-dual roadway" is used by the New Jersey Turnpike Authority to refer to sections along the New Jersey Turnpike with auto-only and general purpose lanes. These sections are also sometimes referred to as "dual roadway" sections.

CHAPTER 2

Background and Key Concepts

This chapter provides a summary of key background concepts and issues that are important to the understanding of potential applications of CMV-only lanes. It summarizes a detailed discussion of these issues that was included in this project's interim report and is contained in this report as Appendix A (available on the TRB website at www.TRB.org by searching for NCHRP Report 649/NCFRP Report 3). The main topics that are discussed in this chapter include the following:

- Planning process issues,
- Configuration and design issues,
- Integration with ITS,
- LCV operations, and
- Tolling and privatization.

2.1 Planning Process Issues

CMV-only lanes should be integrated with long-range planning objectives of a state or MPO, and they should be applied to selected corridors after a thorough evaluation of a number of different alternative approaches to achieve the same objectives. Some of the benefits that are sought from CMV-only lanes include those presented in Table 2.1. This table also indicates why CMV-only lanes might be a superior approach to achieving these benefits in certain circumstances.

Since many applications of CMV-only lanes anticipate tolling as a way to finance the facility, Table 2.2 illustrates how some of the benefits described in Table 2.1 can create value for the private sector that can be captured by the public sector through tolling.

A number of studies cited in Appendix A illustrate how inclusion of CMV-only lanes in long-range plans or how evaluation of CMV-only lanes as options in major corridor studies can be related to regional or corridor-specific planning goals. Specific regional goals that may be supported by CMV-only lane concepts include: safety, improved mobility for both trucks and autos, economic development, and reduced neighborhood impacts (moving trucks to a designated facility with clear mobility benefits). In determining the degree to which CMV-only lanes represent a feasible approach to supporting these objectives, the Georgia Department of Transportation (GDOT) notes, "to achieve the highest and best use of a truck-only lane system investment requires an understanding of the market for truck-only lanes and designing a system that captures the greatest market share and provides the greatest opportunity to garner travel time savings."[2]

[2]Georgia Department of Transportation, *Truck-Only Lanes Needs Analysis and Engineering Assessment,* April 2008.

Table 2.1. Potential benefits of CMV-only lanes.

Category	Benefit	Group Benefiting	Description
Operational Efficiency	• Higher Travel Speeds • Less Delay • Improved Level of Service (LOS)[1]	• General Purpose (GP)[2] Lane Users • CMV-Only Lane Users	• Vehicle separation allows all vehicles to travel at their designated speeds without conflict. Slower commercial vehicles are not present in right (slow) travel lanes. Less weaving. Improved operational efficiency.
Safety	• Enhanced Safety	• General Purpose Lane Users • CMV-Only Lane Users	• Fewer, less severe crashes as a result of vehicle separation (and minimal car-truck interaction).
Economic	• Enhanced Travel Options	• CMV-Only Lane Users	• Increased trip reliability and reduced transportation costs of fuel consumption due to severe congestion or delay caused by truck-car accidents.
	• Improved Freight Productivity	• CMV-Only Lane Users	• The productivity of freight movement in and around major metropolitan areas and along long-haul intercity corridors is an important factor in ensuring local, regional, and national economic competitiveness.
Environmental	• Reduced Vehicle Emissions	• General Purpose Lane Users • CMV-Only Lane Users	• Stop-and-go traffic conditions improve as congestion is decreased on general purpose lanes, and air pollution emissions from slowed or stalled cars and trucks will be reduced.

Notes:

1. LOS is a designation used to assess the state of performance of transportation systems. Usually, LOS categories are defined by the letters A, B, C, D, E, and F; wherein A stands for the best state of performance of the system while F stands for the worst. LOS categories are typically defined based on the performance objectives of a system, such as mobility (in which case, level of congestion measured in terms of volume-capacity (V/C) ratio, for example, is used to define LOS categories), or safety.

2. The mixed-flow lanes (lanes carrying both auto and truck traffic) of a highway are also referred to as general purpose (GP) lanes.

Table 2.2. Additional CMV-only application benefits through tolling.

Category	Benefit	Group Benefiting	Description
Operational Efficiency	• Congestion Management	• General Purpose Lane Users • CMV-Only Lane Users	• By imposing fees when demand levels reach capacity on CMV facilities, the level of congestion on CMV facilities is controlled.
Economic	• Revenue	• General Purpose Lane Users • CMV-Only Lane Users	• Fees can provide an additional source of revenue to pay for transportation improvements, especially the operations and maintenance of the CMV lanes themselves.

Note: Benefits are general, and are not specifically tied to either mandatory or optional tolling scenarios.

Because of the high level of investment required for CMV-only lane projects, several studies have recommended "thresholds" be in place prior to pursuit of the project to be used in screening high potential corridors. These threshold categories are reasonable when considering that CMV-only lanes are most attractive when they provide meaningful blocks of travel time savings to commercial vehicle users, thus minimum values for numbers of trucks or percent trucks on roadway segments can serve as a guide for planning. However, the conditions in the field necessary to ensure a successful CMV-only lane project can be difficult to quantify. By providing thresholds, planners are able to gauge, at a high level, whether the region's conditions warrant the concept. Research[3] shows that a variety of CMV-only lane planning thresholds have been developed as follows:

- Mainline Volume
  - Peak hour > 1,800 vehicles per hour per lane (vphpl) (Janson)
  - Off-peak hour > 1,200 vphpl (Janson)
  - Two-way average daily traffic (ADT) > 120,000 (Douglas)
  - ADT > 100,000 (Battelle)
- Heavy Truck ADT
  - > 20,000 for 10 mi (Douglas)
- Heavy Vehicle Mix
  - > 30% (Janson)
  - 25% Trucks (Battelle)
- Freight Generator Proximity
  - Truck generator at one terminus (Douglas)

Development of performance measures and screening criteria for CMV-only lane projects will aid agencies in ensuring that objectives set early in the planning process are met. Some examples of categories of performance measures that have been used in the studies cited in Appendix A include the following:

- Level of service on CMV-only lanes;
- Level of service or vehicle throughput throughout the corridor (including the multipurpose lanes);
- Safety through reduced number of total crashes but, more particularly, reduced number of fatal or injury crashes;
- Cost-effectiveness;
- Compatibility with local economic development plans (typically measured in terms of improved accessibility to major freight generators); and
- Reduced emissions due to smoother traffic flows.

When evaluating CMV-only lanes as part of long-range plans or corridor studies, it is important to compare CMV-only lanes with other alternatives that can achieve the same objectives. The following appropriate alternatives that have been looked at in several of the studies described in Appendix A include:

- Equivalent capacity in multipurpose lanes,
- CMV-lanes with and without LCV operations and/or tolling,
- High-occupancy vehicle/high-occupancy toll (HOV/HOT) lanes or other types of special purpose lanes, and
- Increased rail capacity.

In many of the studies of CMV-only lanes that were identified in this project, traditional travel demand models have been used as the primary tool for evaluation. As follows, these models have

[3]Paul W. Dorothy, *The Potential for Exclusive Truck Facilities in Ohio,* presentation at Ohio Transportation Engineering Conference, 2007, http://www.dot.state.oh.us/engineering/OTEC/2007%20Presentations/Tuesday/Session7/OTEC%202007%20Truck%20Lane%20(Dorothy).pdf.

some major shortcomings that planners should be aware of when they are using travel demand models to evaluate CMV-only lanes:

- Many state and regional travel demand models do not provide comprehensive coverage of truck activity by corridor with any breakdown by the different markets that trucks serve. This can be a critical shortcoming, especially if tolling is being evaluated. Some studies suggest that value of time for trucks may vary by commodity hauled or purpose of the trip. Another shortcoming of many state and regional travel demand models is that they do not have accurate representation of truck origin-destination patterns, and this can make it difficult to estimate the level of CMV-only lane usage when the facility has limited access/egress locations as compared to existing mixed-flow facilities.
- The operational benefits of separating trucks and autos are not captured in traditional travel demand models, thus the travel time savings may not be accurately reflected in the analysis.
- Traditional travel demand models do not take into account the reliability benefits of CMV-only lanes. Likewise, they do not provide much information that can be used to evaluate safety benefits.

Some of these shortcomings suggest that in the future, simulation models may be a more useful tool for evaluating the benefits of CMV-only lanes. Prior to undertaking a CMV-only lane project, it is important to understand the economic benefits to the community at large of having more efficient freight transportation. It also is important to be able to describe how CMV-only lanes will mitigate impacts of truck traffic as compared to other alternatives that may be seen as having more direct benefits to passenger vehicles. Since long-haul multistate corridors are often candidates for CMV-only lanes, it is important to establish effective planning and funding mechanisms for multistate collaboration. Several of the studies undertaken to date have established pooled funds study efforts that join states in a collaborative planning process, but few have taken the next step into coordinated multistate implementation of a CMV-only lane project.

A wide range of stakeholders should be engaged in planning for CMV-only lanes, and each may have varied positions. Since CMV-only lanes are targeted at a relatively small portion of the motor-vehicle population, getting public support is critical. Since the implementation of CMV-only lanes has a direct impact on travel conditions for autos on general purpose lanes (due to the diversion of trucks to truck-only lanes), public input and outreach would be critical in increasing awareness of the impacts of truck-only lanes (and in many cases, for garnering public support for the implementation of truck-only lanes). Also, public outreach could be essential in understanding public perceptions regarding truck-only lanes, such as the impacts of concentrated truck traffic (traveling on CMV-only lanes) on surrounding neighborhoods, such as on access routes serving CMV-only lanes.

As the primary users of CMV-only lanes, the involvement and acceptance of the trucking industry is critically important. The participation of the trucking industry would be crucial in understanding industry perceptions of, and expectations for, CMV-only lanes. For example, the work conducted by Reich et al.[4] in Florida suggested that motor carriers would be amenable to the CMV-only lane concept if CMV-only lanes provide sufficient access to trucks, serve truckers' desired length of travel, and allow higher speed operations. The work conducted by Samuel et al.[5] from the Reason Foundation talks about the importance of involving shippers and carriers, through the development of shipper/carrier forums, in contributing to policy development

---

[4]Stephen Reich, Janet Davis, Martin Catala, Anthony Ferraro, and Sisinnio Concas, *The Potential for Reserved Truck Lanes and Truckways in Florida,* Center for Urban Transportation Research, Research Report 21-17-422-LO, May 2002.

[5]Peter Samuel, Robert W. Poole, Jr., and Jose Holguin Veras, *Policy Study 294, Toll Truckways: A New Path Toward Safer and More Efficient Freight Transportation,* Reason Foundation, June 2002.

related to toll truckway standards and interoperability. For example, the study talks about how FHWA could potentially sponsor an Operators and Shippers Forum for the exchange of ideas related to toll truckway planning and development. The importance of involving shippers in the CMV-only lane planning process would be critical in the case of analysis of LCV operations, since shipper inputs can be useful in understanding potential markets (types of commodities) along a corridor, and their propensity towards LCVs. The trucking industry has provided extensive comment on issues such as tolling CMV-only lanes (and associated trucking industry equity implications) and LCV operations on CMV-only lanes. These positions are summarized in Appendix A.

The planning issues surrounding mandatory versus voluntary usage of tolled truck-only lanes are also worth noting. The importance of this issue is underscored by the fact that the performance of truck-only lanes is a direct function of truck diversion (from general purpose to truck-only lanes), and tolls can directly impact the level of truck diversion in the case of voluntary usage of truck-only lanes. Also, mandatory usage of truck-only lanes may be associated with opposition from stakeholders, such as the carrier and shipper industry, which would be important issues to consider as part of any planning/policy making processes related to tolling truck-only lanes.

In the case of voluntary usage of tolled truck-only lanes, it would be important to assess the impact of various toll scenarios (variations in toll rates) on utilization of truck-only lanes. This information would, in turn, be useful in determining the revenue generation potential under various toll scenarios, as well as the performance of the corridor under each scenario, to arrive at a scenario that maximizes both the toll revenue as well as corridor performance relative to other scenarios. Chapter 5 presents some key results from the work conducted in this regard as part of the *I-710 Major Corridor Study.*

Mandatory usage of tolled truck-only lanes might be more applicable on truck-only lanes serving specific truck trip purposes, such as truck-only lanes serving major freight facilities like seaports. However, as stated earlier, the issue of industry opposition would be important to address as part of the planning process for these facilities. Another important aspect to analyze in the case of mandatory usage of tolled truck-only lanes is the mobility performance of the truck-only lanes, depending on the capacity of these lanes, and the magnitude of truck demand. For freight facilities generating high daily truck traffic, it would be important to ensure that the truck-only lanes have adequate capacity in order to ensure operational efficiencies on these lanes under mandatory usage.

2.2 Configuration and Design Issues

This section presents a summary of the various types of CMV-only lane applications and the key configurational and design issues pertaining to them. This section is subdivided into the following subsections:

- Types of truck lanes,
- Methods of separation,
- CMV-only lane cross-sectional configurations,
- Right-of-way (ROW) requirements,
- Pavement design,
- Geometric and cross-sectional design issues, and
- Costs.

Additional data and information on each of these subsections can be found in Appendix A. Structural design elements (such as those pertaining to bridges) associated with CMV-only lanes have not been covered in this study, because it was concluded that analysis to elucidate the key issues surrounding this aspect of CMV-only lane projects and their relative comparisons against other alternatives would require substantial resources that are beyond the scope of the current study. It is, however, noted that future research focusing specifically on structural design issues of CMV-only lanes, and how they compare with other alternatives in terms of costs, should be undertaken to supplement the results and inferences obtained from this study. Also, such research might be more relevant for application on a case-by-case basis (for example, in the case of a corridor study where elevated CMV-only lanes might be a viable alternative).

2.2.1 Types of Truck Lanes

As noted in Chapter 1, there are a number of different types of CMV-only lane concepts that include interchange treatments, lane restrictions, and climbing lanes in addition to the mainline treatments that are the focus of this study. Mainline CMV-only treatments include exclusive truck lanes (ETLs), nonexclusive truck lanes, and dual-dual roadways. ETLs physically separate truck lanes from general purpose highway lanes either through the construction of barriers or through grade-separated structures. They also may have dedicated access/egress ramps. By completely separating trucks and autos they minimize weaving and maximize safety benefits. Nonexclusive truck lanes are mainline lanes that are not barrier separated (often using rumble strips) and autos typically weave through the lanes at access/egress ramps. The dual-dual roadway concept has been implemented along the New Jersey Turnpike, which consists of inner auto-only lanes and outer lanes that carry mixed-flow traffic and to which truck traffic is restricted.

Other types of CMV-only treatments include the following:

- Truck interchange bypasses for the purpose of removing trucks from interchange merge areas where their presence could be potentially detrimental to interchange operations, as well as exacerbating interchange safety issues.
- Truck climbing lanes for the purpose of separating slow-moving trucks from the highway mainlines to prevent their impacts on optimal traffic speeds on high grades. In addition to overall speed benefits these lanes offer safety benefits by reducing lane changes by faster-moving vehicles.
- Truck ramps have a similar operational function as interchange bypasses but with the focus on improving operations by allowing more efficient access and egress of trucks by reducing weaving conflicts.

2.2.2 Methods of Separation

Fully separated lanes can involve at-grade lanes separated with a median strip, elevated sections, or tunnels. The latter separations have safety and operational benefits and may reduce right-of-way impacts but at a greater expense than the first option cited. Structural issues associated with these methods of separation that are unique to truck traffic are discussed later and in more detail in Appendix A.

Jersey barriers, as used in the New Jersey Turnpike, are often provided in the case of exclusive CMV-only lanes (ECLs, i.e., CMV-only lanes that are physically separated from general purpose lanes) and dual-dual roadways to ensure complete separation of truck and auto flows. The general configuration of Jersey barriers in terms of the cross-sectional design features is governed by the need to develop a configuration that minimizes the possibility of collisions between opposing traffic movements, as well as minimizing the impacts on vehicles hitting the barrier. A detailed discussion of the configuration features of Jersey barriers is provided in McDevitt.[6] The compendium of CMV-only lane information provided in Appendix A presents a summary of this information, including standards for height and cross-sectional dimensions in different applications.

Rumble strips are a common feature on highways as a safety measure to mark separation in nonexclusive truck lanes. There are many factors that can favor the application of non-ECLs in lieu

---

[6]C. F. McDevitt, "Basics of Concrete Barriers," *Public Roads,* March 2000.

of exclusive facilities for trucks, such as right-of-way (ROW) availability, costs, interchange and ramp requirements, and amount of truck traffic demand. Since the functional characteristics of rumble strips for non-ECLs would be the same as those applied for shoulders in mixed-flow facilities, the configuration of rumble strips for truck-auto lane separation applications is expected to follow the same standards developed by FHWA for mixed-flow facilities.

2.2.3 CMV-Only Lane Cross-Sectional Configurations

Depending on ROW availability and the level of truck traffic, ECLs may include passing lanes to allow for truck passing maneuvers and access for safety vehicles. In long-haul corridors, these lanes can be short length sections placed at appropriate intervals in much the same way that railroad sidings are used. Passing lanes may not be required if shoulder widths are adequate to make them viable as breakdown lanes.

In all situations, cross-sections must take into account general purpose lane requirements (lane-widths may be able to be reduced if trucks are restricted), barrier widths, and inner/outer shoulders (widths are related to separation and access functions).

A study conducted by Middleton, et al.[7] from the Texas Transportation Institute (TTI) on strategies for separating trucks from passenger vehicles presents various types of CMV-only lane facility configurations under different ROW scenarios. Key observations about configuration standards are summarized in Appendix A and include options for standards with respect to CMV-only and general purpose lane widths, Jersey barrier widths, shoulder widths, and median widths under different design conditions. This, and other referenced studies, provides cross-sectional views for various configurations. Middleton's study also provides guidance on cross-sectional design considerations related to truck passing, accommodation of disabled trucks, impacts of configuration elements on capital costs, accounting for future expansion possibilities, and accounting for the efficiency and ease of exit/entrance maneuvers for trucks.

Several other studies are summarized in Appendix A, including the *I-710 Major Corridor Study* (Los Angeles Metro), I-75 truck lanes study (Florida and Georgia DOT), and Reason Foundation studies of LCV proposals. All of these studies present alternative cross-sectional design concepts with their rationale for specific design features that may be appropriate in particular circumstances.

Based on the literature review, the New Jersey Turnpike was identified as the only real-world application of the dual-dual roadway concept. The auto-only and mixed-flow lanes are physically separated from each other, and each is provided with its own access ramps to/from interchanges. Typical cross-sections are presented in Appendix A.

Douglas[8] provides a good discussion of truck ramp configuration issues that address concerns such as location, spacing, length, and geometry.

2.2.4 ROW Requirements

Cross-sectional configuration of CMV-only lanes determines ROW requirements or vice versa. Therefore, the reader is referred to the discussion of cross-sectional configuration in Appendix A for information about ROW requirements. It should be noted that elevated CMV-only lane configurations are increasingly being proposed with innovative elevated structural design concepts such as box girders with slender columns, to minimize their ROW requirements.

---

[7]D. Middleton, S. Venglar, C. Quiroga, D. Lord, and D. Jasek, *Strategies for Separating Trucks from Passenger Vehicles: Final Report,* September 2006.
[8]J. G. Douglas, *Handbook for Planning Truck Facilities on Urban Highways,* August 2004.

2.2.5 Pavement Design

CMV-only facilities will typically experience a higher degree of pavement wear-and-tear compared to mixed-flow facilities, due to the constant heavy truck loads, presumably at higher operational speeds. A study conducted by Button et al.[9] from TTI was identified as a major source providing a discussion of pavement design issues addressing truck traffic loads. The following information draws heavily from this study.

Large stone asphalt mixtures (LSAMs) are increasingly finding applications in the design of heavy-duty flexible pavements. Research conducted by Mahboub and Williams[10] points out that properly designed LSAMs can be potentially attractive candidates for construction in heavy-truck traffic routes owing to their high resistance to deformation.

Researchers are of the opinion that one of the key factors in achieving cost-effective pavement designs for heavy truck lanes is the use of premium base materials. Ongoing projects being conducted by TTI for TxDOT involve field testing of experimental base materials that are expected to provide useful information for the evaluation of existing material specifications, particularly for heavy truck traffic conditions. A key issue that needs to be addressed in conjunction with the development of new material specifications for CMV-only lanes is the application of new construction methods. It is expected that the implementation of new material specifications will likely require changes in existing pavement construction practices such as placing and compacting of new pavement materials.

There also has been an increasing focus on the potential applications of smart materials[11] for heavy truck corridors, because their implementation is expected to have significant benefits associated with reduced costs of pavement maintenance and improvements in traffic safety. An example of a smart material would be a self-healing polymeric substance used in pavements that would automatically heal pavement cracks.

Finally, post-tensioned continuously reinforced concrete pavement designs have been proposed for consideration for the CMV-only lanes for the Trans Texas Corridor (TTC) and some of the cited advantages would appear to have general applicability to CMV-only lanes.

2.2.6 Geometric and Cross-Sectional Design Issues

Although highway mainline design standards typically account for the physical and operating characteristics of trucks in the design processes for geometrics (horizontal and vertical alignments) and cross-sectional features (lane widths, shoulder widths, etc.), it is expected that these design standards would not always be directly transferable to CMV-only lanes, because of factors such as differences in truck operating characteristics on CMV-only lanes compared to general purpose lanes (for example, CMV-only lanes would typically allow for higher truck operating speeds than would general purpose lanes). Also, CMV-only lanes supporting long-haul LCV operations would require the application of a separate set of design guidelines that specifically address the physical and operating characteristics of LCVs, which are quite different from those of regular combination trucks. Appendix A summarizes the major geometric and cross-sectional design parameters that would be important to consider in the design of CMV-only lanes, including sight distance, horizontal and vertical alignment, and cross-sectional elements.

---

[9]J. W. Button, E. G. Fernando, and D. R. Middleton, *Synthesis of Pavement Issues Related to High-Speed Corridors,* Texas Transportation Institute, Research Report 0-4756-1, September 2004.
[10]K. Mahboub and E. G. Williams, "Construction of Large-Stone Asphalt Mixes (LSAMs) in Kentucky," *Transportation Research Record 1282,* Transportation Research Board, Washington, D.C., pp. 41–44, 1990.
[11]*Smart materials,* as defined by Wikipedia (www.wikipedia.org), are materials whose properties can be significantly changed in a controlled fashion under external stimuli, such as temperature, moisture, stress, etc.

2.2.7 Costs

The costs associated with the development and operations of CMV-only lanes can be broken into capital costs and operations and maintenance (O&M) costs. Capital cost components typically include ROW acquisition costs and construction costs. ROW acquisition costs for the development of CMV-only lane facilities depend on the land ownership patterns around existing highway corridors.

It is expected that diversion of trucks from mixed-flow to CMV-only lanes would result in a net reduction in total pavement maintenance costs, since the increased pavement costs associated with the CMV-only lanes would be offset by the reduction in maintenance costs on the general purpose lanes due to reduction in pavement damage resulting from diversion of trucks to the CMV-only lanes. Middleton et al.[12] provides a detailed discussion on the construction costs associated with exclusive CMV-only lane facilities as a function of the number of lanes, and how these costs compare to the construction costs of mixed-flow facilities. Detailed excerpts are provided in Appendix A. The general conclusion is that the costs of building separated CMV-only lanes are always higher than mixed-flow facilities, and these incremental costs can be quite significant. The primary factors contributing to higher costs for separated facilities is the higher quality and thickness of pavement, potentially wider and higher quality shoulders for the separated facilities, and Jersey barriers with larger cross-sectional features and increased reinforcements compared to mixed-flow facilities. However, some of the benefits associated with separated facilities such as safety and reliability improvements can outweigh the increased costs when compared to mixed-flow facilities and justify their implementation.

Reich et al.[13] estimated that the most cost-effective option for an ECL facility is a two-lane facility built on existing median ROW with minimum width of 36 ft, which is nonbarrier separated from the general purpose lanes, the capital cost for which would be around $4 million per mile. The Reason Foundation study on corridors for toll truckways[14] provides even lower capital cost estimates of around $2.5 million per mile for two-lane toll truckways. The differences in unit capital costs (cost per mile) between studies can be attributed to varying assumptions related to type of pavement materials, number of interchanges, and shoulder width and type of material used for shoulders. Consequently, feasibility analyses of CMV-only lanes typically entail conducting a detailed capital cost analysis, based on a key set of assumptions applicable to the corridor being studied. Additional data on CMV-only lane capital costs are provided in Appendix A.

2.3 Integration with Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) have been applied to Commercial Vehicle Operations (CVO) in the United States for a number of years to improve the regulation and enforcement of commercial motor vehicles (CMVs), as well as to improve motor carrier operations. ITS/CVO technologies primarily are used to provide improvements in the following four areas:

1. Safety assurance, for assuring the safety of commercial drivers, vehicles, and cargo, including automated inspections, safety information systems, and on-board safety monitoring systems;

---

[12]D. Middleton, S. Venglar, C. Quiroga, D. Lord, and D. Jasek, *Strategies for Separating Trucks from Passenger Vehicles: Final Report,* September 2006.
[13]S. Reich, J. Davis, M. Catala, A. Ferraro, and S. Concas, *The Potential for Reserved Truck Lanes and Truckways in Florida,* Center for Urban Transportation Research, Research Report 21-17-422-LO, May 2002.
[14]R. W. Poole, Jr. and P. Samuel, *Corridors for Toll Truckways: Suggested Locations for Pilot Projects,* Reason Foundation, Policy Study 316, February 2004.

2. Credentials administration, for improving the procedures and systems for managing motor carrier regulation, including electronic credentialing, electronic tax filing, and collection of electronic payments (and easing these processes for motor carriers);
3. Electronic screening, for facilitating the verification of size, weight, safety, and credentials information, including automated screening at weigh stations, international border crossings, and other inspection locations (one advantage of electronic screening for motor carriers is the significant improvement in carrier productivity—carriers allowed to by-pass weigh stations save fuel, maintain speeds, and incur less pavement wear and tear); and
4. Carrier operations, for reducing congestion and managing the flow of CMV traffic, including traveler information systems and hazardous material incident response.

New technology applications also are being examined for improving operations through automated guidance systems, and this appears to be a particularly promising application consistent with benefits sought in CMV-only lane projects.

2.3.1 ITS/CVO Applications to Increase Capacity and Save Time and Fuel on CMV-Only Lanes

In 2004, Yin, Miller, and Shladover,[15] in affiliation with the California Partners for Advanced Transit and Highways (PATH) Program, examined the use of dedicated truck lanes, with and without the application of ITS technologies, to improve the performance of the freight movement system in metropolitan Chicago. Their focus was the feasibility of applying cooperative vehicle highway automation systems (CVHAS). CVHAS technologies are systems that provide driving control assistance or fully automated driving, based on information about the vehicle's driving environment that can be received by communication from other vehicles or from the infrastructure, as well as from the vehicles' own on-board sensors.

The authors considered both mixed traffic operations and trucks completely segregated from other traffic for their examination of CVHAS-related truck operations. CVHAS technologies included in the analysis consisted of automatic steering, speed, and spacing control, and operation of trucks in either two- or three-truck platoons.

To support their analysis, Yin et al. selected the following five operational concepts:

1. Baseline concept (i.e., no CVHAS technologies, no CMV-only facilities—"do nothing");
2. CMV-only facility without CVHAS technologies and open to all trucks;
3. CMV-only facility with CVHAS technologies (automatic steering) for equipped trucks only;
4. CMV-only facility with CVHAS technologies (automatic steering, automatic speed, and spacing control with two- and three-truck platoons) for equipped trucks only—"fully automated"; and
5. CMV-only facility without CVHAS technologies before a certain year to be determined (eventually set at 2015) and following that year, upgrade to an automated truckway (automatic steering, automatic speed, and spacing control with two- or three-truck platoons)—"time-staged automation."

The results (see Table 2.3) indicated that all CMV-only lane concepts appear to be cost-effective compared to the baseline. However, the benefits of deploying CVHAS technologies in relation to costs are not clear-cut, as evidenced by the benefit/cost ratio for Alternative 2 that did not deploy CVHAS, which is higher than the ratios for Alternatives 3 and 4 that employed CVHAS. Time-

[15] Y. Yin, M. A. Miller, and S. E. Shladover, *Assessment of the Applicability of Cooperative Vehicle-Highway Automation Systems to Freight Movement in Chicago,* Transportation Research Board Annual Meeting, Washington, D.C., January 2004.

Table 2.3. Costs and benefits of truck lane concepts compared to baseline (in millions of dollars).

	Alternative 2 (Without CVHAS)	Alternative 3 (Automatic Steering)	Alternative 4 (Fully Automated)	Alternative 5 (Time-Staged Automation)
Benefits				
Travel Time Savings	2,938	2,186	1,931	2,982
Reduction of Fuel Consumption	10	8	49	28
Total Benefits	**2,949**	**2,194**	**1,980**	**3,010**
Costs				
Construction	692	424	424	459
ROW	74	48	48	52
Annual O&M	14	15	16	15
CVHAS—Facility	0	0.4	1.6	0.8
CVHAS—Vehicle	0	146	269	40
Total Costs	**780**	**634**	**758**	**566**
Benefit/Cost Ratio	**3.78**	**3.46**	**2.61**	**5.32**

Source: Adapted from Shladover, S. E., *Advanced Vehicle Technologies and Exclusive Truck Lanes: Research from California PATH Program*, presented at Transportation Research Board Annual Meeting, Washington, D.C., January 2006.

staged automation, represented by Alternative 5, showed the best benefit/cost ratio. The authors concluded that automation is able to improve the performance of the freight movement system, but timing and how it is deployed are important in determining efficiency and success. The implication is that, as the authors noted, the incremental costs of deploying CVHAS *from the start* outweighed the incremental benefits, as compared with the more conventional CMV-only lanes without CVHAS technologies. On the other hand, Alternative 5 deployed CVHAS at the "right" time, when the cost of the technologies was reduced and the trucking industry was better prepared for the innovative technologies, leading to higher levels of market penetration. Their research recommended for further investigation a concept consisting of a CMV-only facility open to all trucks before 2015, and then upgraded to an automated highway open only to automated trucks.

In 2006, at the TRB Annual Meeting, Shladover[16] looked at the Chicago case study and a Los Angeles study of nonautomated versus automated dedicated truck lanes on SR 60 (also conducted for the California PATH Program) to draw conclusions about advanced technologies and CMV-only lanes. In both the TRB presentation and a recapitulation of the Chicago case study (published in the PATH *Intellimotion* periodical, also 2006), Shladover[17] reported that close-formation, three-truck platoons double the throughput per lane of a CMV-only facility. Greater increases are possible with larger platoons. Further, needed lane widths also can be reduced. As a result, even in corridors with very high truck volumes, ROW requirements may be reduced along with associated construction costs. Shladover also reported significant fuel consumption savings due to reduced aerodynamic drag on trucks that are electronically linked into platoons, although he said emissions reductions are less certain. He noted that truck lanes offer a "protected environment where implementation of truck automation can be effected with a high probability of trucks being able to follow each other directly, without interference from light-duty vehicles, and with reduced technical

[16]S. E. Shladover, *Advanced Vehicle Technologies and Exclusive Truck Lanes: Research from California PATH Program,* Transportation Research Board Annual Meeting, Washington, D.C., January 2006.
[17]S. E. Shladover, "Improving Freight Movement by Using Automated Trucks on Dedicated Truck Lanes: A Chicago Case Study," California PATH *Intellimotion,* Vol. 12, No. 2, 2006.

and safety risks compared to implementations that would require coexistence with unequipped passenger cars."

VanderWerf et al.[18] in a 2004 PATH report, summarized the key benefits of truck automation that would accrue to commercial vehicle operators, as follows:

- Substantial reduction in fuel consumption, on the order of 10% to 20%, would considerably reduce operating costs;
- Reduced and predictable travel times resulting from automated truck platoons would improve the utilization of capital equipment and the ability to meet delivery deadlines; and
- Drivers could travel long distances while resting and earning payment, thereby resolving some of the current problems with driver fatigue and hours of service.

VanderWerf et al. have noted that fully automated trucks on dedicated lanes are being studied in a prototype project called the Underground Logistics System that links the Amsterdam flower market with a major train station and the Schiphol Airport with fully autonomous electric shuttles for small containers.

There has been substantial interest in tolled CMV-only lanes. The rationale, which is discussed later in this chapter, is that if these lanes can generate productivity benefits for users through higher speeds and/or LCV operations, the public sector may be able to share this value with the private sector through tolling that helps generate a new revenue stream to pay for the infrastructure. A major component of this approach is the ability to utilize electronic toll collection technologies that could tap into existing toll collection programs and other types of electronic screening programs. A more extensive discussion of electronic toll collection technologies is included in Appendix A.

2.3.2 ITS/CVO Applications for Weight and Safety Enforcement on CMV-Only Lanes

High-speed, mainline weigh-in-motion (WIM) systems offer states the opportunity to automatically verify weights of trucks traveling at highway speeds on CMV-only lanes. Weight limits can be monitored actively on truck facilities to assure pavement preservation and, when used on toll truckways, equitable collection of truckway tolls. Many states are deploying unstaffed, remote, or virtual weigh stations that feature mainline WIM, camera systems, and near real-time data transmissions. Such a virtual weigh station can be deployed on dedicated truck lanes to spread the enforcement net of the state. On toll truckways that incorporate LCV operations, because LCVs could be required to travel on the truckways in states and on routes that do not currently allow LCV operations, it would enable the state to cost effectively monitor weights of vehicles. On any CMV-only lanes, all vehicles would be weighed-in-motion, and potential violators could be intercepted at special pull-out areas constructed along the CMV-only facility, or as they exit the facility. Deployment of a virtual weigh station on a toll truckway, however, may be a disincentive to a portion of the industry. The self-financing structure of the facility will cause enforcement options to be scrutinized at least as heavily from the industry viewpoint as from the government viewpoint. In the future, direct or automated enforcement of CMV weight limits (or dimension, safety-related, or credentials regulations) is possible using electronically collected weight (or dimension, safety, or credentials) data.

A wireless roadside inspection (WRI) program has been commissioned by FMCSA (the sponsoring agency of the ITS/CVO and CVISN programs) to validate technologies that can improve safety by leveraging on-board sensor systems and wireless communication of the condition of vehi-

[18]J. VanderWerf, S. Shladover, and M. A. Miller, *Conceptual Development and Performance Assessment for the Deployment Staging of Advanced Vehicle Control and Safety Systems,* California PATH, 2004.

cles and their drivers. The WRI program is expected to be fully deployed in 2012. WRI technologies could be applied to CMV-only lanes to maximize CMV inspections with minimal roadside investment costs.

The roadside components of WRI are envisioned to include equipment, positioned along highways, that supports wireless communications to collect safety data message sets from properly equipped CMVs and provide the message sets to the rest of the WRI system. Roadside equipment will include receiver units and mobile enforcement vehicles. CMV-only facilities can be equipped with the necessary roadside units and, because all the traffic consists of CMVs, there is potential for optimal numbers of inspections, constrained only by the level of participation on the part of CMVs (unless equipment is mandated).

It should be noted that the separation of trucks and cars may not improve the technical aspects of collecting information by ITS/CVO technologies for enforcement or tolling purposes. Automatic vehicle identification (AVI), WIM, and WRI technologies are designed to work in a variety of traffic environments, and would not "work better" technically in CMV-only facilities. However, the separation of trucks and cars would ease the challenges of concentrating trucks in weigh stations or in the outermost lanes of multilane highways in order to capture information from them. In this "captive" environment, few, if any, trucks would be able to avoid size, weight, and/or safety monitoring. As larger numbers of trucks use the CMV-only facilities, enforcement agencies will be able to ensure the compliance of a greater percentage of the CMV population.

2.4 Longer Combination Vehicle Operations

Longer combination vehicles (LCVs) were defined by ISTEA as "any combination of a truck tractor and two or more trailers or semi-trailers which operate on the National System of Interstate and Defense Highways with a Gross Vehicle Weight (GVW) greater than 80,000 pounds." ISTEA also allowed grandfathering of existing LCV operations in states where LCVs were allowed prior to June 1, 1991. Because of their larger size and higher weight limit, several potential advantages have been tied to operating LCVs over smaller, lighter commercial vehicles, including increased productivity, reduced truck traffic, reduced cost per unit cargo, and reduced emissions. Similarly, several disadvantages of LCVs also have been associated with the concept and include potential safety issues, potential increases in pavement damage, potential increases in roadside damage (e.g., shoulders, curbs, roadside signs), and inadequate rest area parking for truck driver relief. Appendix A provides more detailed information about current LCV configurations and size and weight limits by state.

According to the Reason Foundation,[19] the existing United States LCV network is fragmented. Although our economy is dependent on global supply chains and efficient goods movement, our internal network for longer commercial vehicle operations does not support the supply chain either at a national level, or between states. While the western U.S. states have the beginnings of an interstate LCV network, there are no LCV routes that provide connectivity between the western United States and the eastern United States over the Mississippi River.

When discussing the use of LCVs and implementation of multistate LCV corridors, it is natural to probe the issue of truck-rail competition. Trucking remains by far the largest freight transportation mode, carrying around 69% of the tonnage for all goods shipped in the United States.[20] This

---

[19]R. W. Poole, Jr. and P. Samuel, *Policy Study 316, Corridors for Toll Truckways: Suggested Locations for Pilot Projects, Reason Foundation,* February 2004.

[20]2007 Commodity Flow Survey (http://www.bts.gov/publications/commodity_flow_survey/preliminary_tables_december_2008/html/table_01.html).

is due to the fact that nearly 55% of all freight shipped (measured in tons) travels less than 50 mi, and around 78% travels less than 250 mi.[21] Shorter trip lengths with lower lane densities are dominated by trucks, while longer trip lengths with higher lane densities are dominated by rail. In recent years, containerizations have turned rail intermodal into more of a long-distance trucking competitor; however, whether a shipper chooses to use truck or rail to transport goods depends on several key factors, including the type of commodity, distance (transit time), service quality, price, and customer preference. Potentially, implementation of LCVs could influence these factors; however, it is not within the purview of this study to investigate them.

2.4.1 LCV Studies

Reason Foundation Study

In order to mitigate some of the perceived disadvantages of LCV operations noted in the previous section, the Reason Foundation proposes that heavy-duty toll truckways be constructed to complement the existing LCV network.[22] The toll truckways would be constructed with the highest regard for pavement, geometric and safety requirements to allow for use by LCVs. These lanes are proposed to be voluntary to all trucks; however, they would be mandatory for LCVs in non-LCV states. According to the return on investment calculated, these lanes would also be self-funding using the following assumptions:

- Two (14-ft) lanes each way,
- Concrete Jersey barrier separation,
- Separate access/egress ramps,
- Nodes (make-up/breakdown yards),
- Variable tolling (all electronic),
- Voluntary for conventional rigs, mandatory for LCVs, and
- Located in existing freeway corridors.

Although truckers are leery of paying tolls in addition to the other fees and taxes already required, the Reason Foundation concludes that productivity gains made possible by truckways would be so large that trucking companies would be willing to pay tolls to use them.

Table 2.4 shows the truck productivity performance of dedicated truckways (with standard truck and LCV operations) compared to mixed freeways with standard truck operations. The semitrailer is the most common long-haul truck in all 48 contiguous states, while the turnpike double is the largest currently operational LCV. The results of this comparison show that significant gains in truck productivity are possible when trucking companies take advantage of dedicated truckways.

I-35 Trade Corridor Study

The *I-35 Trade Corridor Study*[23] reviewed a variety of alternative scenarios aimed at improving local, intrastate, interstate, and international service on I-35 from Texas to Minnesota. One of the alternatives, Trade Focus Strategy, centered on emphasizing the North American Free Trade Agreement (NAFTA) function of the corridor (through the implementation of a partial NAFTA truckway). The alternative proposes to upgrade highways and use truckways to carry

[21]2007 Commodity Flow Survey (http://www.bts.gov/publications/commodity_flow_survey/preliminary_tables_december_2008/html/table_03.html).
[22]P. Samuel, R. W. Poole, Jr., and J. Holguin Veras, *Toll Truckways: A New Path toward Safer and More Efficient Freight Transportation,* Reason Foundation, June 2002.
[23]HNTB and Wilbur Smith Associates, *I-35 Trade Corridor Study, Recommended Corridor Investment Strategies,* Texas Department of Transportation, September 1999.

Table 2.4. Comparison of truck productivity between truckway and mixed freeway.

	Mixed Freeway Semitrailer	Truckway Semitrailer	Truckway Triple Short	Truckway Turnpike Double
Payload (Pounds)	45,000	45,000	67,500	90,000
Metric Tons	20	20	30	40
100-mi Delivery (2004 Freight Rates)	$500	$500	$750	$1,000
Average Speed on the Road	38 mph	60 mph	60 mph	60 mph
Miles Driven in 8-h Shift (6 h Driving)	228 mi	360 mi	360 mi	360 mi
Revenue from 6 h Payload at 2004 Rates	$1,140	$1,800	$2,700	$3,600
Variable Costs	$684	$684	$1,007	$1,165
Available for Overhead, Profits, Tolls	$456	$1,116	$1,693	$2,435
Extra Earnings from Using Truckways per Shift per Day	N/A	$660	$1,237	$1,979
Assume Extra Productivity Split Three Ways	N/A	$220	$412	$660
Shipper Savings on 100-mi Delivery	N/A	$61/12.2%	$76/15.2%	$91/18.3%

Source: Adapted from Poole, Jr., R.W. and P. Samuel, *Toll Truckways: Increasing Productivity and Safety in Goods Movement*, Reason Foundation, http://www.fhwa.dot.gov/download/hep/freightplanning/talkingfreight3_16_05bp.ppt.

commercial vehicles with larger size and weight limits, where practical, for saving in purchase of additional ROW.

The study resulted in the Trade Focus Strategy being recommended with best scores in categories of socioeconomic, environmental, traffic (i.e., operating cost, accident cost savings, and travel time savings), and feasibility. This alternative scored highest in these categories because of the cost-effectiveness of being able to add exclusive lanes for trucks, only where they are required. The study did note that there would be several obstacles to promoting the Trade Focus Strategy through this multijurisdictional study corridor. However, the biggest benefits would be derived by creating a seamless corridor. Some of the key factors that will impact the effectiveness of LCV operations include organizational complexity, regulatory complexity, carrier participation, credentials, and truck size and weight uniformity.

Western Uniformity Scenario Analysis

The Western Governors' Association requested that U.S.DOT[24] assess the impacts of lifting the LCV freeze and allowing harmonized LCV weights, dimensions, and routes among only those western states that currently allow LCVs. The assumption was made that weights would be limited to a maximum gross vehicle weight of 129,000 lbs, and that any benefits achieved would be limited because of the limited scope of the study (i.e., it did not take the whole nation into account). Table 2.5 shows that if LCVs were harmonized in these states, it is predicted that there would be a 76% reduction in travel by conventional five-axle tractor-semitrailers, a 44% reduction of STAA doubles (Surface Transportation Assistance Act of 1982 [STAA] description as five- or six-axle twin trailers with maximum trailer lengths of 28.5 ft) travel, and a 25% reduction in total heavy truck travel. "Because shipments that would divert to LCVs are longer than shipments that would not divert, the decrease in total travel is greater than the decrease in shipments by

[24]U.S.DOT, April 2004, *Western Uniformity Scenario Analysis: A Regional Truck Size and Weight Scenario Requested by the Western Governors' Association.*

Table 2.5. Forecasts of 2010 base case VMT by vehicle configuration and western uniformity VMT impact for 13 analyzed states.

Vehicle Configuration	Base Case VMT (Millions)	Scenario VMT (Millions)	Scenario Percent Change
Five-Axle Tractor Semitrailer	14,476	3,442	-76%
Six-Axle Tractor Semitrailer	1,924	938	-51%
Five- or Six-Axle Double	1,351	750	-44%
Six-Axle Truck Trailer	626	607	-3%
Seven-Axle Double	188	2,190	+1,065%
Eight-or-More-Axle Double	213	5,626	+2,541%
Triples	45	473	+951%
Total	**18,823**	**14,028**	**-25%**

Source: U.S.DOT, *Western Uniformity Scenario Analysis: A Regional Truck Size and Weight Scenario Requested by the Western Governors' Association*, April 2004, http://www.fhwa.dot.gov/policy/otps/truck/wusr/wusr.pdf.

tractor-semitrailer. On a tonnage basis, less than one-half of tractor-semitrailer shipments was estimated to divert to LCVs."[25]

Although costs increase due to bridge and geometric improvements, it is expected that pavement costs will be reduced due to the reduced number of VMT. Also, note that many of the LCV routes are currently designated as such, and already have strengthened pavement and bridges. The costs reported in the study may not be typical of new, exclusive CMV-only applications.

Finally, one of the most significant benefits highlighted in this study is that of shipper savings. Considering that the majority of freight on the system travels by truck (approximately $610 billion in business per year), even a modest saving in shipper cost can make a significant difference. This study suggests that by expanding LCV operations, shipper costs may be reduced by as much as $2 billion per year, representing an almost 4% saving of total shipper costs within the region.

2.4.2 Policy Changes Required for LCV Implementation

Appendix A notes that there are a number of regulatory and policy changes that would be needed to facilitate LCV implementation for CMV-only lanes. The Reason Foundation has provided several recommendations with respect to LCV operations, which include the following:[26]

- Provision of ROW in interstate and freeway corridors,
- Liberalized size and weight limits on truckway lanes, and
- Removal of ban on interstate tolling for truckway lanes.

2.5 Tolling and Privatization

The application of tolls for trucks operating on CMV-only lanes and use of the toll revenues to finance them has been reported to be a particularly promising concept in a variety of studies, due to the higher value of time and reliability of trucks compared to passenger vehicles, and the congestion reduction benefits for trucks operating on CMV-only lanes. Studies conducted by the Rea-

[25] U.S.DOT, April 2004, *Western Uniformity Scenario Analysis: A Regional Truck Size and Weight Scenario Requested by the Western Governors' Association.*
[26] R. W. Poole, Jr. and P. Samuel, *Policy Study 316, Corridors for Toll Truckways: Suggested Locations for Pilot Projects,* Reason Foundation, February 2004.

son Foundation have supported the implementation of toll truckways with LCV operations, based on the rationale that operating LCVs on dedicated truckways offer truckers not only travel time and reliability benefits, but increased productivity, for which truckers would be willing to pay higher tolls.

2.5.1 Truck Value of Time

In order to assess the feasibility of tolling CMV-only lanes, it is important to understand how truck operators value time savings. Generally speaking, a trucker's value of time is a function of many factors, which include, but may not be limited to, the type of trucking business operation (for example, for-hire and private carriers), truck trip length characteristics (short-haul versus long-haul trips), the type of truck (medium versus heavy trucks), the type of delivery schedule (not fixed delivery schedule versus penalty on late delivery), as well as the type of highway facility (noncongested rural highways and heavily congested urban areas). Several methods have been employed to measure a trucker's value of time, including the following:

- **Revenue or net operating profit method.** This method estimates truck value of time in terms of the net increase in profit resulting from reduction in travel times.
- **Cost-saving method.** This method estimates truck value of time in terms of the cost savings to truck operators per unit of time.
- **Cost-of-time method.** This method calculates the cost of providing time savings for a specific project.
- **Willingness-to-pay method.** This method measures the "market" or "perceived" value of time for trucks based on observed or stated choices under tradeoff situations involving time and money.

Appendix A includes data from several studies that have addressed value of time using these methods and the application of these methods to estimate optimum toll rates with various values of time assumptions.

2.5.2 Productivity Benefits from LCV Operations and Associated Tolling Implications

The Reason Foundation study[27] on toll truckways discussed earlier is the first comprehensive study that looks at the feasibility of developing toll truckways to support LCV operations, based on considerations of productivity benefits of LCV operations. The study analyzes how productivity benefits from LCV operations and toll truckways would provide the incentive for the application of tolls on these truckways as a way of financing such facilities. Toll truckways, because of their physical separation from general purpose lanes, also address safety concerns of operating LCVs on general purpose lanes by completely eliminating the interaction between autos and LCVs.

The Reason Foundation approach for the quantification of productivity benefits from LCV operations is based on the estimation of the incremental earnings for truck operators per day and the average number of miles driven per day on toll truckways, to arrive at the incremental earnings per mile. Thus, the approach not only considers the increase in payload due to LCV operations, but also includes the productivity gains associated with higher speeds on toll truckways, in the quantification of productivity benefits. The inherent assumption in this analysis is that trucking firms would be willing to pay one-third of the value of productivity benefits from LCV operations in the way of tolls.

---

[27]P. Samuel, R. W. Poole, Jr., and J. Holguin Veras, *Policy Study 294, Toll Truckways: A New Path toward Safer and More Efficient Freight Transportation,* Reason Foundation, June 2002.

Table 2.6. Private ROI for toll truckways for 40,000 ADT.

Traffic ($1 Million/Mile Capital Cost)	Toll = $0.40	Toll = $0.80
25% Trucks (1,000)	8.60%	17.26%
50% Trucks (2,000)	16.85%	33.12%
75% Trucks (3,000)	23.92%	48.46%
100% Trucks (4,000)	32.72%	64.52%
$2 Million/Mile Capital Cost		
25% Trucks (1,000)	4.12%	9.17%
50% Trucks (2,000)	8.85%	17.34%
75% Trucks (3,000)	13.04%	25.31%
100% Trucks (4,000)	16.97%	33.19%
$3 Million/Mile Capital Cost		
25% Trucks (1,000)	2.26%	6.23%
50% Trucks (2,000)	5.97%	12.02%
75% Trucks (3,000)	9.03%	17.40%
100% Trucks (4,000)	11.76%	22.66%

Source: Reprinted from Samuel, P., R. W. Poole, Jr., and J. Holguin Veras, *Policy Study 294, Toll Truckways: A New Path toward Safer and More Efficient Freight Transportation,* Reason Foundation, June 2002, http://reason.org/files/cce62e3a8ed97d31be8e1094f658968a.pdf.

The study compared a variety of different LCV configurations with conventional semitrailer configurations to determine the potential productivity gains from LCV operations. Based on the results from this study, double-long LCV operations on toll truckways yield maximum productivity benefits and, consequently, the maximum toll rates These are followed by triple-short LCV operations. The maximum feasible toll rate is observed for double-long trucks of $1.83 per mile, followed by $1.15 per mile for triple-short trucks.

Appendix A considers a number of issues associated with the policy and tax implications of tolling truckways and industry concerns. It also provides a discussion of how revenues from tolls could be used to support various forms of financing for the facilities. The notion of privatized toll facilities has been offered as an attractive option for financing CMV-only lanes, because this approach can provide access to large pools of new capital, transfer risk from the public to the private sector, create potential to develop multistate projects, and other potential innovations associated with design and operations concepts. In order to demonstrate the potential viability of CMV-only lanes operating as private facilities, Samuel et al.[28] examined various operating scenarios based on assumptions about capital costs, percent of trucks using the facility (based on average rural interstate truck volumes), and toll rates. The results were presented as potential return on investment (ROI is a measure used to quantify the profitability of an investment for the private sector in relation to the total cost of the investment).

As seen from Table 2.6, the ROI for the private sector is directly proportional to the toll rate and the number of trucks using the CMV-only lanes. Positive ROIs are observed for all the scenarios analyzed (based on varying assumptions related to capital cost, truckway utilization, and toll rates), implying that the investment is always profitable under the given scenarios. The profitability (ROI)

[28]P. Samuel, R. W. Poole, Jr., and J. Holguin Veras, *Policy Study 294, Toll Truckways: A New Path toward Safer and More Efficient Freight Transportation,* Reason Foundation, June 2002.

increases with increased truckway utilization as higher toll revenues (and net earnings) are generated for a given toll rate and capital cost. However, it is important to note that the number of trucks using the CMV-only lanes (utilization) would be a function of the toll-rate. Thus, the results from the table would be particularly useful in analyzing what the optimal toll rates should be that would result in the highest ROI, based on the determination of the percent trucks using the CMV-only lanes (utilization) for different toll rate scenarios (typically, this can be done using data on truck value of time and an understanding of truck behavior under tolls using stated preference surveys).

Appendix A provides information about some recently proposed public-private partnerships in which CMV-only lanes have been incorporated.

2.5.3 Examples of Truck Tolling Approaches from Other Countries

Appendix A presents information on national truck tolling systems that have been implemented in Austria, Switzerland, and Germany. None of these systems are applied on CMV-only facilities. The approaches use different types of electronic toll collection and/or global positioning system (GPS) data systems to collect information about truck use of facilities. These approaches could be applied to tolling/financing of CMV-only lanes.

CHAPTER 3

Performance Evaluation

3.1 Introduction

This chapter presents the results of the work conducted as part of Task 8 (Performance Evaluation) of the project. The primary objective of the performance evaluation task was to conduct a comprehensive comparative assessment of the performance of different truck-only lane concepts, as well as concepts without truck-only lanes.

The analysis is based on a detailed review of analytical/modeling studies of truck-only lane projects and field data from real-world truck-auto separation concepts in the United States and internationally, to the extent that data were available. The performance assessment effort did not involve any new modeling work. Rather, we evaluated each truck-only lane concept against a standard set of performance measures, which are discussed in the following sections:

- **Performance Evaluation Approach** describes the main types of truck-only lane concepts (scenarios) included in the analysis, the types of system improvements (alternatives) considered for the relative performance assessment, the selected set of performance measures, the data sources used for the evaluation, and the methodology used to compile, summarize, and assess the results from the various data sources.
- **Performance Evaluation Results** provides a discussion of the performance analysis results from each of the selected data sources, as well as a comparative summary and analysis of results for each performance measure across data sources to arrive at a consistent assessment of the relative performance of truck-only lane concepts compared to other types of system improvements (alternatives).

3.2 Performance Evaluation Approach

The study team's performance evaluation was based on a procedure that pulled together data reported in other studies in a way that allowed the team to compare the results of, and develop consistent performance metrics for, a variety of different truck-only lane concepts. This approach, shown in Figure 3.1 relied on existing data and information available from evaluations of truck-only lane concepts—the study team did not define new alternatives to be evaluated, develop new data, or conduct new modeling or other detailed analyses. A description of each of the steps shown in Figure 3.1 is presented in this section.

Although this approach presents certain limitations in terms of the types of alternatives that can be compared, the types of performance measures that can be evaluated reliably, and the ability to validate the results of the analysis, it does provide a consistent basis by which different truck-only lane concepts can be compared. This kind of apples-to-apples comparison allowed the researchers to identify the most promising concepts and scenarios for further evaluation in a more

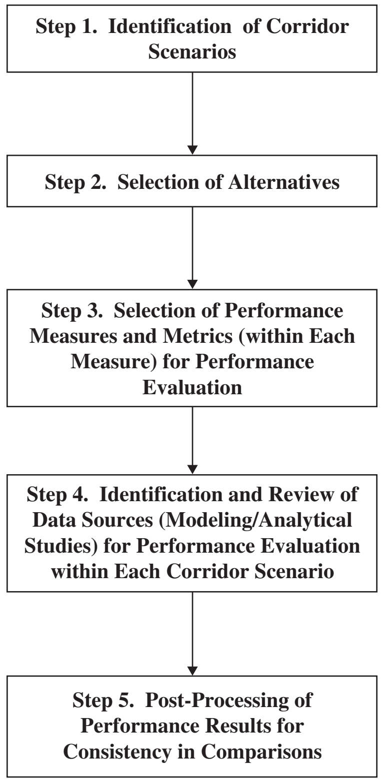


Figure 3.1. Steps involved in truck-only lane performance evaluation.

controlled setting. In addition, this approach clearly defines some of the most critical research and data gaps and helps frame ideas for future research as discussed in the final chapter of this report.

Step 1. Identification of Corridor Scenarios

The first step in the performance evaluation approach involved the identification of key corridor scenarios for the performance evaluation of truck-only lanes. Two main generic scenarios were identified for the analysis, which included: (1.) long-haul intercity corridors and (2.) urban corridors. These two types of corridor scenarios are broadly representative of the major types of corridors for which truck-only lanes have been proposed in the past.

- **Long-haul corridors** include intercity corridors that serve long-haul truck and auto traffic demand. Truck traffic along these corridors is predominantly composed of large (five or more axle) combination trucks moving long-haul freight. Some examples of key long-haul corridors in the U.S. carrying high truck volumes include I-15 between Barstow and Las Vegas, I-94 between Chicago and Detroit, I-5 between Bakersfield and Sacramento, and I-90 between Cleveland and Buffalo. Some of the characteristics of long-haul corridors that would make them particularly good candidates to consider for potential implementation of CMV-only lanes include travel demand (auto and truck traffic volumes), congestion, and LCV network connectivity. Additional discussion of these issues is presented in a later section.
- **Urban corridors** include short-haul corridors in urban areas serving as primary access routes to major freight facilities (such as seaports) or major auto and truck travel corridors in major metropolitan areas. Examples of such corridors include the I-710, SR 60, and I-15 freeways in

Southern California; the I-395, I-95, SR 112, and SR 836 corridors serving the Port of Miami, Florida; and the I-75, I-85, and I-285 freeways in metropolitan Atlanta.

Step 2. Selection of Alternatives

The second step was to select the range of operational and infrastructure investment alternatives against which to evaluate the performance of different truck-only lane scenarios. It is important to note that because our truck-only lane performance evaluation relied on existing feasibility studies and analyses, the range of potential investment alternatives to consider was limited to those evaluated as part of these existing efforts.

Table 3.1 describes the types of alternatives that the study team assessed for both of the truck-only lane scenarios. Since the applicability and viability of various system improvement options is a function of corridor characteristics, the set of alternatives selected for the performance evaluation was specific to each of the two scenarios. To understand the relative performance benefits of truck-only lanes, a no-build alternative was included in all of the analyses in order to compare the performance of truck-only lanes with an alternative without truck-only lanes. Additional alternatives were included in the evaluation process, depending on the availability of performance data.

Step 3. Selection of Performance Measures and Metrics

Because different truck-only lane scenarios may have different performance objectives, appropriate performance measures and metrics must be evaluated for each truck-only lane scenario. It is more critical to assess potential productivity gains along long-haul corridors, for instance, than

Table 3.1. Alternative types by corridor scenario.

Scenario	Alternatives	Description
Long-Haul Corridors	No-build (without LCV operations)	Includes all committed improvement projects to be implemented along the study corridor in the future, without LCV operations
	No-build (with LCV operations)	Includes all committed improvement projects to be implemented along the study corridor in the future, along with LCV operations on general purpose lanes
	CMV-only lanes without LCV operations	Includes implementation of truck-only lanes along the study corridor (in addition to the projects included in no-build), but without LCV operations
	CMV-only lanes with LCV operations	Includes implementation of truck-only lanes along the study corridor (in addition to the projects included in no-build), along with LCV operations on truck-only lanes
Urban Corridors	No build	Includes all committed improvement projects to be implemented along the study corridor in the future
	Additional general purpose lanes	Includes implementation of additional general purpose lanes along the study corridor (in addition to the projects included in no-build as well as Transportation Supply Management/Transportation Demand Management (TSM/TDM*) strategies)
	CMV-only lanes	Includes implementation of truck-only lanes along the study corridor (in addition to the projects included in no-build as well as TSM/TDM strategies), without the application of tolls

Note:

*TSM strategies include projects that optimize transportation system supply in a region to handle demand. For example, managed lanes optimize capacity of a roadway network by varying bidirectional lane capacities of a roadway for the morning and evening peak periods to account for varying commute travel demand in these time periods. TDM strategies include projects that optimize the demand on the transportation system, to encourage optimal system capacity utilization. An example of a TDM strategy is congestion pricing, which manages demand during congested time periods through the use of user fees.

along urban corridors. Conversely, congestion relief or travel time reliability benefits might be more relevant for urban corridors. It is important to note that this section is solely dedicated to analyzing the relative performance of truck-only lanes (based on consideration of a key set of performance measures) against other alternatives, without consideration of costs. Chapter 4 looks specifically at the net performance benefits of truck-only lanes compared to other alternatives based on an estimation of benefit-cost (B-C) ratios.

The performance measures/metrics considered to guide the study team's evaluation process are as follow:

- **Travel Time.** This measure is used to quantify the mobility benefits of truck-only lanes compared to other alternatives. The benefits are quantified in terms of percent savings in travel time for the build alternatives (including the truck-only lane alternative) compared to the no-build alternative. For the truck-only lane alternative, travel time savings are estimated primarily for autos (and trucks) on general-purpose lanes (and for trucks on truck-only lanes to the extent to which these savings were quantified in the reviewed studies).
- **Travel Time Reliability.** Travel time reliability is measured by the percent change in incident-related (nonrecurrent) delay for the build alternatives (including the truck-only lane alternative) compared to the no-build alternative. The following key aspects of truck-only lanes expected to contribute to reliability improvements along a corridor include:
  - Reduction in accidents due to mobility improvements on the general purpose lanes (due to diversion of trucks to truck-only lanes),
  - Accident reduction due to truck-auto separation and improvements in general flow conditions due to less weaving of trucks and autos, and
  - Increased capacity on the general purpose lanes resulting in improved processing of bottlenecks during incidents (increased capacity will result in increased efficiency in alleviating the traffic impacts of incidents).
- **Productivity.** This measure is used to quantify the productivity enhancements realized by the private sector (shippers and carriers) due to operations on truck-only lanes. The parameter used to quantify productivity benefits is the increase in net earnings (revenue less cost) per ton mile[29] for carriers. This parameter is computed based on (1.) the contribution of speed improvements on truck-only lanes to increased productivity of trucking operations (i.e., increased trucking industry earnings per ton mile from improvements in truck operating speeds); and (2.) contribution of LCV operations to productivity enhancements (increased net earnings per ton mile due to increase in truck payloads).
- **Safety.** Safety benefits are quantified in terms of reduction in the number of accidents on general purpose lanes for the build alternatives (including the truck-only lane alternative) relative to the no-build alternative. Truck-only lanes also contribute to safety improvements along a corridor by improving mobility on the general purpose lanes, and by reducing interactions between autos and trucks by diverting trucks to truck-only lanes.

Step 4. Identification and Review of Data Sources

As described earlier, the study team's evaluation approach relied on data and information from existing planning and analytical/modeling studies of truck-only lane projects conducted in the United States. Although there have been a number of truck-only lane projects, studies, and

[29]*Earnings per ton mile* is an appropriate parameter to quantify productivity benefits of truck-only lanes because it can capture increased earnings for truckers due to improved speeds and an increase in payloads. Improved speeds (for truckers on truck-only lanes) would result in a reduction in operating costs per mile, which would translate into increased net earnings per mile. An increase in payloads (from LCV operations on truck-only lanes) would result in reduction in operating costs per ton, which would result in increased net earnings per ton.

Table 3.2. Alternatives considered within long-haul corridor truck-only lane studies.

Study	No-Build	General Purpose Lanes with LCVs	Truck Lanes with LCVs	Truck Lanes without LCVs
Reason Foundation Study	✓		✓	✓
Western Uniformity Scenario Analysis	✓	✓		
I-35 Trade Corridor Study	✓		✓	
Georgia *Statewide Truck Lane Needs Identification Study*	✓			✓

initiatives in the United States, the study team only used those studies that analyzed long-haul or urban corridors and provided performance analysis results that could be used, either directly or after post-processing, for the performance evaluation process. The following data sources were used for performance evaluation:

- Long-haul corridors
  - Reason Foundation study on long-haul truck corridors,[30]
  - *Western Uniformity Scenario Analysis,*[31]
  - *I-35 Trade Corridor Study,*[32] and
  - Georgia *Statewide Truck Lane Needs Identification Study.*[33]
- Urban corridors
  - *I-710 Major Corridor Study,*[34]
  - *I-15 Comprehensive Corridor Study,*[35]
  - Georgia *Statewide Truck Lane Needs Identification Study,*[36] and
  - PSRC FAST corridor study.[37]

Tables 3.2 through 3.5 describe the alternatives considered by each of these studies, and provide information on which of the key performance metrics described in this section (travel time, travel time reliability, productivity, and safety) are considered in these studies.

It is clear from this analysis that different truck-only lane scenarios have different performance objectives. Long-haul corridor scenarios, for instance, are concerned with improving overall travel time, productivity, and safety (in cases where corridor configurations and truck-auto interactions are having safety impacts). As part of the performance analysis, these studies typically compared truck-only lane concepts against a no-build alternative (and, in some cases, against the benefits

[30]R. W. Poole, Jr. and P. Samuel, *Toll Truckways: Increasing Productivity and Safety in Goods Movement,* Reason Foundation, http://www.fhwa.dot.gov/download/hep/freightplanning/talkingfreight3_16_05bp.ppt.
[31]U.S.DOT, *Western Uniformity Scenario Analysis: A Regional Truck Size and Weight Scenario Requested by the Western Governors' Association,* April 2004.
[32]HNTB and Wilbur Smith Associates, *I-35 Trade Corridor Study: Recommended Corridor Investment Strategies,* Texas Department of Transportation, September 1999.
[33]Georgia Department of Transportation, *Statewide Truck Lane Needs Identification Study,* "Technical Memorandum 3: Truck-Only Lane Needs Analysis and Engineering Assessment," April 2008.
[34]Los Angeles County Metro, *I-710 Major Corridor Study: Final Report,* March 2005.
[35]Southern California Association of Governments, *I-15 Comprehensive Corridor Study,* December 2005.
[36]Georgia Department of Transportation, *Statewide Truck Lane Needs Identification Study,* "Technical Memorandum 3: Truck-Only Lane Needs Analysis and Engineering Assessment," April 2008.
[37]Kuppam, et al., *Evaluating Freight Mobility on a Regionwide Basis Using EMME/2—Freight Action Strategy (FAST) Truck Model for the Puget Sound Region,* 16th International EMME/2 User's Group Conference, Albuquerque, New Mexico, March 2002.

Table 3.3. Alternatives considered within urban corridor truck-only lane studies.

Study	No-Build	Mixed-Flow Lanes	Truck-Only Lanes	TSM/TDM Strategies
I-710 Major Corridor Study	✓	✓	✓	✓
I-15 Comprehensive Corridor Study	✓	✓	✓	✓
Georgia *Statewide Truck Lane Needs Identification Study*	✓		✓	
PSRC FAST Corridor Study	✓		✓	

Table 3.4. Performance metrics described within long-haul corridor truck-only lane studies.

Study	Travel Time	Productivity	Safety
Reason Foundation Study		✓	
Western Uniformity Scenario Analysis		✓	
I-35 Trade Corridor Study	✓		✓
Georgia *Statewide Truck Lane Needs Identification Study*	✓	✓	✓

Table 3.5. Performance metrics described within urban corridor truck-only lane studies.

Study	Travel Time	Reliability	Safety
I-710 Major Corridor Study	✓	✓	✓
I-15 Comprehensive Corridor Study	✓	✓	✓
Georgia *Statewide Truck Lane Needs Identification Study*	✓	✓	✓
PSRC FAST Corridor Study	✓		

and impacts of LCV operations on truck-only lanes). Conversely, urban corridor scenarios are more concerned with improving overall travel time, travel time reliability, and safety. Truck-only lane concepts in these areas were compared with other congestion-reduction alternatives, such as additional general purpose (GP) lanes and transportation system management strategies. As a result, these different scenarios use different performance metrics—long-haul corridors use travel time, productivity, and safety measures, while urban corridors calculate travel time, reliability, and safety measures.

Recognizing these key differences, the study team structured their evaluation approach to normalize only those performance metrics that are applicable to each corridor scenario, as shown in Table 3.6.

Step 5. Post-Processing of Performance Results

In order to ensure consistent comparisons of performance results, the study team found it necessary to normalize the results from studies in order to develop a common metric for comparisons. The team used post-processing factors in cases where the desired performance metric was not esti-

Table 3.6. Applicability of performance measures to scenarios.

Performance Measure	Scenario	
	Long-Haul Corridors	Urban Corridors
Travel Time	✓	✓
Travel Time Reliability	N/A	✓
Productivity	✓	N/A
Safety*	✓	✓

Note:

* There appear to be some key limitations in the evaluation methodologies and tools used to assess the safety benefits of truck-auto separation. However, there is a body of research (described in subsequent sections) that will allow us to consider safety impacts using post-processing techniques.

mated in a study, or where limitations were identified in the approach used by studies in the estimation of specific performance metrics. Post-processing tools and sources included the following:

- **Intelligent Transportation System (ITS) Deployment Analysis System (IDAS).** IDAS is an analytical tool that provides post-processing factors for the performance evaluation of transportation capacity improvement strategies. Although the tool is intended to analyze the performance benefits of ITS deployments, the factors can be used to assess other transportation investments as well (such as infrastructure projects), as long as information is available on the level of capacity improvement achieved on the transportation system. The post-processing factors used from IDAS for the performance evaluation included the following:
  – Accident rates (number of accidents per million VMT) by type of accident for autos and trucks as a function of V/C[38] ratio, for the estimation of safety benefits (reduction in accidents); and
  – Incident delay rates (hours of incident-delay per vehicle mile) as a function of V/C and number of lanes, for the estimation of reliability benefits (savings in incident-related delay).
- ***Handbook for Planning Truck Facilities on Urban Highways***[39] **(Douglas handbook) and New Jersey Turnpike Accident Data.** The Douglas handbook serves as a compendium of key issues related to the planning, policy, and performance/feasibility evaluation of truck facilities. The handbook provides recommendations on approaches to analyze the performance benefits of truck facilities. The handbook, based on an analysis of historic accident statistics for the New Jersey Turnpike, recommends a 15% accident reduction factor due to truck-auto separation (not taking into consideration the safety benefits of capacity improvements). This 15% accident reduction factor is used in the study team's analysis. (A summary of historic accident statistics on the dual-dual and non dual-dual sections of the New Jersey Turnpike and the basis for arriving at a 15% accident reduction factor to account for the safety benefits of truck-auto separation is provided in Appendix B, Section B.3, which is available on the TRB website at www.TRB.org by searching for NCHRP Report 649/NCFRP Report 3).

3.3 Performance Evaluation Results

The following sections provide a brief overview of each of the major truck-only lane studies identified in Step 4, discuss important findings within the four key performance metrics identified in Step 3 (Selection of Performance Measures and Metrics), and identify key assumptions and data

[38]V/C is a parameter used to quantify the level of congestion on a roadway. It is calculated as the ratio of the level of demand (traffic volume) to the supply (capacity of roadway). Typically, V/Cs are measured for a specific time period (e.g., hourly or daily).

[39]J. G. Douglas, *Handbook for Planning Truck Facilities on Urban Highways,* August 2004. This reference was used primarily to estimate safety benefits consistently.

Table 3.7. Reason Foundation study's truck-only lane productivity benefits.

	Mixed Freeway Semitrailers	Truckway Semitrailer	Truckway Triple Short	Truckway Turnpike Double
Payload (Pounds)	45,000	45,000	67,500	90,000
Metric Tons	20	20	30	40
100-mi Delivery (2004 Freight Rates)	$500	$500	$750	$1,000
Average Speed on the Road	38 mph	60 mph	60 mph	60 mph
Miles Driven in 8-h Shift	228	360	360	360
Revenue from 6-h Payload at 2004 Rates	$1,140	$1,800	$2,700	$3,600
Variable Costs	$684	$684	$1,007	$1,165
Earnings (Revenue—Costs)	$456	$1,116	$1,693	$2,435
Earnings (per Ton-Mile)	$0.100	$0.155	$0.157	$0.169
Productivity Benefit (% Increase in Earnings per Ton-Mile) (Truck Lanes Compared to Mixed-Flow Lanes)	–	55%	63%	
Productivity Benefit (% Increase in Earnings per Ton-Mile) (Truck Lanes with LCVs Compared to Truck Lanes without LCVs)	–	–	5%	

Source: Adapted from Poole, Jr., R. W., and P. Samuel, *Toll Truckways: Increasing Productivity and Safety in Goods Movement*, Reason Foundation, 2005, http://www.fhwa.dot.gov/download/hep/freightplanning/talkingfreight3_16_05bp.ppt.

gaps that hindered the study team's ability to draw specific conclusions from each of these scenarios. A more detailed discussion and summary of each of these studies is provided in Appendix B (Sections B.1 and B.2, which are available on the TRB website at www.TRB.org by searching for NCHRP Report 649/NCFRP Report 3).

3.3.1 Long-Haul Corridors

The following sections present the results of the performance evaluation of truck-only lanes along long-haul corridors, based on a detailed review of studies listed in Step 4.

Reason Foundation Study

The Reason Foundation conducted an analysis[40] of toll truckways that compared the incremental productivity benefits of three types of truck-only lanes to mixed-flow facilities without LCV operations (the no-build scenario). In addition to a "standard" semi-trailer option (i.e., 80,000-lb, 53-ft trailers), two LCV options were evaluated—one allowing triple shorts and one allowing turnpike doubles. The Reason Foundation study is useful in presenting an illustrative methodological framework for the analysis of productivity benefits and for providing estimates to determine the relationship between speed improvements and LCV operations, as well as productivity benefits measured in terms of increased earnings per truck per ton mile. Table 3.7 presents the productivity benefits per truck estimated by the Reason Foundation study to provide insights into the following areas:

- Relative productivity benefits of truck-only lanes (with and without LCV operations) compared to a no-build alternative to understand the relative contributions of travel time savings and LCV operations on truck-only lanes to productivity benefits and

[40]R. W. Poole, Jr. and P. Samuel, *Toll Truckways: Increasing Productivity and Safety in Goods Movement,* Reason Foundation, http://www.fhwa.dot.gov/download/hep/freightplanning/talkingfreight3_16_05bp.ppt.

- Incremental productivity benefits to trucks from LCV operations on truck-only lanes compared to standard truck operations on truck-only lanes (this provides insights into the productivity benefits associated with increased payloads alone, without taking into consideration the productivity benefits from travel time savings).

Performance Results

Productivity Benefits. As shown in Table 3.7, the productivity benefits of truckways can be attributed to travel time savings, as well as increased payloads from LCV operations. Assuming an equal split of triple-short and turnpike double trucks under the truck-only lanes with the LCV operations alternative, some of the key findings from the Reason Foundation analysis results on productivity benefits are summarized below.

- A large share of the productivity benefits of truck-only lanes are observed to be associated with travel time savings (55% increase in earnings per ton mile from travel time savings compared to 63% from LCV operations, which include the benefits from travel time savings). Thus, the incremental benefits to trucking productivity from LCV operations are observed to be small compared to the benefits from travel time savings. This is because of the assumptions in the Reason Foundation analysis, wherein it is assumed that the no-build alternative experiences significant congestion.
- To quantify the relative productivity benefits of LCVs compared to standard truck operations without considering the contribution of travel time savings to productivity improvements, a comparison was made of the earnings per ton mile between the truck-only lane alternative without and with LCV operations. The study team observed that LCV operations provide only a 5% increase in earnings per ton mile compared to standard truck operations on truck-only lanes.

Travel Time Improvements. The study did not analyze travel time savings.

Safety Improvements. The study did not analyze safety benefits.

Assumptions and Data Gaps. Some of the key assumptions and data gaps in the Reason Foundation approach that potentially impact the ability to draw conclusions about the actual performance benefits of truck-only lanes are as follow:

- The productivity benefits from the study are based on arbitrary assumptions regarding the congestion conditions in the no-build and truckway alternatives. The study assumes a very high average level of congestion in the no-build alternative. As a result, a large share of the productivity benefits accrue from travel time savings compared to the benefits from increase in payload. Due to this assumption, the results from the study could potentially be inconclusive in providing insights into the incremental productivity benefits of LCV operations on long-haul corridors, particularly among corridors with low congestion levels.
- The study does not provide any insights into the diversion potential of truck-only lanes (due to their performance benefits), and only provides estimates for productivity benefits per truck. Thus, the study, although providing a useful analytical framework for the evaluation of productivity benefits of truck-only lanes, can not be used to assess the total productivity benefits of implementing truck-only lanes along a corridor (since these benefits are inherently tied to the total trucks that divert to the truck-only lanes).

Western Uniformity Scenario Analysis

The *Western Uniformity Scenario Analysis*, conducted by U.S.DOT in 2004, analyzed the impacts of lifting the LCV freeze and allowing uniformity in LCV operations (weights and dimensions) among western states with current LCV operations based on a key set of performance criteria, including safety, pavement, bridge and infrastructure costs, shipper costs, energy consumption, environmental quality, and traffic operations. To understand the productivity benefits of LCVs

Table 3.8. Annual shipper cost savings from *Western Uniformity Scenario Analysis.*

Source of Savings	Amount (Millions of 2000 Dollars)	Percentage of Change
Truck to Truck Diversion	2,036	3.9%
Rail to Truck Diversion	3	.01%
Rail Discounts	26	.11%
Total	**2,065**	**n/a**

Source: Reprinted from U.S.DOT, *Western Uniformity Scenario Analysis: A Regional Truck Size and Weight Scenario Requested by the Western Governors' Association,* April 2004, http://www.fhwa.dot.gov/policy/otps/truck/wusr/wusr.pdf.

compared to standard truck operations on general purpose lanes, this section presents the results from the study on shipper cost savings from uniform LCV operations.

The study estimated total annual shipper cost savings resulting from uniform LCV operations in western states of around $2 billion per year, as shown in Table 3.8. The vast majority of these savings would accrue to shippers diverting shipments from standard trucks to LCVs, with minor benefits resulting from rail to LCV diversions and more competitive rail rates provided to shippers.

Performance Results

Productivity Improvements. According to the study, the implementation of LCV operations on existing facilities (to achieve uniformity in LCV operations in all the western states considered in the analysis) will result in total productivity benefits (in terms of shipper cost savings) of close to 4% (around $2 billion annually) compared to the no-build scenario. These benefits are associated with reduced operating costs to the trucking industry from shifting to LCV operations.

Travel Time Improvements. The study did not analyze travel time savings benefits due to LCV operations on mixed-flow lanes.

Safety Improvements. The study, although providing a comprehensive comparative discussion of accident rates associated with LCVs and non-LCVs, does not quantify the safety benefits of the LCV uniformity alternative compared to the base case (no-build).

Assumptions and Data Gaps. Some of the key assumptions and data gaps in this study that potentially impact the ability to gain insights and draw conclusions on the performance benefits of truck-only lanes are discussed below.

- The results from this study have been included in the performance evaluation to assess the relative improvements in productivity from LCV operations compared to standard truck operations. Since the two alternatives in the study do not involve any system capacity improvements, the results provide insights into the productivity benefits solely associated with increased payloads from LCV operations.
- The study quantifies productivity benefits of LCV operations in terms of shipper cost savings, while the total productivity benefits accruing to the trucking industry (in terms of increased earnings from LCV operations, for example) are not reported. Since shipper cost savings only account for a share of the total productivity benefits, the results from the study only provide the lower threshold of the total productivity benefits of LCV operations.
- Since the study does not consider CMV-only lanes as part of the LCV uniformity scenario, results from the study cannot be used to assess the performance benefits of truck-only lanes with LCV operations.

- The study assumes close to 50% diversion of tractor-semi-trailer shipments to LCVs for the LCV scenario, but there is inadequate explanation of the rationale and data to support this assumption. Also, since this assumption is for an LCV uniformity scenario that does not include truck-only lanes, this assumption is expected to not be applicable to a truck-only lane alternative with LCV operations.

I-35 Trade Corridor Study

Completed in 1999, the I-35 Trade Corridor Study evaluated a set of alternatives with the objective of arriving at recommended corridor investment strategies to improve local, intrastate, interstate, and international service along the I-35 corridor between Laredo, Texas, and Duluth, Minnesota, in the future (2025). The results from the study provide some useful insights into the performance benefits of truck-only lanes along long-haul corridors, compared to alternative investment strategies. The primary performance criteria evaluated in the study included savings in vehicle operating costs, travel time savings, and safety benefits.

Performance Results

Productivity Improvements. The study quantified the productivity benefits of the truck-only lane alternative in terms of reduction in truck operating costs. The study estimated that the truck-only lane alternative will provide around 36% savings in truck operating costs compared to the no-build alternative. These savings result from increased travel speeds as well as increased payloads from LCV operations on the truck-only lanes.

Travel Time Improvements. Travel time savings estimates for the various alternatives were derived using the regional travel demand model, which employs volume-delay functions (VDF) to generate vehicle speeds (and travel times) as a function of congestion parameters such as V/C. The study estimated that the truck-only lane alternative provides around 21% savings in travel time compared to the no-build alternative.

Safety Improvements. Since the I-35 study did not estimate percent reductions in accidents associated with truck-only lanes, an attempt was made to quantify the approximate percent improvement in safety, based on the estimation of percent reduction in passenger car equivalents (PCEs), assuming a PCE factor of 2.0 for trucks, on the general purpose lanes. The percent change in congestion (V/C) along the corridor for the truck-only lane alternative (relative to the alternative without truck-only lanes) was assumed to be the same as the percent change in PCEs, since the general purpose lane capacity along the corridor does not change under the two alternatives, and safety benefits are directly proportional to change in corridor congestion. Results from the study indicate an average safety improvement of 38% along the corridor due to truck-only lanes. Since these benefits are solely associated with congestion reduction and do not include the safety benefits of truck-auto separation, an additional accident reduction factor of 15% (as recommended by the Douglas handbook) was applied to the results, providing a total percent reduction in accidents for the CMV-only lane alternative of around 47% compared to the no build alternative.

Assumptions and Data Gaps. Some of the key assumptions and data gaps in this study that potentially impact the ability to draw conclusions about the actual performance benefits of truck-only lanes are discussed below.

- The estimates in the study on the diversion of trucks to the truck-only lanes are observed to be very optimistic, compared to the diversion rates under LCV operations derived in other studies[41] (note that the study referenced is ongoing, and the results from the study on LCV diversion rates are potentially subject to change as more detailed analyses of the diversion potential

[41]FHWA, *Technological Challenges and Policy Implications for LCVs on Exclusive Truck Facilities, I-90 Gap Closing Scenario, Draft Evaluation Results.*

of LCV operations are conducted). The study estimated that the trucks on the truck-only lanes (adjusted for LCVs) accounted for 79% of total trucks. This implies that the assumption in the study on the actual diversion of trucks to the truck-only lanes would be greater than 79%, since the adjustment for LCVs would result in a net reduction of total truck volumes on the truck-only lanes. Although part of this diversion would be driven by congestion relief considerations, the diversion would also be impacted by productivity improvements offered by LCV operations, the propensity of the trucking market (type of commodities and origination-destination [O-D] patterns) toward shifting to LCVs, and other LCV operational considerations (e.g., equipment and operational costs). It is unclear if these issues associated with LCVs were considered in the study in arriving at the diversion rates (and corresponding utilization of the truck-only lanes). Since the performance benefits of the truck-only lane alternative are directly linked with the assumptions on the level of diversion of trucks from the general purpose lanes, it is difficult to draw conclusions from the results of this study on the performance benefits of truck-only lanes without adequate information on the inherent factors driving these diversion estimates.
- The study uses a regional travel demand model to quantify the travel time savings benefits of the truck-only lane alternative associated with speed improvements on the general purpose lanes from diversion to truck-only lanes. This approach could potentially underestimate the travel time savings benefits of the truck-only lane alternative, since travel demand models typically underestimate the congestion relief impacts of truck diversion based on their assumptions on truck PCE factors.
- The alternatives defined in the study prevented the ability to compare the performance benefits of the truck-only lane alternative against an alternative with additional mixed-flow capacity (Appendix B provides a detailed description of the alternatives considered in this study.).
- The study does not consider the impacts of differences in time-of-day distributions between trucks and autos on the utilization and associated performance benefits of the truck-only lane alternative, which could potentially impact the results reported in the study on the relative performance benefits of the truck-only lanes.

Georgia Statewide Truck Lane Needs Identification Study

The Georgia *Statewide Truck Lane Needs Identification Study* (i.e., the Georgia study) was conducted to evaluate the feasibility of implementing truck-only lanes on Georgia's statewide highway network. The main objectives of the study included quantifying the performance benefits of truck-only lanes (relative to an alternative without truck-only lanes), identifying potential corridors for implementation (based on certain feasibility criteria such as truck volumes, congestion, and market accessibility), and assessing the benefits and costs of implementing truck-only lanes. The horizon year for the study was 2035.

The initial phase of the study considered all the major Interstate facilities and access controlled state routes in Georgia for the truck-only lane needs identification analysis. An initial screening process (based on a qualitative performance evaluation process) was undertaken to evaluate the feasibility of truck-only lanes along these corridors, which resulted in the identification of a set of "candidate corridors" showing the greatest potential for the implementation of truck-only lanes to meet the freight and transportation needs in the state. The candidate long-haul corridors identified in the study to have the greatest potential for truck-only lanes included the following:

- I-75 (southern segment) between I-285 (south end) and I-475 (near Macon). This segment was divided into the following subsegments:
  - Segment 3A: Henry/Butts County line to I-285 and
  - Segment 3B: I-475 to Henry/Butts County line.
- I-75 (northern segment) between I-285 (north end) and Georgia/Tennessee boundary. This segment was divided into the following subsegments:
  - Segment 4A: I-285 to Bartow/Gordon County line and
  - Segment 4B: Bartow/Gordon to Tennessee.

- I-85 (southern segment) between I-285 and Georgia/Alabama boundary. This segment was divided into the following subsegments:
  - Segment 6A: Alabama to Coweta/Troup County line and
  - Segment 6B: Coweta/Troup County line to I-285.
- I-85 (northern segment) between I-285 and Georgia/South Carolina boundary. This segment was divided into the following subsegments:
  - Segment 7A: I-285 to Gwinnett/Jackson County line and
  - Segment 7B: Gwinnett/Jackson County line to South Carolina.
- Segment 8: I-20 (western segment) between I-285 and Georgia/Alabama boundary.
- Segment 9: I-20 (eastern segment) between I-285 and Georgia/South Carolina boundary.

Appendix B provides a detailed description of the candidate corridors, auto and truck traffic demand along these corridors and how these were generated, and the performance benefits estimates for the alternatives considered in the study.

Performance Results

Productivity Benefits. The study did not look at productivity benefits as an exclusive performance metric in evaluating the performance benefits of truck-only lanes. Therefore, productivity benefits were derived using a post-processing analysis based on the Reason Foundation approach to estimating productivity benefits of truck-only lanes presented in Table 3.7. This post-processing analysis used the speeds from the Georgia study as inputs along with other assumptions on freight rates and truck variable costs (consistent with the assumptions used by the Reason Foundation and presented in Table 3.7), to derive the relative increase in trucking industry earnings due to truck-only lanes. Table 3.9 presents the productivity benefits to truckers for a select set of corridor segments (Segments 3B, 4A, 4B, 6B, and 7A) due to usage of truck-only lanes (without and with LCV operations) compared to the no-build alternative.

Although the study did not consider LCV operations, the post-processing analysis also considered a truck-only lane alternative with LCV operations, to assess the incremental productivity benefits of truck-only lanes with LCV operations (due to increased payloads). The productivity benefits results are summarized below.

- Truck-only lanes without LCVs more than double the productivity of trucking operations (in terms of increased annual trucking industry earnings) compared to the no-build alternative;
- Truck-only lanes with LCV operations provide close to 7% incremental productivity benefits compared to truck-only lanes without LCV operations, due to the productivity benefits of increased payloads; and
- The incremental productivity benefits due to increased payloads are observed to be significantly lower compared to the productivity benefits from travel time savings on the truck-only lanes, due to high congestion conditions on many of the intercity corridor segments, particularly those falling within the outer-limits of the Atlanta metropolitan area.

Travel Time Improvements. Travel time savings of truck lanes are estimated as the savings in vehicle hours traveled (VHT) between the no-build and the truck-only lane alternatives. Total VHT for autos and trucks are derived for the study alternatives using travel demand models for each of the candidate corridor segments, and these results are presented in Table 3.10. VHT savings are considered to be representative of travel time savings under the assumption that traffic volumes do not change significantly between the no-build and the truck-only lane alternatives. Truck lanes along the intercity corridors considered in the study are estimated to provide 20% savings in travel time compared to the no-build alternative.

Safety Improvements. Safety performance evaluation of alternatives was conducted in terms of change in the number of fatal accidents, using crash rate data from the Georgia DOT, as a func-

Table 3.9. Productivity benefits estimates of truck-only lanes using the Reason Foundation methodology applied to data from the Georgia study,[1] 2035.

	Segment 3B: I-75 South			Segment 4A: I-75 North			Segment 4B: I-75 North			Segment 6B: I-85 South			Segment 7A: I-85 North		
	Without TOL[2]	No LCV[3]	LCV[4]	Without TOL	No LCV	LCV	Without TOL	No LCV	LCV	Without TOL	No LCV	LCV	Without TOL	No LCV	LCV
Speeds (mph)	61	64	64	27	52	52	56	62	62	38	57	57	29	51	51
Freight Rate (per 100 mi)	500	500	875	500	500	875	500	500	875	500	500	875	500	500	875
Miles per 8-h Day Shift (6 h Driving)	366	384	384	162	312	312	336	372	372	228	342	342	174	306	306
Revenue per Day Shift	1,830	1,920	3,360	810	1,560	2,730	1,680	1,860	3,255	1,140	1,710	2,993	870	1,530	2,678
Variable Costs	684	684	1,086	684	684	1,086	684	684	1,086	684	684	1,086	684	684	1,086
Net Earnings	1,146	1,236	2,274	126	876	1,644	996	1,176	2,169	456	1,026	1,907	186	846	1,592
Earnings per Ton Mile	0.16	0.16	0.17	0.04	0.14	0.15	0.15	0.16	0.17	0.1	0.15	0.16	0.05	0.14	0.15
% Increase in Earnings per Ton Mile		3	8		261	287		7	12		50	59		159	178

Source: Cambridge Systematics, Inc. (based on the Reason Foundation approach and data inputs from the Georgia study).

Notes:

1. Productivity benefits of truck-only lanes are estimated separately in the table for each of the major corridor segments in the Georgia study. The corridor segments in the table include 3B, 4A, 4B, 6B, and 7A. The key data inputs used for estimating productivity benefits include speeds, freight rates, and variable costs. Speed data is derived from the Georgia study, while assumptions on freight rates and variable costs are taken from the Reason Foundation methodology for the estimation of productivity benefits.
2. Refers to the no-build alternative (without truck-only lanes [TOL]).
3. Refers to the truck-only lane alternative with standard truck (no LCV) operations.
4. Refers to the truck-only lane alternative with LCV operations.

Table 3.10. Travel time savings due to truck-only lanes, estimates from the Georgia study, 2035 (percentage change in VHT [millions]).

Corridor Segments	Without Truck-Only Lanes				With Truck-Only Lanes				% Travel Time Savings[1]			
	Facility[2]	4-Mile Buffer[3]	12-Mile Buffer[4]	Region[5]	Facility	4-Mile Buffer	12-Mile Buffer	Region	Facility	4-Mile Buffer	12-Mile Buffer	Region
3A: I-75 South	0.3	1.0	2.6	10.3	0.2	0.8	2.5	10.1	42	15	7	2
3B: I-75 South	0.1	N/A	N/A	38.1	0.1	N/A	N/A	38.1	0	N/A	N/A	0
4A: I-75 North	0.3	1.1	3.3	10.3	0.2	1.0	3.1	10.0	23	11	5	2
4B: I-75 North	0.1	N/A	N/A	38.1	0.1	N/A	N/A	38.1	8	N/A	N/A	0
6B: I-85 South	0.1	0.5	1.9	10.3	0.1	0.5	1.8	10.3	9	6	1	0
7A: I-85 North	0.2	1.1	3.7	10.3	0.2	1.0	3.6	10.1	11	5	3	1
8: I-20 West	0.2	0.7	2.5	10.3	0.1	0.6	2.8	10.2	20	8	-15	1
9: I-20 East	0.1	0.6	2.6	10.3	0.1	0.6	2.6	10.2	13	2	1	0
Total VHT and Average Savings	**1.2**	**4.9**	**16.5**	**137.7**	**1.0**	**4.5**	**16.4**	**137.0**	**20**	**9**	**1**	**0**

Source: Adapted from Georgia Department of Transportation, *Statewide Truck Lane Needs Identification Study, Technical Memorandum 3: Truck-Only Lane Needs Analysis and Engineering Assessment,* April 2008.

1. Percent savings in travel time are calculated as the percent reduction in VHT between the "with truck-only lanes" and "without truck-only lanes" alternatives.

2. The cells in this column represent daily VHT (in millions) for users on each of the Interstate corridor segments.

3. The cells in this column represent daily VHT (in millions) for users traveling on roadways within a 4-mi buffer area on either side of each of the Interstate corridor segments.

4. The cells in this column represent daily VHT (in millions) for users traveling on roadways within a 12-mi buffer area on either side of each of the Interstate corridor segments.

5. The cells in this column represent daily VHT for users on the entire roadway network (within the study area).

Table 3.11. Safety benefits due to truck-only lanes, 2035 (fatal accident reduction).

Corridor	Estimated Annual Fatal Accidents			Percentage of Savings in Accidents
	Without TOL	With TOL	15% Additional Adjustment for TOL	
3A: I-75 South	11	7	6	46%
3B: I-75 South	10	7	6	41%
4A: I-75 North	14	9	8	45%
4B: I-75 North	10	7	6	41%
6B: I-85 South	9	6	5	43%
7A: I-85 North	10	7	6	41%
8: I-20 West	10	6	5	49%
9: I-20 East	8	5	4	47%
Total Fatal Accidents and Average % Savings	**82**	**54**	**46**	**44%**

Source: Adapted from Georgia Department of Transportation, *Statewide Truck Lane Needs Identification Study, Technical Memorandum 3: Truck-Only Lane Needs Analysis and Engineering Assessment,* April 2008.

tion of roadway facility type and congestion. Clearly, the method used for accident estimation in the study did not consider the incremental safety benefits associated with truck-auto separation. As a result, additional post-processing was conducted to account for the safety benefits of truck-auto separation, by applying an additional 15% accident reduction factor (as recommended by the Douglas handbook). Table 3.11 presents the safety benefits estimates from the study. Truck lanes along the intercity corridor segments considered in the study are estimated to reduce accidents by 44% compared to the no-build alternative, as a result of congestion reduction as well as separation of trucks and autos.

Assumptions and Data Gaps. Some of the key assumptions and data gaps in this study that potentially impact the ability to draw conclusions about the performance benefits of truck-only lanes are as follow:

- The study only considers the performance benefits of truck lanes compared to a no-build alternative and does not provide insights into the relative performance of truck lanes compared to adding mixed-flow capacity. This appears to be particularly relevant, since some of the corridor segments considered in the study experience significant congestion.
- The study uses travel demand models to estimate the travel time savings benefits of truck lanes compared to the no-build alternative. Since trucks account for a large share of total traffic volumes along most of the corridor segments (close to 40% on average), the estimation of the congestion relief benefits of eliminating trucks from the general purpose lanes has to accurately consider the congestion impacts of trucks (when trucks represent a large share of the total traffic volumes) through the use of representative PCE factors. Typically, this is a limitation with travel demand models, which do not consider variable PCEs. Consequently, the results from the study could be underestimating the travel time savings of truck lanes, particularly along the congested corridor segments.
- The safety benefits results from the study are based on the congestion reduction benefits of truck lanes, and the safety benefits of truck-auto separation are accounted for by applying an additional accident reduction factor as part of a post-processing analysis. Clearly, the safety benefits estimates are not based on robust analytical tools (such as simulation) that can capture the true safety benefits of truck-auto separation.

- The study does not consider differences in time-of-day distributions between trucks and autos, which could impact the performance of truck-only lanes.

3.3.2 Urban Corridors

I-710 Major Corridor Study

The *I-710 Major Corridor Study* was initiated in 2001 to analyze future year traffic volumes, congestion, safety, and environmental issues along the I-710 corridor in Southern California, with the objective of developing transportation solutions to address these issues. Traffic forecasts along the corridor for each of the alternatives were generated using a subarea travel demand model for the I-710 study area. These forecasts served as inputs in the estimation of key performance measures, including V/Cs, speeds, travel times, and number of accidents. The following sections describe the results from the study related to travel time savings, reliability, and safety.

Additional post-processing was conducted to estimate reliability (since the study did not estimate these benefits), and safety (this was done for the truck-only lane alternative since the study did not specifically account for the safety benefits of truck-auto separation). Appendix B provides a detailed description of the alternatives, performance measures considered, and performance benefits results from the study for each of the alternatives. The following sections summarize the key performance results from the study to gain insights into the relative performance of truck-only lanes compared to no-build and additional mixed-flow lane alternatives.

Performance Results

Travel Time Savings. The study evaluated mobility performance among alternatives in terms of speeds on general purpose lanes (and speeds on truck lanes in the case of the truck-only lane alternative) for each of the alternatives that were derived using a subarea travel demand model. These speeds were translated into equivalent travel time savings as part of a post-processing analysis. The relative savings in travel time for the build alternatives compared to the no-build alternative are presented in Table 3.12.

Following are some insights into the travel time savings benefits of truck-only lanes estimated in the study:

- For the truck-only lane alternative, the travel time savings for trucks using the truck-only lanes are significantly higher (more than double) than the savings for autos and trucks on the general

Table 3.12. Percent travel time savings compared to no build, 2025 (northbound lanes, P.M. peak period).

Alternatives	General Purpose Lanes	Truck/Carpool Lanes
TSM/TDM[1]	8%	N/A
Mixed-Flow Lanes (One Lane in Each Direction)	14%	N/A
Mixed-Flow Lanes (Two Lanes in Each Direction) with Additional HOV Lanes[2]	21%	37%
Truck-Only Lanes	16%	33%

Source: Adapted from Los Angeles County MTA, *I-710 Major Corridor Study—Final Report,* March 2005.

Notes:

1. Includes improvement strategies such as added bus service for local area communities, ramp metering system on I-710, advanced technologies for traffic management, and motorist information systems for route choice decision making based on traffic congestion.
2. Four additional bidirectional lanes between SR 91 and SR 60 and six additional bidirectional lanes between Ocean and SR 91.

purpose lanes. This is because of the lower level of congestion on the truck-only lanes compared to the congestion relief provided on the general purpose lanes due to truck diversion.

- The relative travel time savings benefits on the general purpose lanes between the truck-only lane and mixed-flow lane (one lane in each direction) alternatives are observed to be not that significant, even though the truck-lane alternative has higher capacity. This could be attributed to the lower level of contribution of trucks to congestion in the P.M. peak period.

Reliability Benefits. The I-710 study did not estimate the reliability benefits associated with each of the build alternatives. In order to estimate percentage change in reliability for each of the build alternatives compared to the no-build, the study team used a post-processing approach. This approach involves estimating total nonrecurrent/incident-related delays for each of the alternatives, and comparing these estimates for the build alternatives against the no-build alternative to arrive at percent change in incident-related delays.

Total nonrecurrent delay per vehicle mile is estimated using post-processing factors as a function of V/C and number of lanes. The approach involves estimating nonrecurrent delay per vehicle mile for various sections of the I-710 corridor based on information on V/C and number of lanes from the *I-710 Major Corridor Study.* The nonrecurrent delay estimates per vehicle mile are then averaged out for the corridor, and multiplied by the total VMT along the corridor (from the *I-710 Major Corridor Study*) for each of the alternatives.

IDAS post-processing factors do not consider the improvements in travel time reliability for the truck lane alternative associated with truck-auto separation. Since nonrecurrent delays are directly proportional to, and can be assumed to have a linear relationship with, the number of accidents, a 15% accident reduction factor (as recommended by the Douglas handbook) is applied to the nonrecurrent delay estimates for the truck-only lane alternative from the I-710 study. The final estimates for percentage change in reliability for the build alternatives in the I-710 study compared to the no-build alternative are presented in Table 3.13.

The percentage change in reliability for the truck lane alternative in Table 3.13 includes reliability improvements both on the GP and truck lanes. Since reliability improvements on the truck lanes are expected to be significantly higher than those for the GP lanes (as was observed from the Georgia study), the reliability improvements on the GP lanes for the truck-only lane alternative are expected to be lower than the 59% figure for the truck-only lanes.

Safety Benefits. The I-710 study analyzed safety benefits among alternatives in terms of reduction in accidents under each of the build alternatives compared to the no-build alternative. These results are presented in Table 3.14.

In order to determine percent improvements in safety relative to the no-build alternative, additional post-processing of the results from the I-710 study was conducted, using IDAS safety factors

Table 3.13. Percent change in travel time reliability.

Alternatives	Total Annual Savings in Nonrecurrent Delay (Hours)	Percentage of Reliability Improvement
A. No Build	–	–
B. TSM/TDM	2,375	15%
C. Mixed-Flow Lanes (One Lane in Each Direction)	7,403	47%
D. Mixed-Flow Lanes (Two Lanes in Each Direction) with Additional HOV Lanes	9,935	63%
E. Truck-Only Lanes	9,308	59%

Source: Adapted from Los Angeles County MTA, *I-710 Major Corridor Study—Final Report,* March 2005.

Table 3.14. Annual accident reduction (2025).

Alternatives	Reduction in Accidents*
B	316
C	554
D	480
E	539

* When compared to Alternative A.

Source: Adapted from Los Angeles County MTA, *I-710 Major Corridor Study—Final Report,* March 2005.

as a function of V/C, to determine annual accidents under the no-build alternative. The approach and results from this post-processing are shown in Table 3.15.

Combining the results from Table 3.14 and Table 3.15, Table 3.16 presents the percent improvement in safety for each of the build alternatives. For the truck-only lane alternative, an additional 15% reduction factor was applied to the total accidents to account for the safety benefits of truck-auto separation (as recommended by the Douglas handbook).

Table 3.15. Annual accidents under the no-build alternative, 2025.

V/C	1.42
Daily VMT	4,400,000
Fatality Rate (Accidents per Million VMT)	0.0066
Injury Rate (Accidents per Million VMT)	0.71
Property Damage Rate (Accidents per Million VMT)	0.9192
Daily Fatality Accidents	0
Daily Injury Accidents	3
Daily Property Damage Accidents	4
Total Daily Accidents	**7**
Total Annual Accidents (Assuming a Factor of 300)	**2,159**

Source: Adapted from Los Angeles County MTA, *I-710 Major Corridor Study—Final Report,* March 2005.

Table 3.16. Percent safety improvement, 2025.

Alternatives	Annual Accidents	Additional Reduction Due to Truck-Auto Separation	Net Annual Accidents	Percentage of Accident Reduction
No Build	2,159	N/A	2,159	–
TSM/TDM	1,843	N/A	1,843	15%
Mixed-Flow Lanes (One Lane in Each Direction)	1,605	N/A	1,605	26%
Mixed-Flow Lanes (Two Lanes in Each Direction) with Additional HOV Lanes	1,679	N/A	1,679	22%
Truck-Only Lanes	1,620	243	1,377	36%

Source: Adapted from Los Angeles County MTA, *I-710 Major Corridor Study—Final Report,* March 2005.

Some key insights from the performance benefits results from the I-710 study are as follow (potential limitations associated with these results are discussed in the next section):

- The study provides insights into the relative performance of truck-only lanes compared to no-build and additional mixed-flow lane alternatives for travel time savings, reliability, and safety performance measures;
- Relative improvements in reliability and safety benefits of truck-only lanes (compared to additional mixed-flow lanes) are observed to be higher compared to travel time savings because, in addition to congestion relief (which contributes to reliability and safety improvements), the separation of trucks and autos in the truck-only lane alternative also provides incremental reliability and safety benefits; and
- The truck-only lane alternative provides the highest safety benefits compared to all other alternatives.

Assumptions and Data Gaps. Some of the key assumptions and data gaps in this study that potentially impact the ability to draw conclusions about the performance benefits of truck-only lanes are as follow:

- The mixed-flow and truck-only lane alternatives considered in the study have different capacities. Therefore, without a B-C analysis, it is difficult to assess, from the results, the relative overall performance of truck-only lanes compared to adding mixed-flow capacity.
- The travel time savings benefits are calculated using the speed outputs from a subarea travel demand model. As discussed earlier, the applications of travel demand models to analyze the mobility performance of truck-only lanes have potential limitations, especially in congested corridor conditions (such as in the case of the I-710 corridor), particularly regarding assumptions related to truck PCE factors, which could result in an underestimation of the actual travel time savings benefits of truck-only lanes.
- The study provides mobility performance results for the build alternatives in terms of average speeds for the P.M. peak period, which are translated into travel time savings benefits as part of a post-processing analysis. However, travel time savings for only the P.M. peak period are inadequate in assessing the performance of truck-only lanes since differences in time-of-day patterns of trucks in the A.M. peak and mid-day time periods could potentially affect the performance of the truck-only lane alternative relative to adding mixed-flow capacity.

Georgia Statewide Truck Lane Needs Identification Study

The Georgia *Statewide Truck Lane Needs Identification Study* used a two-pronged approach in the performance evaluation and needs analysis process for truck-only lanes. The first step in the process involved the analysis of individual corridor segments and the quantification of performance benefits of truck lanes on these corridors. The results from this analysis for the long-haul corridors in the state were discussed previously in the long-haul corridor performance evaluation section. The second step involved the development of truck-only lane systems (combination of individual corridors) and a detailed evaluation of the performance benefits of truck-only lane systems compared to a system without truck-only lanes.

The performance measures evaluated in the study for the analysis of truck-only lanes along the above-mentioned corridor systems included travel time savings, reliability, and safety benefits. The study used a combination of the Georgia statewide model, the Atlanta Regional Commission (ARC) travel demand model, and the Savannah Metropolitan Planning Organization (MPO) model to generate traffic forecasts on the corridor systems, and estimate travel time and reliability performance measures for each alternative. Safety performance was analyzed using crash rates available from GDOT, in terms of number of accidents using V/C and VMT outputs from the model. Appendix B provides a detailed description of the metropolitan corridor systems, alternatives, and performance measures considered in the study. The following sections present the key performance benefits results from the study to gain insights into the relative performance of truck-only lanes compared to the no-build alternative.

Performance Results

Travel Time Savings. Travel time savings due to truck-only lanes were evaluated in terms of changes in VHT in 2035 for each of the corridor systems. Analysis of change in VHT to evaluate travel time savings provides a conservative estimate for travel time savings, because part of the VHT change is contributed by increase in traffic volumes on the corridor due to increased capacity. Table 3.17 summarizes these results. The average 2035 change in VHT due to the implementation of truck-only lanes, by location, is as follows:

- Facility: –17%,
- Corridor Buffer—4 mi: –11%,
- Corridor Buffer—12 mi: –8%, and
- Region: –6%.

Table 3.17. Change in daily VHT (2035), buffer index (2035), and estimated annual crashes (2030).

	System 1 I-75/I-20W/ I-285W			System 2 I-75/I-675/ I-20W/I-285W			System 3 I-75/I-85N/ I-20W/I-285 All			System 4 I-75/I-85N/ I-675/I-285 E		
	No Project	Truck-Only Lanes	Percent Change	No Project	Truck-Only Lanes	Percent Change	No Project	Truck-Only Lanes	Percent Change	No Project	Truck-Only Lanes	Percent Change
Vehicle Hours Traveled per Day (Millions)												
Facility	0.59	0.48	-19%	0.59	0.48	-19%	0.98	0.85	-14%	0.80	0.68	-15%
Corridor Buffer = 4 Miles	2.68	2.37	-11%	2.81	2.50	-11%	4.60	4.11	-11%	3.70	3.34	-10%
Corridor Buffer = 12 Miles	5.97	5.48	-8%	6.20	5.71	-8%	8.39	7.61	-9%	7.86	7.21	-8%
Region	10.66	10.11	-5%	10.66	10.12	-5%	10.66	9.82	-8%	10.66	9.93	-7%
Buffer Index												
Truck-Only Lanes	N/A	43%	-81%	N/A	44%	-79%	N/A	40%	-78%	N/A	45%	-80%
GP Lanes	124%	72%	-42%	124%	70%	-43%	118%	77%	-35%	124%	82%	-34%
2030 Estimated Annual Crashes												
Total	7,867	7,860	0%	7,955	7,948	0%	13,564	13,553	0%	10,540	10,531	0%
Injury	1,708	1,686	-1%	1,727	1,705	-1%	2,944	2,910	-1%	2,288	2,262	-1%
Fatal	30	18	-40%	30	17	-43%	50	30	-40%	38	23	-39%
Reduction in Fatal Crashes		12			13			20			15	

Source: Adapted from Georgia Department of Transportation, *Statewide Truck Lane Needs Identification Study, Technical Memorandum 3: Truck-Only Lane Needs Analysis and Engineering Assessment,* Tables 43, 52, and 51, April 2008.

Reliability Benefits. Reliability benefits in the study were evaluated in terms of change in the Buffer Index which is the ratio of the extra time travelers must build into the trip when planning their travel (to ensure reaching their destination on time 95% of the time), to the average travel time. The Buffer Index was estimated as a function of the Travel Time Index (TTI, which is defined as the ratio of the congested travel time to the free-flow travel time), using model outputs for congested and free flow travel times for the no-build and truck-only lane alternatives. The reliability benefits (in terms of percent change in the Buffer Index) were evaluated both for trucks using the truck lanes, as well as for autos and trucks using the general purpose lanes. See Table 3.17.

Under the no-project scenarios, travelers allowed for significantly high buffer times (118% to 124%) to reach their destination on time 95% of the time (implying that their total travel times were more than double their average travel times). The implementation of truck lanes was estimated to result in significant reduction in buffer times for trucks on truck lanes (percent reduction of 80%). The reduction in buffer times for autos and trucks on the general purpose lanes were not as significant as on the truck lanes, but still was observed to be notable (percent reduction of close to 40%). The 2035 average percentage reduction in buffer times based on the results is as follows.

- Trucks on truck-only lanes = 80%.
- Autos/trucks on general purpose lanes = –39%.

Safety Benefits. Safety benefits were evaluated in terms of percent reduction in injury and fatality accidents due to the implementation of truck lanes compared to the no-build alternative for each of the corridor systems. See Table 3.17. Since the Georgia study did not specifically account for the safety benefits of truck-only lanes accruing from truck-auto separation, a 15% reduction factor was applied to the total, fatality, and injury accidents estimates for the truck-only lane alternative. These results are presented in Table 3.18.

Average fatality accident reduction of 50% due to the implementation of truck-only lanes is observed. The percent reduction for injury accidents is estimated to be lower (average reduction of 16%), which is as expected, since a large share of the fatality accidents are influenced by the involvement of trucks (while this share is significantly lower for injury accidents).

Assumptions and Data Gaps. Since the performance results from the study for the urban corridors scenario are based on the same procedures and tools as described for the study under the long-haul corridor scenario, the assumptions/data gaps and their impacts on the ability to assess the relative performance of truck-only lanes described under the long-haul corridor scenario are applicable here as well. The procedure used to derive the reliability benefits estimates from the study, using the Buffer Index as the performance metric, has the following potential impacts on the accuracy of the results:

- The Buffer Index is estimated as a function of the Travel Time Index, which implies that the analysis only considers the reliability benefits associated with congestion reduction without considering the benefits of truck-auto separation.
- The Travel Time Index estimates are derived from model outputs for congested and free flow travel times, and the limitations of travel demand models in assessing the mobility performance of truck-only lanes have been described earlier. Thus, the Travel Time Index estimates from the model for the truck-only lane alternative may be miscalculated, which would impact the accuracy of the Buffer Index estimates.

Puget Sound Region Freight Action Strategy (FAST) Corridor Analysis

The FAST corridor analysis project in the Puget Sound region involved the development and application of a regional truck model (the FAST truck model) to evaluate the benefits associated

Table 3.18. Safety benefits estimates of truck-only lanes using accident data from the Georgia study, 2030.

	No-Build[a]	Truck-Only Lanes[b]	Truck-Only Lanes (After 15% Reduction)[c]	Safety Benefits (Percentage of Reduction due to Truck-Only Lanes)[d]
Fatality Accidents				
System 1[e]	30	18	15	49%
System 2	30	17	14	52%
System 3	50	30	26	49%
System 4	38	23	20	49%
Average				**50%**
Injury Accidents				
System 1	1,708	1,686	1,433	16%
System 2	1,727	1,705	1,449	16%
System 3	2,944	2,910	2,474	16%
System 4	2,288	2,262	1,923	16%
Average				**16%**
Total Accidents				
System 1	7,867	7,860	6,681	15%
System 2	7,955	7,948	6,756	15%
System 3	13,564	13,553	11,520	15%
System 4	10,540	10,531	8,951	15%
Average				**15%**

Source: Adapted from Georgia Department of Transportation, *Statewide Truck Lane Needs Identification Study*.

Notes:

a. The cells in this column represent number of accidents for the no-build alternative.

b. The cells in this column represent number of accidents for the truck-only lane alternative.

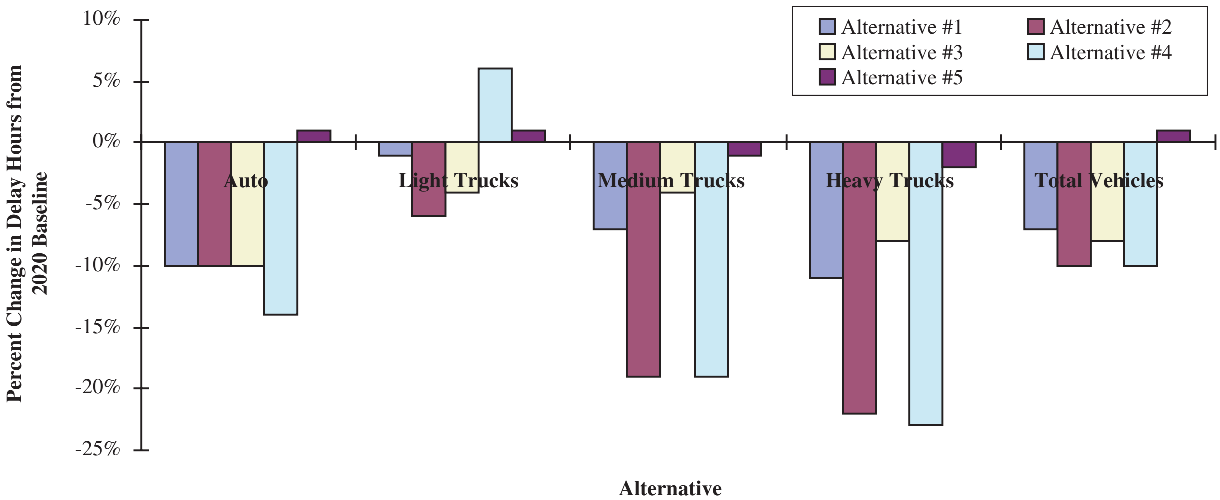
c. The cells in this column represent the number of accidents for the truck-only lane alternative after accounting for accident reduction due to truck-auto separation (a 15% reduction factor is applied to the accidents in the "Truck-Only Lanes" column based on recommendations from the Douglas handbook).

d. The cells in this column represent the % reduction in accidents (safety benefits) due to truck-only lanes. This is estimated from the accidents under the "Truck-Only Lanes (after 15% reduction)" and "No Build" columns.

e. Systems 1 through 4 represent combinations of individual corridors analyzed in the Georgia study.

with a variety of transportation investments impacting goods movement in the four-county Puget Sound region. The analysis involved conducting model runs for a set of alternatives and comparing model outputs for a set of performance measures against the future no-build alternative. The primary performance measures evaluated in the study included travel time savings in terms of change in VHT, and change in delays (congested travel time—free-flow travel time). The following alternatives were considered in the study, in addition to the no-build alternative:

- Alternative 1. "Operational" improvements of facilities, such as upgrading arterials to freeways, interchange improvements, and capacity improvements for trucks;
- Alternative 2. "Infrastructure–related" improvements consisting mainly of adding general purpose lanes and truck lanes along the larger corridor network;
- Alternative 3. Addition of truck-only lanes along the I-405 corridor;
- Alternative 4. Addition of truck-only lanes along the I-5 corridor; and



Source: Adapted from Arun R. Kuppam and Maren L. Outwater, *Evaluating Freight Mobility on a Regionwide Basis Using EMME/2 —Freight Action Strategy (FAST) Truck Model for Puget Sound Region,* submitted for the 16th International EMME/2 User's Group Conference, Albuquerque, NM, March 18–20, 2002.

Figure 3.2. Percentage change in vehicle hours traveled (VHT) from 2020 future baseline.

- Alternative 5. Changes in land-use patterns for the 2020 no-build scenario, and associated impacts.

Appendix B provides a detailed description of the performance measures and benefits results from this study for each of the alternatives. The following sections summarize the key performance benefits results from the study.

Performance Results

Travel Time Savings. Travel time savings is the only performance measure quantified in the study as part of the alternatives analysis process. As mentioned previously, these benefits are generated in terms of percent change in VHT for each of the build alternatives compared to the no-build alternative using VHT outputs from the FAST truck model. Figure 3.2 presents the VHT results from the alternatives analysis.

Table 3.19 summarizes the percentage change in VHT for the truck-only lane alternatives (Alternatives 3 and 4) compared to the no-build alternative, by vehicle class and total vehicles.

Assuming the total VMT to be relatively the same along the I-5 and I-405 corridors, average travel time savings from truck-only lanes are estimated to be around 9% compared to the no-build alternative.

Table 3.19. Change in VHT, truck-only lanes, compared to no-build, 2020.

	Autos (%)	Light-Heavy (%)	Medium-Heavy (%)	Heavy-Heavy (%)	Total Vehicles (%)
Truck-Only Lanes (Alternative 3)	-10	-4	-10	-8	-8
Truck-Only Lanes (Alternative 4)	-14	6	-19	-23	-10

Source: Adapted from PSRC FAST corridor study.

Assumptions and Data Gaps. Some of the key assumptions and data gaps in this study that potentially impact the ability to draw conclusions about the performance benefits of truck-only lanes are as follow:

- The study does not consider an exclusive mixed-flow lane alternative to allow for the comparisons of mobility performance benefits of truck-only lanes compared to adding mixed-flow capacity.
- A travel demand model (FAST truck model) is used to evaluate the travel time savings benefits of truck-only lanes. The limitations of travel demand models in assessing the mobility performance of truck-only lanes has been discussed earlier.
- The study does not consider other key performance measures such as safety and travel time reliability in the alternatives analysis, which are important metrics to consider, particularly as part of the performance evaluation of truck-only lanes.
- The study does not consider differences in time-of-day distributions between trucks and autos in analyzing the travel time savings benefits of truck-only lanes by time of day. An assessment of the actual mobility benefits of truck-only lanes should be based on a time-of-day analysis, to take into consideration the inherent differences in time-of-day patterns of trucks and autos in an urban corridor environment.

I-15 Comprehensive Corridor Study

The I-15 study was sponsored by the Southern California Association of Governments (SCAG), the California Department of Transportation (Caltrans), and the San Bernardino Associated Governments (SANBAG) with the primary objectives of analyzing right-of-way needs along the corridor, assessing the feasibility and costs of implementing truck lanes, and performing a comprehensive evaluation of transportation needs along the corridor to feed the development of a long-range improvement plan and implementation strategy for the corridor. The study conducted an initial screening evaluation of a comprehensive list of alternatives, which were narrowed down to a final set of five alternatives for detailed screening and alternative selection process: no-build, TSM/TDM, HOV lanes, full corridor dedicated truck lanes, and reversible managed lanes. Traffic (truck and auto) volume forecasts and a mobility performance measure (V/C) for each of the alternatives were generated using the 2004 SCAG Regional Transportation Plan (RTP) model. Appendix B provides a detailed description of the alternatives, and performance benefits results estimated in the study.

Table 3.20 shows the 2030 forecast for truck and auto volumes along the corridor by segment (the study analyzed travel demand along the corridor for seven segments) under each of the alternatives. Following are some key insights from the data:

- Truck volumes are projected to represent a notable share (more than 25%) of the total traffic volumes along most segments of the corridor.
- The data show an increase in auto traffic volumes along the corridor for each of the build alternatives (HOV lanes, truck lanes, and managed lanes) relative to the no-build alternative due to the availability of additional capacity and the shifting of demand onto the corridor from adjacent facilities. In the case of the HOV lane alternative, this shifting of demand compensates for the reduction in auto traffic along the corridor due to shifting of demand from single-occupancy to multiple-occupancy vehicles.
- Auto volumes are projected to be slightly lower for the TSM/TDM alternative compared to the no-build alternative because of the implementation of increased transit service under this alternative.
- There is only a marginal increase in truck volumes under the build alternatives relative to the no-build alternative.

The following sections summarize the key performance benefits results from the study to gain insights into the performance benefits of truck-only lanes.

Table 3.20. Daily auto and truck volumes along I-15 by segment and alternative, 2030.

Segment*	No Build			TSM/TDM			HOV Lanes			Truck Lanes			Managed Lanes		
	Autos	Trucks	Truck %	Autos	Trucks	Truck %	Autos	Trucks	Truck %	Autos	Trucks	Truck %	Autos	Trucks	Truck %
1	103,133	34,749	25%	103,473	34,777	25%	108,985	34,835	24%	110,093	35,237	24%	113,332	34,755	23%
2	98,240	42,047	30%	98,704	42,004	30%	103,340	42,167	29%	105,404	43,079	29%	108,787	42,013	28%
3	101,608	48,330	32%	100,414	48,268	32%	102,100	48,464	32%	105,329	48,664	32%	98,301	48,120	33%
4	142,320	49,575	26%	141,585	49,547	26%	142,922	49,920	26%	147,598	50,161	25%	142,574	49,663	26%
5	96,515	39,559	29%	96,333	39,532	29%	100,713	39,885	28%	104,212	40,316	28%	99,034	39,681	29%
6	163,796	27,704	14%	163,500	27,521	14%	175,326	30,172	15%	173,552	32,319	16%	173,871	27,717	14%
7	223,860	42,250	16%	224,995	42,422	16%	245,335	46,071	16%	244,013	56,828	19%	234,762	42,477	15%

Source: Adapted from Southern California Association of Governments (SCAG), *I-15 Comprehensive Corridor Study,* December 20, 2005, as found at http://www.scag.ca.gov/goodsmove/pdf/I-15_Comprehensive_Corridor_Study.pdf.[cf29]

Note:
* Segments are defined as Segment 1—Mojave River Crossing to Bear Valley Road; Segment 2—Bear Valley Road to US 395; Segment 3—U.S. 395 to SR 138; Segment 4—SR 138 to I-215; Segment 5—I-215 to I-210; Segment 6—I-210 to I-10; and Segment 7—I-10 to SR 60.

Performance Results

Travel Time Savings. The I-15 study analyzed the mobility performance of each of the alternatives based on the estimation of V/C, using the SCAG RTP model. For the current analysis, these estimates were post-processed to arrive at travel time savings benefits of the build alternatives relative to the no-build alternative. The steps involved in this process include conversion of V/C estimates to average speeds along corridor segments using a volume-delay function (VDF)[42]. The speed improvements for the build alternatives are then converted to equivalent travel time savings. The travel time savings benefits estimated from this process are as follows for the 2030 forecast of the northbound P.M. peak period average travel time savings relative to no-build:

- TSM/TDM (0% savings),
- HOV lanes (16% savings),
- Truck-only lanes (23% savings), and
- Managed lanes (29% savings).

Reliability Benefits. Reliability benefits are estimated in terms of reduction in incident-related delay for the build alternatives relative to the no-build alternative using IDAS post-processing factors for delay per VMT as a function of congestion (V/C) and number of lanes. The incident-related delay per VMT estimates from IDAS for each of the segments of the I-15 corridor (based on congestion and number of lanes) are presented in Appendix B.

Using the percent change in daily VMT estimates (derived from Table 3.20, assuming average trip lengths do not change significantly between alternatives), and the delay per VMT estimates from IDAS, the percent change in incident-related delay for the build alternatives relative to the no-build are calculated and presented in Table 3.21.

Safety Benefits. Safety benefit comparisons between alternatives are conducted by estimating total accidents (fatality, injury, and property damage) per million VMT as a function of V/C along the corridor (by segment) using the IDAS software, and estimating percentage change in total accidents using the percent change in VMT estimates between alternatives. For the truck-only lane

[42]For the current analysis, the following VDF was used: $Speed = 65/(1 + [1.16 * (V/C)^{4.33}])$.

Table 3.21. Percent change in incident-related delay relative to no-build (P.M. peak period, northbound), 2030.

Segment	TSM/TDM (%)	HOV Lanes (%)	Truck-Only Lanes (%)	Managed Lanes (%)
1	0	-86	-88	-86
2	0	5	-88	-85
3	-1	-79	-82	-97
4	-1	-66	-70	-91
5	0	-86	-88	-87
6	0	-78	-81	-78
7	1	-70	-74	-71
Average	**0**	**-66**	**-82**	**-85**

alternative, an additional 15% reduction factor is applied to the total accidents estimate to account for the safety benefits of truck-auto separation. Table 3.22 presents these results.

Assumptions and Data Gaps. Some of the key assumptions and data gaps in this study that potentially impact the ability to draw conclusions about the performance benefits of truck-only lanes are as follow:

- The I-15 study does not consider a conventional mixed-flow lane alternative as part of the alternatives analysis process. The alternative that comes closest to a conventional mixed-flow lane alternative is the managed lanes alternative. However, differences in operational characteristics of conventional mixed-flow and managed lanes imply that even with similar capacities, the performance characteristics of these alternatives are expected to be quite different. Thus, the results from the study are inconclusive in providing insights into the relative performance benefits of truck-only lanes compared to additional mixed-flow lanes.
- The study, as with other studies described earlier, uses a travel demand model to evaluate the mobility performance of truck-only lanes, and based on the assumptions related to PCE factors, this process could potentially underestimate the travel time savings benefits of truck-only lanes.
- Since IDAS factors only account for the reliability benefits of capacity improvement but do not consider the benefits of truck-auto separation, the actual reliability benefits of truck-only lanes are expected to be higher than estimated in Table 3.21.

Table 3.22. Percent change in total accidents compared to no-build (P.M. peak period, northbound), 2030.

Segment	TSM/TDM (%)	HOV Lanes (%)	Truck Lanes		Managed Lanes (%)
			From IDAS (%)	After 15% Reduction Factor Adjustment (%)	
1	0	-8	-21	-33	-4
2	0	-8	-20	-32	-3
3	-1	0	-12	-25	-15
4	-1	0	-12	-25	0
5	0	-9	-20	-32	-10
6	0	7	-10	-24	6
7	1	10	-7	-21	-19
Average	**0**	**-1**	**-15**	**-27**	**-6**

- The study only looked at the performance of alternatives for the A.M. and P.M. peak periods. Although this would suffice for the other alternatives, analyzing the impact of time-of-day distributions of autos and trucks in the mid-day period on utilization of truck-only lanes and the overall performance of the truck-only lane alternative would be important to assess the applicability and effectiveness of truck-only lanes in meeting performance objectives based on corridor auto and truck demand characteristics.

3.4 Comparative Summary of Results and Conclusions

This section draws together the results of a number of different studies that all concluded in their own context that truck-only lanes of different configurations provide positive benefits and may be a preferred choice for improvements in both long-haul corridors and urban corridors. Although the particular studies that are drawn on for performance evaluation are by no means exhaustive of all the studies that have been conducted that evaluate truck-only lanes, they are representative of the general configurations that have been evaluated and the methodologies that have been used to conduct these evaluations. Several general conclusions can be obtained from reviewing these performance evaluations. These conclusions are presented and discussed first, then followed by a discussion of conclusions that relate to each of the specific corridor scenarios (long-haul and urban corridors) that formed the basis of this chapter.

3.4.1 General Conclusions

There are several general conclusions that can be drawn from the performance evaluations. These include the following:

- The primary analytical tool used to evaluate truck-only lanes is a traditional travel demand model that incorporates truck trip tables. This limits the analysis to the types of travel behaviors that are best captured in these models and misses many of the key potential benefits of truck-only lanes. Operational benefits of truck-only lanes are largely absent from the analyses or are estimated on the basis of relationships between operations and V/C ratios.
- The benefits of truck-only lanes are highly sensitive to the methods and assumptions regarding diversion of trucks to these lanes (or truck lane utilization). In most of the analyses, these methods and assumptions have been driven by the level of congestion in the mixed-flow facility and the data on origin-destination (O-D) patterns of the truck-only lanes. A more market-focused analysis of the drivers of truck lane utilization than what was found in most of the studies is needed to draw conclusions about the feasibility of truck-only lanes.
- Assessing the performance benefits of truck-only lanes effectively requires the definition of appropriate alternatives as a standard of comparison. If a primary benefit driving the performance assessment is response to congestion, then a baseline alternative for comparison purposes should include other methods of alleviating congestion (e.g., equivalent capacity in general purpose lanes).
- Despite these shortcomings, the performance evaluations do demonstrate that there are corridors with high volumes of truck traffic where truck-only lanes could provide benefits to freight users (and thus would achieve high levels of utilization) as well as to nonfreight users who would continue to use mixed-flow facilities.

The reliance on travel demand models as the primary analytical tool used to evaluate performance of truck-only lanes presents a serious drawback to the analyses. It focuses much of the analysis on benefits that are derived from evaluation of general congestion conditions. The standard approach is to assign multiclass vehicle trip tables to a network with and without truck-only lanes. Routing decisions of the trucks are a function of travel times on the network given the O-D patterns reflected in the truck trip tables. Other benefits (such as productivity, travel time savings for users of the mixed-flow lanes, safety, and reliability) are generally derived from relationships between V/C ratios (i.e., general recurrent congestion conditions) and these other benefit categories. The result is that evaluations in which there are high levels of congestion in the corridor generally will show benefits for adding capacity as truck-only lanes as long as the access and egress locations to the truck lanes are chosen to serve general O-D patterns of the trucks. However, this approach does not adequately address some of the following purported benefits of truck-only lanes:

- **Safety benefits.** Relationships between lane configurations and V/C ratios were used to estimate safety benefits in the performance evaluations and for the purposes of this project, these were adjusted by a simple factor to account for additional benefits that accrue from truck-auto separation. This simple factor was derived from the few studies that attempted to draw some data from the limited applications of truck-auto separations such as the New Jersey Turnpike and the limited applications of truck interchange bypasses. A more rigorous analysis of truck-auto interactions using simulation models and more detailed statistical analysis of how truck-involved accidents vary with the relative amount of truck traffic and congestion might identify additional safety improvements that are associated with truck-auto separations. Research conducted at the University of Tennessee[43] on the safety benefits of truck-only lanes using simulation models has demonstrated that this would be a potentially useful technique to conduct this type of analysis. Appendix B (Section B.4) provides a discussion of this approach and the safety benefits results from this research.
- **Reliability benefits.** The shortcomings with respect to the analysis of safety benefits extend to the analysis of reliability benefits as well. None of the literature sources report any attempts to examine how variability in speeds (and travel times) is related to truck-auto interactions whereas at least some efforts have been made to show how crashes might be reduced through truck-auto separations. A more thorough operations analysis capable of analyzing merge and weave behavior, near crashes, and the different rates of recovery from crashes that are truck-involved—versus those that are not—could provide a more definitive assessment of the reliability benefits of truck-only lanes. Current *Highway Capacity Manual (HCM)* approaches to conducting operational analysis are likely to be insufficient for this type of analysis because of limitations on the percentage of trucks in the traffic stream that can be handled by this approach. Again, simulation models appear to be a more appropriate tool.

There may be some additional shortcomings associated with using travel demand models to analyze the congestion or travel time savings benefits of truck-only lanes. A standard approach used in modeling the impacts of truck traffic on congestion is to convert truck volumes to passenger car equivalents (PCEs). However, given potential operational improvements associated with truck-auto separations and the variability of truck PCE factors as a function of demand (truck share of total traffic volume) and certain roadway geometric characteristics, current travel demand models may not be properly accounting for changes in PCE factors as trucks and autos are separated. Thus, it is possible that the performance evaluations conducted in the studies reviewed for this project may be underestimating the travel time savings associated with truck-only lanes.

The general approach to estimating truck lane utilization in the studies reviewed for this performance evaluation was the use of travel demand models where routing decisions are based on minimum time or cost path assignments. This may be an appropriate method for estimating diversion of trucks to truck lanes when the primary motivation for using the truck lanes is to avoid congestion, but a more market-focused analysis is necessary when considering routing decisions for LCVs in long-haul corridors. The motivation for LCV operation should be based primarily on

[43]A. A. Adelakun, *Simulating Truck Lane Management Approaches to Improve Efficiency and Safety of Highways in Knoxville, Tennessee,* Master of Science thesis, University of Tennessee, Knoxville, December 2008.

increased productivity and potential net earnings increase to carriers. However, there are a variety of limiting factors that may reduce this benefit because of off-setting costs of operation and limited markets. This issue is discussed in more detail later in this chapter in the discussion of conclusions under the long-haul corridor scenario.

In light of how important congestion relief benefits appear to be in supporting positive conclusions about the value of truck-only lanes, it is disconcerting to find how few of the studies look at the performance tradeoffs between adding truck-only lanes versus adding more general purpose lanes in congested corridors. Inclusion of alternatives that add equivalent capacity for mixed-flow operations is important in determining the congestion relief benefits of truck-only lanes in comparison with the benefits provided by adding mixed-flow capacity. Nonetheless, the results of the studies evaluated in this project suggest that there are likely to be many congested corridors with sufficient truck volume to ensure high utilization of truck-only lanes. Given that benefits associated with truck-auto separation are not well captured with the current data and tools, these high levels of utilization suggest that truck-only lanes can be a desirable alternative to other forms of capacity expansion. This conclusion needs to be further explored with a more complete analysis of the time-of-day characteristics of congestion and truck traffic patterns.

3.4.2 Conclusions for Long-Haul Corridors

The evaluation of truck-only lanes in long-haul corridors focused on three primary performance measures and two primary scenarios (with and without LCV operations; the "with LCVs" scenario only looks at longer-combination truck configurations operating on truck-only lanes (such as turnpike doubles and triple shorts), and does not consider special permit vehicles, such as oversize/overweight (OS/OW) trucks). As stated earlier in Section 3.2 (Step 3), the conclusions presented here are based on an analysis of performance benefits of truck-only lanes, without consideration of costs. These results are intended to provide an understanding of how truck-only lanes perform compared to other alternatives. The planning and policy/decision making processes for truck-only lanes call for the evaluation of the benefits of truck-only lanes (compared to other alternatives) in relation to costs. To address this issue, the next Chapter delves into the B-C performance of truck-only lanes compared to other alternatives.

The performance measures analyzed in this section were as follow:

- **Productivity benefits.** Measured in a variety of different ways, including reductions in operating costs or increased net earnings to truckers per day, these benefits generally are compared to a no-build scenario. Productivity improvements are the result of reduced travel times for trucks on the truck-only lanes and increased payloads per unit cost for LCVs.
- **Travel time savings for mixed-flow traffic.** By removing trucks from the mixed-flow lanes, travel time savings can be obtained by other motorists.
- **Safety benefits.** Safety benefits for all motorists accrue from reduced congestion and truck-auto separations.

The results of the performance evaluation for long-haul corridors are summarized in Table 3.23. The key conclusions from the review of studies on the performance evaluation of truck-only lanes along long-haul corridors are contained in the following discussion.

- In selecting the long-haul corridor scenario, it was observed that there was a high level of interest in using truck-only lanes as a way of moving to LCV operations, thereby promoting greater freight efficiency in key freight corridors. Although the studies that were examined do show incremental benefits from LCV operations regardless of the method used to measure productivity benefits, these incremental benefits associated with LCV operations are generally small as compared with the potential benefits associated with travel time savings achieved from the

Table 3.23. Summary comparison of performance evaluation results, long-haul corridors.

Productivity Benefits			Travel Time Savings		Safety Benefits		
	Truck-Only Lanes		Truck-Only Lanes		Truck-Only Lanes		
No-Build with LCV Operations (%)	Without LCV Operations (%)	With LCV Operations (%)	Without LCV Operations (%)	With LCV Operations (%)	Without LCV Operations (%)	With LCV Operations (%)	Source
–	–	36[a]	–	21	–	47	*I-35 Trade Corridor Study*
–	106	120[b]	20	–	44	–	Georgia *Statewide Truck Lane Needs Identification Study*
–	55	63[c]	–	–	–	–	Reason Foundation, *Toll Truckways: Increasing Productivity and Safety in Goods Movement*
4[d]	–	–	-	–	–	–	*Western Uniformity Scenario Analysis*

Notes:

a. The study provides productivity benefits in terms of savings in truck operating costs, but without information on the share of the total revenues accounted for by operating costs, the % increase in truck earnings could not be determined from the study.

b. These results are the relative productivity benefits of truck-only lanes (without and with LCV operations) compared to a no-build alternative. LCV operations provide around 6.8% incremental productivity benefits compared to standard truck operations on truck-only lanes (this is the productivity benefit associated solely with increase in payloads without considering the impacts of travel time savings on productivity improvements).

c. LCV operations provide around 5% incremental productivity benefits compared to standard truck operations on truck-only lanes.

d. The study reports productivity benefits of LCV operations on mixed-flow lanes (compared to standard truck operations on mixed-flow lanes) in terms of % savings in shipper costs. The information available from the study is inadequate to be able to translate these cost savings into equivalent productivity benefits in terms of increased truck earnings.

additional capacity in the truck lanes. This is because all of the long-haul corridors that were analyzed included large segments moving through congested metropolitan areas. In the long run, this may be a prerequisite for successful application of truck-only lanes even in long-haul corridors—that is, unless there is a substantial need for new freight capacity in the corridor because of congested operations, there may not be sufficient benefit from truck-only lanes to justify the investment. This is difficult to determine from the analyses conducted in the various studies of long-haul corridors and without a more complete B-C evaluation.

- Incremental benefits of LCV operations relative to truck-only lanes without LCV operations are in the range of 4% to 7% and are much less than the magnitude of productivity benefits associated with operations over long distances in reduced congestion (i.e., productivity benefits associated with travel time savings over long-haul distances). A reassessment of the travel time savings portion of productivity benefits in corridors with less congested operations would be beneficial since multistate corridors that are being considered for LCV operations often have long stretches of uncongested operations and truckers may be able to plan their routes to avoid traveling in metropolitan areas during periods of peak congestion. Since the productivity benefits are assessed on a per truck basis, it is possible that with high levels of truck usage even small relative productivity benefits may prove cost effective when compared to costs. This will be explored further in the next chapter on benefit-cost evaluations and points out the importance of the level of utilization in assessing the cost-effectiveness of truck-only lanes with or without LCV operations.
- All of the studies that considered truck lane utilization (which were most often done with travel demand models) estimated high levels of truck diversion to the truck-only lanes, driven largely by the need to avoid congestion. Truck diversion rates of over 65% were reported in some studies and even higher rates of diversion were estimated in the I-35 study for LCV operations. As noted previously, market limitations suggest that much lower diversion rates for LCVs would be appropriate in less congested long-haul corridors because the markets may not be present to support this level of diversion. It appears that none of the studies considered market factors in assessing the potential rate of LCV usage on truck-only lanes.
- Two of the studies did examine the potential travel time savings for the mixed-flow traffic in long-haul corridors with and without LCV operations and both studies showed travel time savings on the mixed-flow lanes of around 20%. In both cases, there were significant fractions of the total corridor length that were very congested (around Atlanta, Georgia, and in the metropolitan areas along I-35 in Texas) and the additional capacity compared to a no-build condition both encouraged truck use of the truck lanes and freed up capacity on the mixed-flow lanes. However, neither study looked at a comparison with an alternative to build additional mixed-flow capacity.
- It should be noted that the large increases in productivity benefits to trucks using the truck-only lanes (due to both travel time savings and increased payloads in the case of LCV operations) suggest that it may be possible for the public sector to capture some of the value of the productivity benefits of the truck lanes through tolling while still providing sufficient benefits to trucks so that drivers would continue to prefer the truck lanes. As part of this analysis, it would be important to assess the impacts of incremental productivity benefits of LCV operations on truck-only lanes on the feasibility of tolls. The Reason Foundation has conducted sensitivity analysis to assess the return on investment (ROI) for toll truckways under various toll, truck diversion rate, and facility cost scenarios. However, a more detailed evaluation of tolling concepts for specific congested long-haul corridors is needed to assess the viability of tolls on truck-only lanes under realistic long-haul corridor demand and operational conditions.
- Results from the review of studies indicate safety benefits to be significant for truck-only lanes in long-haul corridors. This can be attributed to the mobility benefits provided by truck-only lanes along those intercity corridor segments experiencing notable congestion (such as along the outer boundaries of the Atlanta metropolitan area). Although the approach to estimating safety

benefits is not very sophisticated and is driven largely by improvements in overall V/C ratios, the post-processing of results conducted as part of the performance evaluation to some extent takes into account the safety effects of separating trucks and autos. Techniques that are able to focus more specifically on the benefits of truck-auto separation are likely to show even greater safety benefits. This is clearly an area where lack of field data is a critical deficiency.

3.4.3 Conclusions for Urban Corridors

The evaluation of truck-only lanes in urban corridors focused on comparisons between additional capacity in truck-only lanes and similar capacity additions in mixed-flow lanes. In order to properly assess the performance of truck-only lanes in comparison to additional mixed-flow lanes along urban corridors, it is necessary to have models that differentiate performance at different times of day (since trucks and autos may have different time-of-day demand characteristics), and the data on truck activity must properly take into account truck time-of-day demand. The performance measures that were considered in the performance evaluation of truck-only lanes for urban corridors included the following:

- **Travel time savings.** Travel time savings were noted for autos (and trucks) on the general purpose lanes (and for trucks on the truck-only lanes to the extent to which these savings are reported in the reviewed studies).
- **Reliability.** In order to evaluate projects on a consistent basis, reliability benefits are analyzed in terms of savings in nonrecurrent (incident-related) delay, which are estimated using incident delay look-up factors as a function of V/C and number of lanes from IDAS, as described previously.
- **Safety.** The approach used to evaluate safety benefits was the same as that used for long-haul corridors.

The results of the performance evaluation for urban corridors are summarized in Table 3.24. The key conclusions from the review of studies on the performance evaluation of truck-only lanes along urban corridors are as follow:

- As mentioned in the discussion of the assumptions and data gaps associated with the reviewed literature sources, the differences in capacity assumptions between the truck-only lane and mixed-flow lane alternatives and the omission of the mixed-flow lane alternative in the performance evaluation in some of the reviewed studies result in the findings being inconclusive or inadequate in assessing the relative performance benefits of truck-only lanes against mixed-flow lanes with similar capacity. This limitation is addressed in the next chapter as part of the B-C analysis.
- Given that the principal tool used to conduct the evaluations was a traditional travel demand model, truck-only lanes in urban settings would only compete favorably with additional mixed-

Table 3.24. Summary comparison of performance evaluation results, urban corridors.

Travel Time Savings		Reliability		Safety		
Mixed-Flow Lanes (%)	Truck-Only Lanes (%)	Mixed-Flow Lanes (%)	Truck-Only Lanes (%)	Mixed-Flow Lanes (%)	Truck-Only Lanes (%)	Source
14	16	47	59	26	36	*I-710 Major Corridor Study*
29	23	85	82	6	27	*I-15 Comprehensive Corridor Study*
–	17	–	39	–	15	Georgia *Statewide Truck Lane Needs Identification Study*
	9	–	–	–	–	PSRC FAST corridor study

flow lanes in settings with enough truck traffic throughout the day to achieve high levels of utilization during all periods. Further, the corridor would need to have reasonably congested conditions during the mid-day periods when truck traffic tends to peak, and the contribution of truck traffic to peak-period congestion also would need to be significant (so that diversion of trucks in the peak-period can contribute to notable relief in congestion). These conclusions point out the necessity of obtaining better data on PCE factors for trucks in truck-only lanes as compared to mixed-flow conditions with varying levels of congestion and percent trucks in the mixed-flow. It is very likely that trucks have higher PCE factors when in mixed-flow conditions even with the same level of traffic; thus the separation of trucks and autos could result in greater congestion relief than is indicated in these studies.

- The impacts of truck-only lanes in urban corridors, as estimated in most of the existing studies, do not adequately address potential benefits of truck-auto separation in terms of reliability and safety. These impacts would be even more pronounced when measuring reliability and would be related to the safety benefits of truck-auto separations as well as the general traffic flow patterns. As noted previously, when trucks and autos mix, crashes are more likely and these crashes generally are severe. The time to recover from such crashes is greater than that needed for recovery from auto-only crashes and results in more significant impacts on reliability. The inability to capture the true reliability benefit of truck-auto separation in the performance evaluations is observed to be a major deficiency of the studies conducted to date.

This chapter pointed out some deficiencies in prior studies with regard to the performance evaluation of truck-only lanes for both long-haul corridors and urban corridors. Chapter 4, which follows, addresses some of these deficiencies by developing representative generic corridors for both the long-haul and urban corridor scenarios, developing an appropriate set of alternatives, monetizing the benefits so that they can be compared on a consistent basis, and evaluating these benefits in comparison to costs to get a better sense of the potential B-C tradeoffs of truck-only lanes against adding mixed-flow lane capacity. Although this addresses some of the deficiencies of prior analyses, there are other issues that can only be addressed through a combination of additional field data collection, focus on specific corridors where actual traffic conditions can be taken into account, and the application of different analytical techniques (such as traffic simulation modeling). Some proposals for future research to address remaining deficiencies in the data and analysis methodologies to support the performance evaluation and B-C analysis of truck-only lanes are presented in Chapter 5 of this report. Also, the performance evaluations presented in this chapter did not consider the application of tolls on truck-only lanes. To understand the feasibility of tolls and their impacts on the performance of truck-only lanes, a discussion of tolls on truck-only lanes and their implications is presented in Appendix B (Section B.5).

CHAPTER 4

Benefit-Cost Analysis

The previous chapter demonstrated from prior analyses that there are truck-only lane configurations that, in different types of corridors, can provide positive benefits that meet regional and corridor planning objectives. The chapter also was able to identify some patterns in the types of truck-only lanes that have the highest level of benefits in different scenarios, as well as the key variables that drive benefits.

Nonetheless, there were some serious shortcomings when it comes to drawing definitive conclusions about the performance benefits and feasibility of truck-only lanes. Some of the most important shortcomings included the following:

- **Lack of a complete set of appropriate alternatives.** The most obvious example of this problem is cases in which mitigating congestion was an objective but the study did not examine an alternative that added capacity that was not a truck-only alternative. Congestion reduction benefits of truck-only lanes were often based on comparison with doing nothing (no-build alternative). Also, in some of the cases where additional mixed-flow lanes were considered in the alternatives analysis, there were differences in capacities between the mixed-flow and truck-only lane alternatives, due to which, the performance results were inconclusive in assessing the actual benefits of truck-only lanes relative to additional mixed-flow lanes.
- **Not taking into account an appropriate range of values for key variables.** For example, to the extent that diversion to LCV configurations has a direct impact on the productivity benefits of LCV lanes, no studies did a market assessment for LCVs to determine which truck trips/commodity flows would represent real candidates for diversion. In many cases, diversion scenarios for trucks from general purpose to truck-only lanes looked unrealistically high.
- **Inability to measure all benefits with a single metric (such as monetized values) so that relative importance of benefits across types (e.g., travel time savings, reliability, and safety) and relationships between benefits and costs can be assessed.** Benefit-cost (B-C) analysis is needed to complete the assessment of overall economic feasibility.
- **Lack of important tools necessary to analyze specific truck-only lane benefits.** Studies relied heavily on traditional travel demand models and relationships between V/C ratios and other performance measures. Tools such as traffic simulation models could have enhanced the effort to examine actual travel times, incident-related delay, reliability, and potential safety benefits of truck-only lanes.
- **Lack of data on specific performance changes when trucks and autos are separated.** Changes in traffic flows and speeds and crash rates that are a direct function of the operational improvements of separating trucks and autos were not included in any of the analysis because there is so little field data with which to estimate these specific benefits. To the extent that data are available, they are usually associated with auto-only lanes and not with truck-only lanes.

This section attempts to address the first three shortcomings to a limited degree through development of a "generic corridor" analysis framework for the B-C analysis of truck-only lanes.

4.1 Benefit-Cost Analysis Approach

As noted in the previous section, a B-C analysis would have allowed for the assessment of the relative importance of different types of benefits for any given scenario/alternative for truck-only lane application. It also would have allowed for a determination of which configurations appear to deliver the highest level of net benefits after taking costs into account. This is particularly important when comparing LCV versus non-LCV operations on truck-only lanes since costs may be higher for LCV systems off-setting some of the productivity benefits. Yet, most of the studies reviewed for the performance evaluation task did little to assess the cost-effectiveness of truck-only lanes compared to other alternatives (such as additional mixed-flow lanes) based on the development of B-C ratios. Due to this constraint, alternative approaches were developed for the B-C analysis in this study.

The approach that was taken in this study was to define a representative baseline (generic) corridor for each of the two scenarios/corridor types (long-haul intercity and urban), to apply the approaches and data provided by the previously reviewed studies, use standard values from the literature to monetize benefits, and use data from the prior studies to estimate costs. The B-C analysis was based on a net present value (NPV) analysis approach, which is described below.

4.1.1 Net Present Value Analysis

The B-C analysis was based on an NPV analysis approach using a base year of 2008 and a time horizon of 2030 for the analysis. Monetized benefits and costs were estimated for each year in the 2008 through 2030 time period and discounted to the base year (2008) to get the NPV of B-C ratios for each alternative. Benefits were calculated for a similar set of performance measures as those evaluated in the reviewed studies. The benefits were monetized using monetary values for travel times and reliability (using auto and truck value of time estimates) and monetary values for accidents (by type of accident). Costs were calculated based on unit cost factors developed from the literature (a detailed discussion of the benefit monetization factors and unit costs is presented in Appendix C, which is available on the TRB website at www.TRB.org by searching for NCHRP Report 649/NCFRP Report 3, and summarized later in this chapter). A later section describes the traffic growth and other economic assumptions used for the NPV analysis.

As described earlier, representative baseline corridors were defined for the B-C analysis, so that the relative benefits-costs of truck-only lanes in different corridor applications could be evaluated. The following section describes the corridor concepts defined for the B-C analysis.

4.1.2 Representative Baseline Corridors

The representative baseline corridors defined for the B-C analysis are not actual corridors but are generic corridors, that provided us with the opportunity to control characteristics of the corridors for analysis purposes. Although not actual corridors, the characteristics (e.g., auto and truck traffic volumes, length of corridor, and number of lanes) are derived from actual corridors evaluated for truck-only lanes throughout the country. Readers should view the B-C ratios calculated with this approach with some caution as they are not based on detailed analysis using data from actual corridors. However, for comparative purposes, and to give an idea of the range of assumptions that would make truck-only lanes a preferred alternative, the approach is useful.

For each baseline corridor scenario (long-haul and urban), a set of general corridor and traffic characteristics were defined. These characteristics included the following:

- Length of corridor,
- Number of lanes and capacity, and
- Total average daily traffic (ADT) and heavy-truck ADT.

For each baseline corridor scenario, a set of meaningful alternatives was defined including a truck-only lane alternative (which included two operational scenarios—with and without LCVs—in the case of a long-haul corridor), a mixed-flow lane alternative (to assess the relative benefits and costs of truck-only lanes compared to additional mixed-flow lanes), and a no-build alternative. Subsequent sections provide a more detailed description of the alternatives considered within each corridor scenario.

Because the data inputs for the B-C analysis for the urban and long-haul corridor scenarios have a high degree of uncertainty associated with them (such as costs and factors impacting truck diversion rates), and the magnitude of this uncertainty is unknown, the study team felt uncomfortable computing a single B-C ratio for each alternative. In order to recognize uncertainty in key input variables, a sensitivity analysis approach was used for the B-C analysis, which is described below.

4.1.3 Sensitivity Analysis Approach

To capture some of the uncertainties involved in the range of factors driving the diversion of truck traffic to truck-only lanes (which have a direct impact on the performance benefits estimates of truck lanes), as well as the uncertainties in capturing the range of costs for truck-only lane projects, a sensitivity analysis approach was used for the B-C analysis. A key variable in the analysis is the assumption about how much truck traffic diverts to the truck-only lanes. In the case of truck-only lanes without LCV operations, diversion rates should be a function of the relative congestion conditions on the mixed-flow lanes (assuming trucks are not required to operate on the truck-only lanes), number and placement of the exits and entrances to the truck-only lanes (and an associated cost tradeoff), and the O-D patterns of the trucks. In the case of truck-only lanes with LCV operations, diversion rates are expected to be a function of the connectivity to a larger LCV network, commodities carried (not all commodities will benefit from LCV operations), O-D patterns of the trucks, and off-system infrastructure availability (staging areas) and costs of LCV operations. None of the performance evaluations of LCV operations described in the previous chapter have conducted this type of thorough evaluation of the LCV market opportunities and they have tended to assume very high levels of trucks diverting to LCVs. However, analysis conducted for the *I-15 Comprehensive Corridor Study* in Southern California and analysis underway at the time of this study of potential LCV operations in the I-80/90 corridor between Chicago and Boston conducted for FHWA suggest that the markets for LCV operations in real corridors might be considerably smaller than previous studies have assumed. Therefore, the sensitivity analysis involved considering a range of diversion rates and assessing the impact of diversion rates on B-C ratios. The sensitivity analysis also considers the uncertainty in cost estimates and varies these in order to take into account potentially missing cost elements or certain widely varying unit cost factors reported in the literature.

For long-haul corridors, the sensitivity analyses included the following:

- Variations in rates of diversion to LCV lanes and truck-only lanes without LCVs, and
- Variations in costs.

For urban corridors the sensitivity analyses included the following:

- Variations in rates of diversion to truck-only lanes, and
- Variations in costs.

The sensitivity analysis approach for the B-C analysis of truck-only lanes along long-haul and urban corridors is useful in gaining the following key insights:

- Assessing the range of diversion rates that would result in truck-only lanes being cost-effective in comparison to adding mixed-flow capacity;

- Assessing what the minimum level of diversion would need to be in the case of LCV operations to make truck-only lanes a viable investment option in comparison to additional mixed-flow lanes;
- Assessing optimal diversion rates for truck-only lanes that provide the highest levels of cost-effectiveness (for congested corridors with high truck volumes, very high diversion rates would not necessarily maximize cost-effectiveness since congestion reduction on the general purpose lanes due to truck diversion might be offset by high levels of congestion on the truck-only lanes—this would be particularly relevant in the case where use of the truck-only lanes is mandatory); and
- Assessing the differences in diversion rates required for truck lanes with and without LCV operations to achieve similar levels of cost-effectiveness in the case of long-haul corridors.

4.2 Performance Metrics Considered for Benefit-Cost Analysis

The performance metrics discussed in the remainder of the following subsections were considered for the B-C analysis of truck-only lanes.

4.2.1 Public Benefits

Public benefits could include the following:

- **Travel time savings** that accrue to autos on general purpose lanes as trucks divert from general purpose lanes to truck-only lanes, thereby reducing congestion and improving travel speeds on the general purpose lanes. This metric is typically evaluated in terms of percent savings in travel times on the general purpose lanes due to the implementation of truck-only lanes.
- **Reliability benefits** that accrue to autos on general purpose lanes due to the implementation of truck-only lanes. The diversion of trucks to truck-only lanes reduces congestion and truck-auto interaction on the general purpose lanes, thereby improving safety and providing associated reliability benefits (in terms of reduction in incident-related nonrecurrent delay). This metric is typically evaluated in terms of percent savings in incident-related (nonrecurrent) delay on general purpose lanes due to the implementation of truck-only lanes.
- **Safety benefits** that accrue to all users. As discussed previously, the implementation of truck-only lanes can provide safety benefits on the general purpose lanes, since diversion of trucks to truck-only lanes would reduce congestion and truck-auto interaction on the general purpose lanes. This metric is typically evaluated in terms of percent reduction in total accidents (fatal accidents, if total accidents were not reported) on the general purpose lanes.

Reduction in emissions due to improved travel speeds on the general purpose and truck-only lanes would be another important public benefit of implementing truck-only lanes. The capacity enhancement along a corridor due to the implementation of truck-only lanes would result in improved travel speeds for autos and trucks on the general purpose lanes, as well as for trucks using the truck-only lanes. This improvement in travel speeds is expected to directly contribute to a net reduction in emissions along the corridor. However, the B-C analysis conducted in this study did not include environmental benefits (reduced emissions) as a public benefit category, primarily because of the lack of data required to accurately estimate travel speeds on general purpose and truck-only lanes. Also, the capacity enhancement due to the implementation of truck-only lanes is expected to result in some induced traffic along the corridor, as well as the displacement of auto and truck traffic from other corridors. This resulting increase in total VMT along the corridor would offset some of the emissions reduction from improved travel speeds. However, without the availability of a travel demand model, the net impact of increased VMT and improved travel speeds on emissions could not be assessed as part of the current study. Also, the analysis did not consider the negative environmental impacts of CMV-only lanes such as the noise impacts of concentrated truck traffic, due to inadequate information and methods for monetizing noise impacts (also, none of the available studies provided any data that could be used to support this analysis).

4.2.2 Private-Sector Benefits

Private-sector benefits could include the following:

- **Productivity benefits** including productivity enhancements realized by trucks using the truck-only lanes, as a result of increased speeds as well as increased payloads in the case of LCV operations.
- **Travel time savings and reliability benefits for trucks** such that trucks diverting to truck-only lanes from the general purpose lanes will experience significant improvements in performance associated with improved travel speeds (travel time savings) and reliability benefits due to reduction in accidents as a result of more stable traffic flows and homogeneity of traffic on the truck-only lanes. Since the travel time savings benefits for trucks on the truck-only lanes are captured under the productivity benefits (due to increased speeds) above, these savings are not included under the travel time savings performance measure (to avoid double-counting benefits). Trucks choosing to remain on the general purpose lanes (i.e., trucks not diverting to the truck-only lanes) will have travel time savings and reliability benefits (due to congestion reduction on the general purpose lanes), which are included in the travel time savings and reliability performance measures.

4.3. Data Inputs for Monetization of Performance Metrics

In order to compare benefits across benefit categories and to costs, the performance metrics had to be converted to a consistent unit of valuation. This involved monetizing the performance benefits to equivalent dollar values. In order to monetize benefits, the default factors in Table 4.1 were used. The values presented in Table 4.1 are for 2008 dollars (in the NPV analysis, these fac-

Table 4.1. Default values for benefits monetization factors, indexed for 2008.

Monetization Factor	Default Value	Source
Truck Value of Time ($ per Hour)[1]	39	Average value (indexed to 2008) for heavy-heavy duty trucks (HHDT) derived from various sources (refer to Table C.1 in Appendix C)
Auto Value of Time ($ per Hour)	10	Average value (indexed to 2008) based on the assumption that auto value of time is approximately 50% of average wage rate
Fatality Accidents ($ per Accident)	4,365,164	FHWA[2]
Injury Accidents ($ per Accident)	131,642	FHWA[2]
Property-Damage-Only Accidents ($ per Accident)	8,226	FHWA[2]

Notes:

1. The auto and truck value of time estimates presented in the table are used to monetize travel time savings. For monetizing travel time reliability benefits (measured in terms of savings in incident-related delay), these estimates are adjusted by a factor of 1.5.
2. Federal Highway Administration, *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries*, Publication No. FHWA-HRT-05-051, October 2005.

tors are adjusted for inflation for the future years using average rate of inflation of 3% derived from historic growth in the consumer price index [CPI]).

4.4 Unit Cost Data

Table 4.2 provides unit cost estimates associated with the implementation of truck-only lane and mixed-flow lane facilities. The unit costs in Table 4.2 include capital costs associated with right-of-way acquisition and construction costs (including lanes, interchanges, and staging areas in the case of LCV operations). Since the costs may also vary depending on the type of corridor (long-haul versus urban), the cost information is presented separately for the two corridor scenarios. O&M costs are estimated based on the assumptions in the Georgia *Statewide Truck Lane Needs Identification Study,* which assumes O&M costs for truck-only toll lane corridors to be 0.5% of total project capital costs in the base year, which increase each year at a 3% rate of inflation (based on historic growth in CPI).

4.5 Economic Assumptions for Net Present Value Analysis

For the purpose of the B-C analysis, it is assumed that the corridor is operational beginning in 2008, and benefits are accrued for a study time horizon up to 2030. The discount rate is assumed to be 7%, as recommended by the Office of Management and Budget (OMB) for projects providing societal benefits. Average annual growth rate in truck and auto traffic for the NPV analysis is assumed to be 3.3% and 1.8%, respectively, based on truck and auto VMT growth estimates from FHWA's Freight Analysis Framework (FAF).[44] Annual rate of inflation for truck freight rates and operating costs (which are used as inputs in the calculation of truck productivity benefits) is assumed to be 3% based on historic trends in the CPI. Key assumptions used in the NPV analysis are summarized as follows for annual changes from 2008 to 2030:

- Growth rate for autos—1.8% (based on FHWA FAF VMT growth estimates),
- Growth rate for trucks—3.3% (based on FHWA FAF VMT growth estimates),
- Rate of inflation—3.0% (based on historic trends in CPI), and
- Discount rate—7.0% (based on OMB recommendations).

4.6 Corridor Descriptions and Corridor-Specific Benefit-Cost Methodologies

4.6.1 Long-Haul Corridors

Long-haul corridors can experience a wide range of traffic conditions. Unlike urban corridor scenarios where truck-only lanes are generally part of a strategy to meet capacity improvement needs (in cases where truck traffic has a disproportionate impact on corridor congestion), the rationale for truck-only lanes along long-haul corridors can sometimes be to address congestion moving in, out, or around metropolitan areas, to increase truck productivity in low-volume rural corridors, or to achieve freight efficiency and reduce costs to businesses. Examples of long-haul corridor rationales other than to address congestion include the following:

- **Need to operate LCVs to enhance trucking productivity along long-haul corridors.** Operating LCVs on general purpose lanes is known to have safety issues due to interactions of LCVs with passenger vehicles;

[44]See http://www.ops.fhwa.dot.gov/freight/presentations/lambert_nasto.htm, Slide 7.

Table 4.2. Unit costs for truck-only and mixed-flow lane facilities.

Corridor Scenario	Cost Category	Alternative	Value	Source
Urban Corridors	Construction costs—lanes ($ million per lane mile)	Mixed-flow lane	2.8	Middleton, D., S. Venglar, C. Quiroga, D. Lord, and D. Jasek, *Strategies for Separating Trucks from Passenger Vehicles: Final Report*, Texas Transportation Institute (TTI), September 2006.
		Truck-only lane	5.5	Middleton, D., S. Venglar, C. Quiroga, D. Lord, and D. Jasek, *Strategies for Separating Trucks from Passenger Vehicles: Final Report*, Texas Transportation Institute (TTI), September 2006.
	Construction costs—interchange ($ million per interchange)	Mixed-flow lane	80	Cambridge Systematics (assumption based on Highway Economic Requirements System [HERS] base case value)
		Truck-only lane	80	HERS
	Right-of-way (ROW) acquisition costs ($ million per lane mile)	Mixed-flow lane	1.2	Woudsma, C., T. Litman, and G. Weisbrod, *A Report on the Estimation of Unit Values of Land Occupied by Transportation Infrastructures in Canada*, Transport Canada, 2006.
		Truck-only lane	1.2	Woudsma, C., T. Litman, and G. Weisbrod, *A Report on the Estimation of Unit Values of Land Occupied by Transportation Infrastructures in Canada*, Transport Canada, 2006.
Long-Haul Corridors	Construction costs—lanes ($ million per lane mile)	Mixed-flow lane	2.8	Middleton, D., S. Venglar, C. Quiroga, D. Lord, and D. Jasek, *Strategies for Separating Trucks from Passenger Vehicles: Final Report*, Texas Transportation Institute (TTI), September 2006.
		Truck-only lane—without LCV	5.5	Middleton, D., S. Venglar, C. Quiroga, D. Lord, and D. Jasek, *Strategies for Separating Trucks from Passenger Vehicles: Final Report*, Texas Transportation Institute (TTI), September 2006.
		Truck-only lane—with LCV	5.9	Incremental costs due to LCV operations derived from data presented in the *Western Uniformity Scenario Analysis*
	Construction costs—interchange ($ million per interchange)	Mixed-flow lane	80	Cambridge Systematics (assumption based on HERS base case value)
		Truck-only lane—without LCV	80	HERS
		Truck-only lane—with LCV	86	Incremental costs due to LCV operations derived from data presented in the *Western Uniformity Scenario Analysis*
	Construction costs—staging areas ($ million per staging facility)	Mixed-flow lane	N/A	N/A
		Truck-only lane—without LCV	N/A	N/A
		Truck-only lane—with LCV (staging area in rural location)	2.8	U.S.DOT's *Comprehensive Truck Size and Weight Study*, http://www.fhwa.dot.gov/reports/tswstudy/tswfinal.htm.
		Truck-only lane—with LCV (staging area in urban location)	4.5	U.S.DOT's *Comprehensive Truck Size and Weight Study*, http://www.fhwa.dot.gov/reports/tswstudy/tswfinal.htm.

Table 4.2. (Continued).

Corridor Scenario	Cost Category	Alternative	Value	Source
	ROW acquisition costs ($ million per lane mile)	Mixed-flow lane	0.1	Trans-Texas Corridor (TTC) cost assumptions and Washington State Department of Transportation, *Washington Commerce Corridor Feasibility Study*, December 2004, http://www.wsdot.wa.gov/NR/rdonlyres/5A1D7325-AFAF-4BD1-9336-BECCDEE92ADF/0/WCC_FinalReport.pdf..
		Truck-only lane—without LCV	0.1	Trans-Texas Corridor (TTC) cost assumptions and Washington State Department of Transportation, *Washington Commerce Corridor Feasibility Study*, December 2004, http://www.wsdot.wa.gov/NR/rdonlyres/5A1D7325-AFAF-4BD1-9336-BECCDEE92ADF/0/WCC_FinalReport.pdf.
		Truck-only lane—with LCV	0.1	Trans-Texas Corridor (TTC) cost assumptions, and Washington State Department of Transportation, *Washington Commerce Corridor Feasibility Study,* December 2004, http://www.wsdot.wa.gov/NR/rdonlyres/5A1D7325-AFAF-4BD1-9336-BECCDEE92ADF/0/WCC_FinalReport.pdf.

- **Need to meet truck oversize/overweight (OS/OW) requirements.** Operating OS/OW trucks on general purpose lanes is known to have safety issues, and is expected to have a detrimental impact on pavements; and
- **Need to separate trucks from autos along corridors.** Terrain and other system configurational issues may be leading to safety problems due to truck-auto operational conflicts.

Based on these observations, the representative baseline scenario for long-haul corridors assumes modest overall traffic volumes (some congestion) with high levels of truck traffic. Both average daily total and truck traffic volumes grow over the forecast period, but truck traffic grows at a faster rate. To evaluate the travel time benefits of truck-only lanes, in addition to a no-build alternative, an alternative with additional general purpose lanes has been considered in the analysis. In addition to analyzing congestion reduction benefits (in terms of travel time savings), a major feature of the analysis involves examining the benefits and costs of LCV operations on the truck-only lanes (OS/OW truck operations were not considered as part of the current analysis since there was a limited body of research available to provide inputs to allow for a robust assessment of the performance benefits of truck-only lanes with OS/OW truck operations). Considering the increased interest of states to allow special permit OS/OW truck operations based on permit fees, however, the performance and feasibility of these operations on truck-only lanes would be an important issue to consider as part of future research on truck-only lanes.

Generic Corridor Characteristics

The characteristics of the generic baseline corridor for the B-C analysis of truck-only lanes along long-haul corridors were derived from the characteristics of the long-haul corridors analyzed in the Reason Foundation study[45] for the selection of pilot corridors for the implementation of toll truckways. Table 4.3 summarizes these characteristics for the base year (2008).

[45]R. W. Poole, Jr. and P. Samuel, *Policy Study 316: Corridors for Toll Truckways: Suggested Locations for Pilot Projects,* Reason Foundation, February 2004.

Table 4.3. Generic baseline long-haul corridor characteristics.

Parameter	Value	Rationale
Length of Corridor	400 mi	Long-haul corridors considered in the Reason Foundation study ranged in length from 15 to 973 mi and the average length was estimated to be 400 mi
Number of Lanes	6	Corridors ranged in number of lanes between 4 and 7 lanes and average was estimated to be 6 lanes
Average Daily Total Traffic	105,000	Corridors ranged between 57,000 and 196,000 average daily traffic (ADT) and average was estimated to be 105,000
Average Daily Truck Traffic	14,000	Corridors ranged between 6,000 and 20,000 average daily truck traffic (ADTT) and average was estimated to be 14,000
Truck Share of Total Traffic	13.3%	

For the baseline analysis, assumptions were needed for the level of usage of the truck-only lanes (otherwise termed truck diversion to truck-only lanes). This information is used to determine V/C ratios, speeds, and travel time benefits. However, the results of the benefits analysis suggest that the level of diversion is critical to the potential success of truck-only lanes, particularly when LCV operations are involved. In the case of truck-only lanes without LCV operations, truck lane usage largely will be a function of the difference in speeds between the mixed-flow lanes and the truck-only lanes and the availability of access points. Generally, this can be determined using standard travel demand models and commodity flow and truck O-D data. In the case of truck-only lanes with LCV operations, a more comprehensive analysis of markets that take into account the O-D patterns of the trucks, the types of commodities carried, locations of staging areas, and business characteristics of the motor carriers is required to accurately determine the diversion from standard trucks to LCVs. None of the studies reviewed for this project included this type of market analysis. These studies arbitrarily hypothesized ranges of utilization that tended to be fairly high (40% or more). The I-15 Comprehensive Corridor Study in Southern California and recent work for FHWA have made high-level estimates of diversion to LCV lanes based on data on commodities typically carried in LCVs on the existing LCV network, O-D patterns of trucks relative to the existing LCV network, and configurations that might switch to LCV operations. These estimates suggest that diversion markets might be substantially smaller than the ranges represented in the studies reviewed for this project. Therefore, a wider range of diversion rates was examined in this project as part of a sensitivity analysis approach.

Description of Alternatives

In addition to the baseline no-build corridor, three build alternatives were developed for the B-C analysis of long-haul corridors, which included the following:

- **Additional mixed-flow lanes.** Although long-haul intercity corridors generally do not have high levels of congestion, in certain high-potential corridors, particularly in the industrial midwestern United States and along the U.S. coasts in certain key corridors, there are high levels of congestion around cities and sufficient volumes that over the time horizon of the analysis, congestion levels are expected to grow. Thus, the evaluation of travel time benefits would tend to favor truck-only lane solutions if they are only compared with no-build conditions, because the truck-only lanes have more capacity. In many of the studies used in the performance evaluations presented in the previous chapter, this was a shortcoming since they only compared truck-only lanes with a no-build alternative (without considering an additional mixed-flow lane alternative). Therefore, in the generic corridor analysis, a build alternative was defined that included additional mixed-flow lanes. In the long-haul corridor, this alternative includes two additional mixed-flow lanes in each direction along the entire length (400 mi) of the corridor.

- **Truck-only lanes without LCV operations.** This alternative is comprised of two truck lanes in each direction along the entire length (400 mi) of the corridor. This alternative was included to analyze the performance benefits and relative costs of truck lanes (without LCV operations) in comparison with additional mixed-flow lanes.
- **Truck-only lanes with LCV operations.** As discussed earlier, many long-haul corridor concepts are focused on improving freight operations through productivity improvements while at the same time gaining the operational and safety benefits of truck-auto separation. Therefore, this generic corridor analysis includes an alternative with LCV operations. This alternative is comprised of two truck lanes in each direction along the entire length of the corridor, and these truck lanes allow LCV operations.

Calculation of Benefits

Net present value of productivity benefits. For the purposes of this study, the calculation of productivity benefits follows the methods used by the Reason Foundation analysis of LCV operations. This approach calculates productivity benefits as a private-sector benefit that only accrues to users of the truck-only lanes (both cases, with and without LCVs). The approach is based on the estimation of the net increase in trucking industry earnings due to operations on truck-only lanes and derives from both reduced travel times (which create the opportunity to carry more loads and achieve higher equipment utilization) and the ability to carry higher payloads per unit operating costs. The specific assumptions and approaches used are described in more detail in Appendix C, along with the results of the NPV calculation of these benefits.

Net present value of travel time savings for mixed-flow traffic. Travel time savings benefits are quantified for each of the years (2008 to 2030) for each of the build alternatives relative to the no-build alternative, to estimate the total NPV of travel time savings for the B-C analysis. Note that these estimates only include the total travel time savings for mixed-flow traffic (autos and trucks on the general purpose lanes). As discussed earlier, for the truck-only lane alternatives, travel time savings for trucks on the truck-only lanes are not included in this performance measure since these benefits are captured in the productivity benefits calculations. A more detailed description of the calculation methodology is presented in Appendix C, along with complete results of the calculations.

Net present value of safety benefits. Safety benefits are quantified in terms of the NPV of monetary savings in total accidents (fatality, injury, and property-damage only [PDO]) for the 2008 to 2030 time period for each of the build alternatives compared to the no-build alternative. Total accidents for each of the alternatives are estimated using inputs on auto and truck VMTs, level of congestion (V/C) on the general purpose and truck lanes, and accident rates (for fatality, injury, and PDO accidents in terms of accidents per million VMT) as a function of V/C from the IDAS *User Manual*.[46] Additionally, as discussed in the performance evaluation task, for the truck lane alternatives, the total accidents on the general purpose lanes estimated using IDAS inputs are reduced by a factor of 15%, as recommended by the Douglas handbook[47] to account for the safety benefits of truck-auto separation. A more detailed discussion of the calculation methodology and results of the NPV calculation are presented in Appendix C.

4.6.2 Urban Corridors

The B-C analysis approach for urban corridors compares the relative benefits and costs of truck-only lanes with additional mixed-flow lanes, based on a generic corridor analysis approach,

---

[46]See http://idas.camsys.com/userManual/App_b.pdf.

[47]J. G. Douglas, *Handbook for Planning Truck Facilities on Urban Highways,* August 2004.

similar to the one described in the previous section for long-haul corridors. Urban corridors with high auto and truck traffic volumes would be primary candidates requiring such a comparative assessment, since congestion, reliability, and safety are expected to be key issues along such corridors, and adding capacity not only to mitigate congestion, but also to improve reliability and safety would be a primary need. It would be important to analyze if adding capacity while at the same time achieving truck-auto separation (through truck-only lanes) would be more cost effective along these corridors compared to adding mixed-flow capacity.

A key consideration in analyzing the differential capacity benefits of truck lanes as compared to mixed-flow lanes is the difference in the time-of-day characteristics of truck traffic and auto traffic. Auto volumes tend to peak during the morning and evening commuter hours whereas truck volumes tend to peak in the middle of the day. The benefits of truck-only lanes will therefore depend largely on the degree to which congestion extends throughout the day, truck and auto peaks overlap, and truck volumes are high enough to achieve high levels of truck lane use. Unfortunately, the study team was unable to account for time-of-day variations between trucks and autos in the B-C analysis because of the lack of a travel demand model or a simulation tool to assess the time-of-day variations between trucks and autos. However, future analyses to assess the performance benefits of truck-only lanes should consider time-of-day variations between trucks and autos through the use of travel demand models and/or simulation tools to conduct an accurate assessment of the true performance benefits of truck-only lanes.

Since none of the reviewed studies under the urban corridor scenario provide B-C analysis results based on a one-to-one comparison between truck-only lanes and additional mixed-flow lanes, the B-C assessment presented in this section is based on comparing truck-only lanes and mixed-flow lane alternatives that add the same amount of capacity. The benefits included in the B-C analysis include travel time savings, reliability, and safety.

Generic Corridor Characteristics

The I-710 corridor in Southern California serves as a prime example of a corridor in an urban area with configurational, demand, and operational characteristics that are suitable for the comparative assessment of the relative benefits and costs of truck-only lanes and additional mixed-flow lanes. Some of these characteristics include the following:

- Location (impacts corridor demand characteristics):
  - Access to major freight facilities. Primary access route to major seaports, thereby resulting in high truck (port-related) volumes on the corridor; and
  - Primary urban area corridor with high auto and truck (port as well as domestic truck) traffic volumes.
- Safety:
  - High accident rates due to congestion in the peak periods, as well as high level of truck-auto interactions.
- Reliability:
  - Due to congestion and high truck-auto interactions (and associated incident-related issues) and high port truck traffic volumes, improving reliability is not only important for autos, but also for the international goods movement supply chains whose efficiency is affected by reliability issues along the corridor.

Consequently, the characteristics of the urban area generic corridor for the B-C analysis, including the length, auto and truck volumes, and number of lanes, draw heavily from analysis of the I-710 corridor. The B-C analysis approach involves conducting sensitivity analyses to provide a basis for drawing conclusions from a wide range of critical urban corridor characteristics and addressing uncertainty in estimates of some of the cost and benefit parameters.

The demand and configurational characteristics of the generic urban corridor are defined as follows:

- Length = 20 mi,
- Number of lanes (bidirectional) under the no-build alternative = 10,
- Daily auto volume = 200,000,
- Daily truck volume = 60,000,
- Daily total traffic volume = 260,000, and
- Truck share of total traffic = 23%.

Description of Alternatives

To ensure consistency in the comparisons of relative benefits and costs between the build alternatives (additional mixed-flow and truck-only lanes), it is assumed that these alternatives provide similar levels of additional capacity along the corridor. The characteristics of these alternatives are as follows:

- **Additional mixed-flow lanes.** This alternative includes two additional mixed-flow lanes in each direction over the entire stretch of the corridor; and
- **Truck-only lanes.** This alternative includes two truck-only lanes in each direction over the entire stretch of the corridor.

The assumptions related to data inputs (study time period, auto and truck volume growth rates, inflation rate, and discount rate) for the NPV analysis of various benefits components have been discussed in Section 4.5. The following sections discuss the performance measures estimated.

Calculation of Benefits

NPV of travel time savings. The estimation of the NPV of travel time savings associated with the build alternatives (additional mixed-flow lanes and truck-only lanes) relative to the no-build alternative was based on estimating average daily V/C and associated speeds on general purpose lanes and truck-only lanes given the assumptions about utilization of the truck lanes. Since this corridor scenario does not consider productivity benefits, for the truck-only lane alternative the travel time savings for trucks diverting to the truck lanes are included in the total travel time savings benefits. The estimates do not take into account time-of-day variation in traffic volumes for autos and trucks. A complete description of the methodology and the results of the calculations are presented in Appendix C.

NPV of reliability benefits. Reliability benefits are quantified in terms of the monetized savings in incident-related delay. Techniques and specific performance metrics for predicting and measuring reliability are still very much under development. One approach to assessing the value of reliability benefits has been to assume that the value of time for incident-related delays is significantly higher than that of recurrent delay because incident-related delay is inherently unpredictable. For trucking, it is possible to plan for recurrent delay and to incorporate these plans into cost structures, whereas unplanned incidents can have highly variable (and sometimes very significant) cost implications. Appendix C presents a more detailed review of the approach used to monetize reliability benefits and provides references to the supporting studies justifying this approach. In this project, incident-related delay was calculated using incident-delay rates (delay per vehicle mile) from IDAS as a function of V/C and configuration of the highway and was valued at 1.5 times the recurrent delay VOT (value of time) estimates to arrive at the value of incident-related delay for the monetization of reliability benefits. For the truck-only lane alternative, the incident-related delays are reduced by an additional factor of 15%, to account for the reduction in incidents due to truck-auto separation.

NPV of safety benefits. The estimation of NPV of safety benefits associated with the build alternatives was developed by calculating accident rates per million VMT as a function of V/C using look-up factors from the previously mentioned IDAS handbook. These were further reduced by 15% for the truck-only lanes to account for the benefits of truck-auto separations based on the results of previously cited research by Douglas. A more complete description of this approach is included in Appendix C.

4.7 Results of the Benefit-Cost Analysis

4.7.1 Long-Haul Corridor

In order to develop the B-C analysis of a generic corridor, a number of assumptions about key variables needed to be made. In analysis of an actual corridor, these need not be assumptions but could be based on market analysis of actual conditions. Further, without taking into consideration actual corridor conditions, the need for interchanges, and the need for supporting infrastructure (like staging areas), cost estimates for the long-haul corridor alternatives could vary widely from the assumptions used in the generic corridor analysis.

Costs

This section presents the comparative costs for all cost components of each alternative. The cost estimates are developed using the unit costs presented in an earlier section, and the configurational and travel demand characteristics along the generic corridor. Since there is inadequate information on some of the truck-only lane cost components such as O&M costs and LCV equipment costs, the B-C analysis uses a range of costs. The range of costs was developed by first estimating a baseline total cost for each alternative, and varying the costs across the baseline (lower and upper limit costs with the baseline as the mean) using a variance of ±20% relative to the baseline.

Table 4.4 presents the baseline cost components for each of the alternatives. A detailed discussion of the approach to calculating costs and their relationship to the NPV analysis is presented in Appendix C.

As mentioned previously, to account for the uncertainty in costs in the sensitivity analysis, the total costs for each alternative in Table 4.4 are varied to arrive at a representative range of cost estimates for the B-C analysis. Table 4.5 presents these cost variations for the long-haul corridor alternatives.

Table 4.4. Baseline cost components for long-haul corridor alternatives, in billions of dollars (indexed to 2008).

Costs	Additional Mixed-Flow Lanes	Truck-Only Lanes: Without LCV Operations	Truck-Only Lanes: With LCV Operations
ROW Acquisition	0.2	0.2	0.2
Construction (Lanes)	4.5	8.8	9.4
Construction (Interchanges)	0.7	0.7	0.8
Construction (Staging Areas—Rural Locations)	–	–	0.003
Construction (Staging Areas—Urban Locations)	–	–	0.009
O&M	0.4	0.8	0.8
Total	**5.8**	**10.5**	**11.2**

Table 4.5. Range of costs considered for the B-C analysis, in billions of dollars (indexed to 2008).

Alternative	Lower Limit for Cost (20% Below Baseline)	Baseline Cost	Upper Limit for Cost (20% Above Baseline)
Additional Mixed-Flow Lanes	4.7	5.8	7.0
Truck-Only Lanes without LCV Operations	8.4	10.5	12.6
Truck-Only Lanes with LCV Operations	9.0	11.2	13.5

Monetized Benefits

As mentioned, a range of diversion rates is considered in the B-C analysis to assess the impact of diversion rates on the performance benefits of truck-only lanes and to identify the range of diversion rates for which truck-only lanes are observed to be cost-effective compared to adding mixed-flow capacity. The results for the monetized benefits under each performance measure for each alternative under different diversion rate assumptions are presented in Table 4.6. Note that the results for the additional mixed-flow lane alternative do not change under different diversion rate scenarios because they are only applicable to the truck-only lane alternative.

Benefit-Cost Results

Figure 4.1 shows the comparison of B-C results for each alternative as a function of diversion rates.

Conclusions

The following are key conclusions from the B-C analysis of truck-only lanes in the long-haul generic corridor:

- The results suggest that high levels of diversion would be needed for truck-only lanes to be judged a preferred alternative both in terms of getting to a B-C ratio greater than 1.0 and exceeding the B-C ratio of adding more general purpose lanes.
- In the case of truck-only lanes without LCV operations, even under the most optimistic scenario favoring this alternative (i.e., truck-only lane costs being closer to the lower threshold—20% below the baseline; and additional mixed-flow lane costs falling in the upper threshold—20% above the baseline), a minimum of 50% diversion would be required before the truck-only lanes become more cost-effective compared to adding mixed-flow capacity. Under the applicability

Table 4.6. Monetized benefits of alternatives for different diversion rate assumptions, in millions of dollars (indexed to 2008).

	Additional Mixed-Flow Lanes				Truck-Only Lanes without LCVs				Truck-Only Lanes with LCVs			
Diversion Rate (%)	Productivity	Travel Time	Safety	Total	Productivity	Travel Time	Safety	Total	Productivity	Travel Time	Safety	Total
10	–	4.9	–	4.9	0.6	0.6	0.1	1.4	1.3	0.6	0.3	2.2
20	–	4.9	–	4.9	1.2	1.1	0.3	2.6	2.6	1.1	0.5	4.2
30	–	4.9	–	4.9	1.8	1.6	0.4	3.8	3.8	1.6	0.8	6.2
40	–	4.9	–	4.9	2.4	1.9	0.5	4.9	5.1	1.9	1.1	8.1
50	–	4.9	–	4.9	3.0	2.2	0.7	5.9	6.4	2.2	1.3	9.9
60	–	4.9	–	4.9	3.6	2.4	0.8	6.8	7.7	2.4	1.6	11.7
70	–	4.9	–	4.9	4.2	2.6	0.9	7.7	9.0	2.6	1.8	13.3
80	–	4.9	–	4.9	4.8	2.7	1.0	8.5	10.2	2.7	2.0	15.0
90	–	4.9	–	4.9	5.4	2.8	1.1	9.2	11.5	2.8	2.3	16.5
100	–	4.9	–	4.9	5.9	2.8	1.2	9.9	12.8	2.8	2.5	18.0

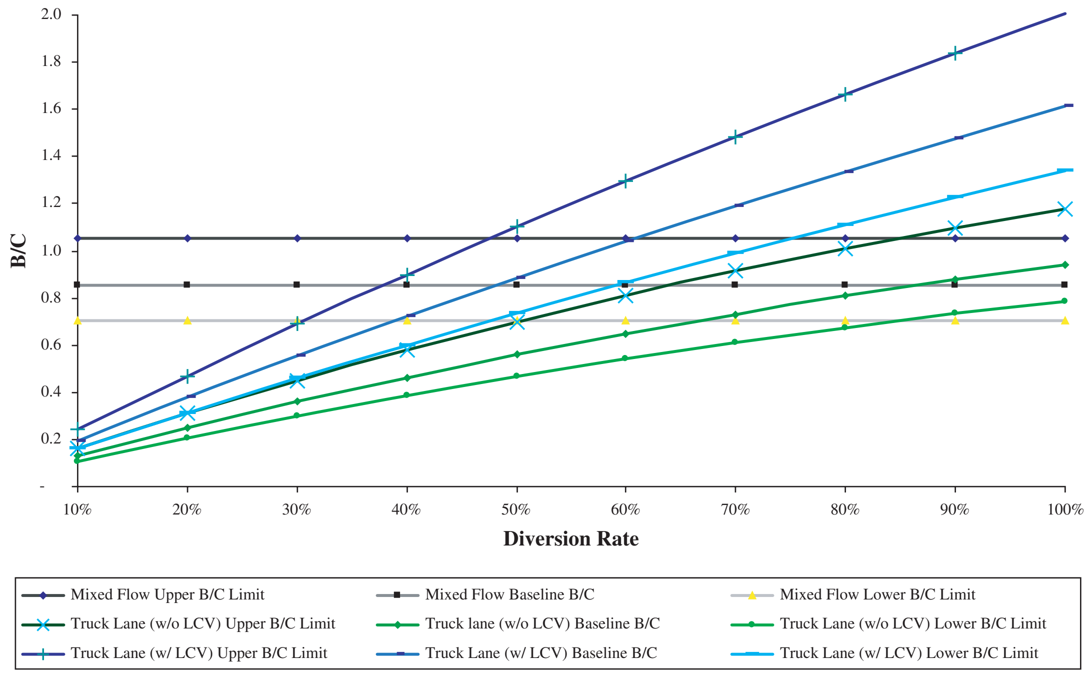


Figure 4.1. B-C ratios for alternatives as a function of diversion rate.

of baseline conditions, the diversion rates would need to be very high (more than 85%) before this alternative performs better in terms of cost-effectiveness compared to adding mixed-flow lanes. Given this high level of diversion, which might not be achievable along long-haul corridors, particularly those with relatively lower levels of congestion, truck-only lanes without LCV operations would generally appear to be an inappropriate choice under the general conditions described for long-haul corridors.

- In the case of LCV operations on truck-only lanes, even under the most optimistic scenario favoring this alternative (i.e., lower end of the costs for truck-only lanes and upper end of the costs for mixed-flow lanes), a minimum of 30% diversion would be required before the truck-only lane alternative becomes more cost-effective compared to adding mixed-flow capacity. Under the applicability of baseline conditions, the diversion rate would need to be at least 50% before truck-only lanes with LCV operations perform better compared to mixed-flow lanes. Also, diversion to the LCVs would need to be in the range of 45% to 70% (depending on costs) to achieve B-C ratios greater than 1.0.
- Based on the results, it appears that for long-haul corridors, the decision making for corridor investment options would primarily be governed by the relative B-C performance of truck-only lanes with LCV operations compared to additional mixed-flow lanes. If the market for LCVs is not present along a corridor or is such that it would only result in lower diversion rates (less than 30% based on Figure 4.1) based on the type of commodities, connectivity of the corridor to the larger LCV network, and/or truck O-D patterns, it would clearly rule out the applicability of truck-only lanes along the corridor (given that typical conditions along long-haul corridors would make truck-only lanes without LCVs not a preferred alternative compared to adding mixed-flow lanes). Based on the market conditions, which would govern the potential rate of diversion, the results from Figure 4.1 could be applied to assess the cost-effectiveness of implementing truck-only lanes with LCV operations compared to adding mixed-flow capacity along a corridor.
- As mentioned earlier, the results in Figure 4.1 are generated based on the defined characteristics of the representative baseline corridor. Consequently, these trends are expected to change

based on changes in corridor congestion characteristics, which are not reflected in the results. It is expected that these changes will be more pronounced for the mixed-flow lane and truck-only lane without LCV alternatives (compared to the truck-only lane with LCV operation alternatives) because a relatively large share of the benefits for these alternatives is associated with travel time savings (while productivity benefits from LCV operations account for a large share of the benefits for this alternative). This would mean that the relative difference in performance of mixed-flow lanes and truck-only lanes without LCV operations might not change much with a decrease in congestion levels (compared to the conditions defined in this analysis), but the relative performance of the truck-only lane alternative with LCV operations compared to the mixed-flow lane alternative is expected to improve. In other words, decrease in corridor congestion levels would potentially bring the minimum diversion threshold for cost-effectiveness of the truck-only lane alternative to lower than 30%.

- As noted in the introduction to this chapter, the results in Figure 4.1 very likely underestimate the benefits of truck-only lanes because they do not fully account for the safety benefits of truck-only lanes as compared with additional mixed-flow lanes. This shortcoming is unlikely to significantly alter the conclusions since safety benefits are a relatively small contributor to overall benefits.
- The analysis does not take into account potential market diversion from congested rail corridors to the LCV lanes, which could add further benefits without any increase in costs, particularly in cases where LCV lanes provide significant improvements in reliability, speed, and productivity, leading to diversion from rail to LCVs. Market diversion from rail to LCV corridors was not taken into consideration because this type of analysis is typically corridor specific, and would require extensive market analysis to assess the types of commodities along the corridor being studied, commodity O-D patterns, and shipper surveys to assess the propensity for cargo diversion from rail to LCVs, which was beyond the scope of this study. However, it would be critical to account for modal diversion in the feasibility analysis of CMV-only lanes (with LCV operations) along long-haul corridors as part of future research (it is anticipated that the consideration of truck-rail diversion typically would be based on a case-by-case basis, depending on the conditions along specific long-haul corridors being studied for the feasibility of implementing CMV-only lanes).

4.7.2 Urban Corridor

As in the case of the long-haul corridor scenario, the B-C analysis to evaluate the cost-effectiveness of truck-only lanes compared to adding mixed-flow capacity on urban corridors was based on a sensitivity analysis approach that involved analyzing the variations in B-C ratios for the truck-only lane alternative as a function of diversion rate, and comparing these results with the benefit-cost for the additional mixed-flow lane alternative to identify the range of diversion rates for which truck-only lanes are observed to be cost-effective when compared to adding mixed-flow capacity. The following sections present the costs, monetized benefits, and comparisons of benefit-cost between the urban corridor alternatives for various diversion rate scenarios.

Costs

This section quantifies the various cost components associated with implementing the build alternatives for the purpose of conducting a comparative B-C analysis, using the unit cost estimates presented in an earlier section, and the configurational characteristics of the urban generic corridor. As with the long-haul corridors scenario, due to uncertainties in costs associated with implementing truck-only lanes, which could be impacted by corridor (such as number of interchanges) as well as demand characteristics (which would potentially impact O&M costs), the B-C analysis uses a range of costs as part of the sensitivity analysis. The range of costs was developed by first estimating a baseline total cost for each alternative, and varying the costs across the

Table 4.7. Baseline cost components for urban corridor alternatives, in billions of dollars (indexed to 2008).

Costs	Mixed-Flow Lanes	Truck-Only Lanes (without LCV Operations)
ROW Acquisition	0.1	0.1
Construction (Lanes)	0.2	0.4
Construction (Interchanges)	0.4	0.4
O&M	0.1	0.1
Total	**0.8**	**1.0**

baseline (lower and upper limit costs with the baseline as the mean), using a variance of ±20% relative to the baseline.

Table 4.7 presents the baseline cost components for the urban corridor alternatives. A detailed discussion of the approach to calculating costs and their relationship to the NPV analysis is presented in Appendix C.

Similar to the B-C analysis for long-haul corridors, to account for the uncertainty in costs in the sensitivity analysis, the total costs for each alternative are varied to arrive at a representative range of cost estimates for the B-C analysis. Table 4.8 presents these cost variations for the urban corridor alternatives.

Monetized Benefits

As in the long-haul corridor scenario, a range of diversion rates is considered in the B-C analysis to assess the impact of diversion rates on the performance benefits of truck-only lanes and identify the range of diversion rates for which truck-only lanes are observed to be cost-effective when compared to adding mixed-flow capacity along urban corridors. The results for the monetized benefits under each performance measure for each alternative under different diversion rate assumptions are presented in Table 4.9. Note that the results for the additional mixed-flow lane alternative do not change under different diversion rate scenarios because they are only applicable to the truck-only lane alternative.

Benefit-Cost Results

Figure 4.2 shows the comparison of B-C results for each alternative as a function of diversion rates.

Conclusions

Following are some of the caveats associated with the current analysis, which are important to note before discussing the key conclusions from the results in Figure 4.2:

- The B-C ratios from the NPV analysis for the mixed-flow and truck-only lane alternatives are observed to be significantly high, and should be viewed with caution. Since the B-C results are

Table 4.8. Range of costs considered for the B-C analysis, in billions of dollars (indexed to 2008).

Alternative	Lower Limit for Cost (20% Below Baseline)	Baseline Cost	Upper Limit for Cost (20% Above Baseline)
Mixed-Flow Lanes	0.6	0.8	1.0
Truck-Only Lanes	0.8	1.0	1.2

Table 4.9. Monetized benefits of alternatives for different diversion rate assumptions, in billions of dollars.

	Additional Mixed-Flow Lanes				Truck-Only Lanes			
Diversion Rate (%)	Travel Time	Reliability	Safety	Total	Travel Time	Reliability	Safety	Total
10	5.6	1.5	0.4	7.4	1.5	0.4	0.1	2.1
20	5.6	1.5	0.4	7.4	2.8	0.9	0.3	3.9
30	5.6	1.5	0.4	7.4	3.8	1.3	0.4	5.5
40	5.6	1.5	0.4	7.4	4.6	1.7	0.5	6.8
50	5.6	1.5	0.4	7.4	5.2	1.9	0.5	7.6
60	5.6	1.5	0.4	7.4	5.5	2.0	0.6	8.1
70	5.6	1.5	0.4	7.4	5.5	2.0	0.6	8.1
80	5.6	1.5	0.4	7.4	5.1	2.1	0.6	7.7
90	5.6	1.5	0.4	7.4	4.0	2.0	0.6	6.6
100	5.6	1.5	0.4	7.4	2.1	1.9	0.6	4.6

a function of a range of factors, including the demand and configurational characteristics of the representative baseline corridor (as mentioned earlier, the defined conditions along the baseline generic corridor may not be fully representative of conditions along an actual corridor, which may have an impact on B-C results), the time horizon for the NPV analysis, the benefits monetization factors (e.g., value of time estimates) used in the analysis, and uncertainties in the costs, the B-C results in Figure 4.2 are used only to assess the relative B-C performance between the mixed-flow and truck-only lane alternatives, and are not for assessing the B-C performance of each of the build alternatives individually against the no-build alternative.

- The estimation of the performance benefits of alternatives does not consider differences in time-of-day distributions between auto and truck traffic volumes, which could potentially impact the benefits of truck-only lanes, and consequently, the relative B-C performance of truck-only lanes when compared to adding mixed-flow capacity. For the interpretation of the

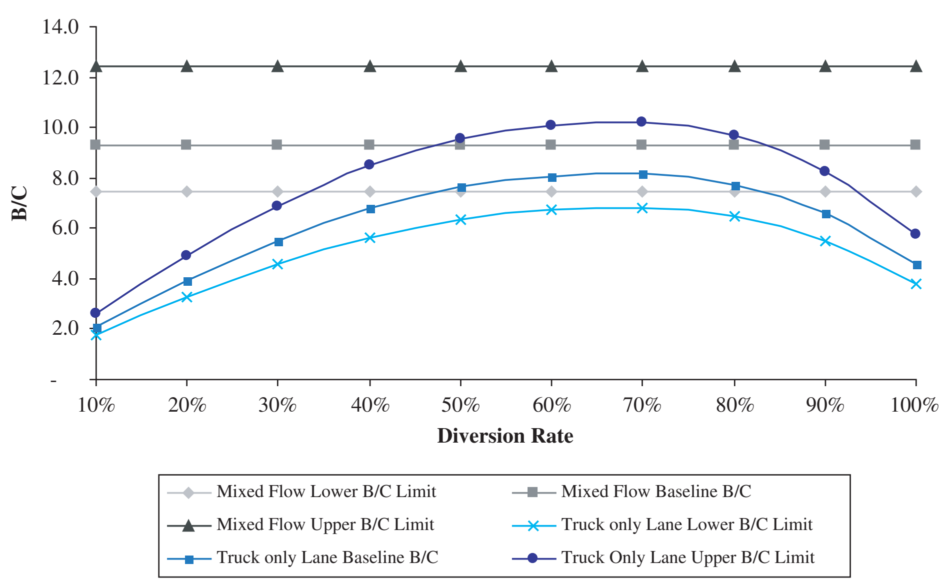


Figure 4.2. B-C results for alternatives as a function of diversion rate.

results in Figure 4.2, it is assumed that time-of-day differences between auto and truck volumes for the representative baseline corridor are not significant, and therefore, would not impact the performance of truck-only lanes.
- Due to a lack of robust analytical tools to assess the true safety benefits of truck-auto separation (which also impacts the accuracy of the estimation of reliability benefits of truck-only lanes), the results in Figure 4.2 could be amiss in providing insights into the relative B-C performance of truck-only lanes when compared to adding mixed-flow capacity, particularly along corridors where safety and reliability issues caused by truck-auto interactions are a major concern.

Given the above caveats, however, the results in Figure 4.2 are useful in gaining insights into the relative B-C performance of truck-only lanes when compared to additional mixed-flow lanes, which are discussed as follows:

- Clearly, as observed under the long-haul corridor scenario, truck diversion rates have a direct impact on the B-C performance of truck-only lanes. Truck diversion rates of 60% to 70% provide the highest B-C ratios for the truck-only lane alternative. Very high diversion rates (greater than 80%) impact overall performance under this alternative as the truck-only lanes begin to experience congestion and the system does not have optimal capacity utilization (both on the general purpose and truck-only lanes). Since trucks have a higher value of time when compared to autos (more than 2.5 times auto value of time in the current analysis), mobility on truck-only lanes is important for the truck-only lane alternative to achieve high levels of performance benefits in monetary terms. The importance of this result is significant in analyzing policy issues associated with the use of truck-only lanes (e.g., in this case, mandatory use of truck-only lanes might not be a feasible policy option because it would not ensure optimal system performance). The B-C performance of the truck-only lane alternative is observed to be low under low diversion rates because there is under-utilization of truck-only lane capacity, and low levels of diversion from the general purpose lanes result in low level of congestion relief from these lanes. These relationships are important in understanding the impacts of tolls on truck-only lanes, since higher tolls can impact diversion rates, thus affecting the benefits of truck-only lanes as well as the revenue potential of tolls.
- Comparing the B-C performance of mixed-flow and truck-only lane alternatives, the mixed-flow lane alternative is observed to generally have a better B-C performance when compared to the truck-only lane alternative under the defined conditions of the representative baseline corridor (although there is a range in the graph where the truck-only lane alternative could have a better performance given the uncertainties in the costs and the variations in the diversion rates). This can be explained to a certain extent from the results in Table 4.9, which indicate that a large share of the benefits for both the alternatives is driven by congestion reduction (travel time savings). These results suggest that for truck-only lanes to have a higher B-C performance when compared to mixed-flow lanes, in addition to travel time savings, they have to provide significantly higher safety and reliability benefits (compared to mixed-flow lanes), which is not being achieved in this case. The implications of this observation include the following:
  - As mentioned earlier, the safety and reliability benefits of truck-only lanes (associated with truck-auto separation) were estimated based on a post-processing approach, which involved application of accident reduction factors, without the use of robust analytical tools such as simulation. Consequently, the post-processing approach could potentially be underestimating the true safety and reliability benefits of truck-auto separation. Given the constraints in the current project, it would, therefore, be important to supplement these results with more detailed analyses of the safety and reliability performance of truck-only lanes to understand the magnitude of these benefits in relation to the mobility benefits of truck-only lanes.

- The results do, however, provide insights into the types of corridor applications under which truck-only lanes could be expected to have a better B-C performance (relative to mixed-flow lanes) compared to the observations in Figure 4.2. For example, the results suggest that truck-only lanes could be more viable compared to mixed-flow lanes on corridors for which, in addition to congestion mitigation, there are specific performance improvement needs that could be better met by truck-auto separation than by adding mixed-flow capacity, which may include the following:
  - Congested urban corridors on which, because of terrain such as grades and other system configurational issues, there may be safety problems due to truck-auto operational conflicts. Implementation of truck-only lanes along these corridors would provide significant levels of safety and reliability benefits in addition to travel time savings from diversion of trucks from the general purpose lanes.
  - Urban corridors serving as key access routes to major freight facilities (such as seaports) where high truck and auto volumes, in addition to causing congestion, may be leading to reliability problems for international goods movement supply chains relying on the corridor for truck shipments. Along these corridors, the implementation of truck-only lanes would not only relieve congestion on the general purpose lanes by diverting trucks, but also provide dedicated lanes for port truck traffic, resulting in improved truck freight mobility and reliability.

CHAPTER 5

Conclusions and Recommendations

This study conducted a detailed review of the experience and analysis of truck-only lanes in the United States and internationally. The objectives of the study included the following:

- Develop a compendium of information about the technical and institutional issues associated with applications of truck-only lanes so that practitioners can make better informed judgments and evaluations of potential costs and benefits of truck-only lanes. This compendium was prepared, to a large extent, in the interim report for this study. Key issues and findings of this compendium are summarized in the next section of this chapter, and the entire contents of the compendium are presented in Appendix A.
- Conduct a performance evaluation of different truck-only lane configurations and applications to assess the potential benefits and performance issues that arise. This performance evaluation was intended to illustrate the key performance metrics and methodologies for conducting the performance evaluation of truck-only lanes and to suggest the configurations and applications in which truck-only lanes are most likely to provide the greatest benefits. In addition, an objective of the study was to evaluate how potential costs of truck-only lanes relate to the benefits, and how these compare against the benefits and costs of other types of highway system investments (such as adding mixed-flow capacity). Chapters 3 and 4 of this report presented the results of the performance evaluations and B-C analyses of truck-only lanes. Since this project did not have the resources to conduct new research, the performance evaluations conducted in Chapter 3 relied on published data primarily from feasibility studies and very limited field observations. Data gathered from these sources also served as key inputs in the B-C analyses of truck-only lanes.
- Suggest areas of future research to improve understanding of the performance of truck-only lanes in various applications. Clearly, the lack of actual field data from which to draw conclusions is a major obstacle to completing the types of evaluations that would be desirable, and the final section of this chapter provides some ideas on how this issue might be addressed. In addition, this chapter suggests some ideas for future research programs and analyses that go beyond what was feasible in this project.

This study determined that there is substantial recent interest in applications of truck-only lanes in the following types of applications:

- Long-haul intercity corridors,
- Major urban corridors with high volumes of truck traffic, and
- Major corridors providing access to ports and intermodal terminals.

As noted several times in this report, there are no actual examples of truck-only lanes in the applications that were identified in the literature review. The closest examples to any of these applications identified are in Rotterdam, Netherlands, where nonseparated and barrier-separated lanes for trucks have been implemented along the A-16 (5.5 km/3.4 mi) and A-20 (2.4 km/1.5 mi) motorways, respectively. These lanes can be considered to be representative of truck-only lane applications along key segments of major urban goods movement corridors. Efforts to obtain any performance data from this roadway were unsuccessful. There are some other limited examples of truck/auto separations providing data to assess the benefits of separating trucks and autos, and these were used to support the analysis in this study. These primarily include truck bypass lanes around interchanges and the dual-dual roadway sections of the New Jersey Turnpike that include auto-only and mixed-flow lanes. There have also been some experiments with truck lane restrictions, such as those conducted by the North Central Texas Council of Governments (NCTCOG) in a study conducted from 2005 to 2006 that collected data on safety and travel time differences in lanes that were restricted to autos only, as compared to right-hand lanes in which trucks were restricted to travel. These experiments also provide information on approaches that might be used to collect data on operational performance of truck-only lanes in the future. Nonetheless, there continue to be some significant gaps in the data and analyses that have been conducted to date. These gaps limited the study team's ability to reach definitive conclusions on many aspects of truck-only lane performance and cost-effectiveness. This chapter will draw together the results of the analyses from the previous chapters to establish some general conclusions about truck-only lanes and to suggest particular areas of research that show reasonable prospects for providing answers to critical outstanding questions.

The remainder of this chapter summarizes key conclusions regarding the applicability of truck-only lanes and configurations first in long-haul intercity corridors and then in urban corridors. This is followed by a summary of ideas for future research. The sections describing conclusions regarding applications of truck-only lanes also note where the current research and data are deficient with respect to the types of performance and B-C evaluations that need to be done, and provide ideas for how the underlying data and analytical methods can be improved.

5.1 Truck-Only Lanes in Long-Haul Intercity Corridors

The primary motivation for developing long-haul intercity truck-only lanes includes the following:

- Increase freight movement efficiency by increasing throughput and reducing travel times and delays for freight movement,
- Provide improved freight efficiency at costs that are lower than the monetized value of the benefits,
- Cost-effectively provide increased freight movement capacity in corridors with limited opportunities to expand rail mode or corridors without existing rail service,
- Provide dedicated facilities on long-haul corridors for longer combination vehicle (LCV) operations or meet truck over-size/over-weight (OS/OW) requirements,
- Increase safety by reducing truck-auto interactions, and
- Encourage economic development by drawing industries with high transport costs to the corridor.

5.1.1 Feasibility Criteria

The literature sources reviewed in this study provide the basis for establishing some general criteria in terms of volumes of truck traffic, length of corridor, auto volumes, and congestion conditions along long-haul corridors to analyze the feasibility of implementing truck-only lanes. The Reason Foundation[48] developed an approach to screening candidate long-haul corridors for tolled

[48]R. W. Poole, Jr. and P. Samuel, *Policy Study 316, Corridors for Toll Truckways: Suggested Locations for Pilot Projects,* Reason Foundation, February 2004.

truck-only lanes and a congestion measure based on Highway Performance Monitoring System (HPMS) forecasts of truck and auto traffic in the corridors was included as one of the screening criteria. The Reason Foundation study also used a minimum truck volume threshold of 10,000 trucks per day to screen candidate corridors that would be viable (in terms of revenue generation potential) for the implementation of tolled truck-only lanes. The study reported that "a basic toll truckway probably needs between 2,000 and 4,000 trucks per day to be self-sufficient from toll revenues." Corridors were scored based on congestion considerations, so that the congestion score for each corridor was developed based on an estimate of the average daily volume capacity (V/C) ratio and fraction of the total corridor mileage with V/C greater than 1. The highest possible score was 15. Corridors with high congestion scores[49] were as follows:

- Congestion score of 10
  - I-76 Pennsylvania Turnpike,
  - I-15 Barstow—Las Vegas,
  - I-81 Knoxville—Harrisburg,
  - I-5 Bakersfield—Sacramento,
  - I-94 Chicago—Minneapolis,
  - I-85 Montgomery—Richmond,
  - I-78 Harrisburg—New York City, and
  - I-80 Oakland—Nevada Line.
- Congestion score of 9
  - I-75 Toledo—Tampa and
  - I-65 Nashville—Gary.
- Congestion score of 8
  - I-10 Los Angeles—Phoenix,
  - I-20 Dallas—Atlanta, and
  - I-90 Cleveland—Buffalo.

As indicated, the work of the Reason Foundation indicated potential corridors that might be good candidates for LCV operations based on some key feasibility criteria, which include the following:

- Daily truck volumes;
- Fraction of corridor length with daily truck volumes greater than a threshold (typically, 10,000 trucks per day);
- Congestion (V/C);
- Connectivity (whether the corridor provides connectivity to the existing national LCV network); and
- Trucking company responses (willingness of trucking companies to use LCV corridors with tolled truck-only lanes).

However, there is a need for additional analysis beyond what has been done to date to confirm the benefits of LCV operations, establish concepts of operations, and establish optimum configurations. Some examples of work needed to analyze the feasibility of LCV operations on truck-only lanes are as follow:

- Gaining a better understanding of what types of commodities and trucking operations most benefit from LCV operations and developing better corridor-level origin-destination (O-D) information for these commodities in the priority corridors. The Reason Foundation work has approached the demand issue in terms of scenarios that assume a particular level of market pen-

[49]R. W. Poole, Jr. and P. Samuel, *Policy Study 316, Corridors for Toll Truckways: Suggested Locations for Pilot Projects,* Reason Foundation, February 2004.

etration of LCVs expressed as a percentage of some average level of truck demand on a heavily truck-trafficked rural corridor. But not every commodity and trucking operation is a candidate for LCV operations, and there is no basis for determining whether the assumed scenarios in the Reason Foundation work are at all representative of what might occur in these corridors. Analysis that takes into account the types of commodities hauled and the O-Ds (to reflect potential links to a multistate LCV network) might provide a better idea of potential demand levels for LCV operations.

- Understanding the impact of LCV operations on rail-truck mode share. In selecting LCV corridors, highest priority should be given to corridors that do not have rail service or that have very congested rail systems. In these cases, it is appropriate to look at the tradeoffs between adding new LCV lanes and investments in rail systems. In any event, the Reason Foundation corridors should at least be screened to see what opportunities exist to expand rail services in these corridors and the degree to which there are commodities moving in these corridors for which rail and trucking modes compete. In order to conduct these analyses, state DOTs will need access to good modal diversion models in order to analyze the propensity for cargo diversion between truck and rail modes.
- Developing concepts of operations for the high-priority LCV corridors. B-C studies need to be conducted in each corridor to determine what types of trucking configurations would be optimal (in terms of productivity benefits traded off against cost of design features), how to best link new LCV corridors with the existing national LCV network, the design of the optimal system of truck staging areas to provide off-network access, and regulatory/enforcement mechanisms to ensure compliance and efficiency in LCV operations.

Once these issues are addressed in the screening of corridors and the designing of a concept of operations, it would be beneficial to focus on those corridors that meet the more rigorous screening criteria and repeat the B-C analysis with new information about configurations and costs, estimate new demand volumes and re-set tolling and revenue forecasts to develop advanced financial models and establish the most cost-effective corridor configurations.

5.1.2 Productivity

With respect to improving productivity and freight movement efficiency, truck-only lanes on long-haul corridors have two potential benefits: the potential to increase truck average speeds (truck mobility and the benefits of improved speeds on trucking productivity) and the potential to improve productivity through use of LCVs (productivity improvements due to increased payloads). Eliminating auto-truck interactions and addressing geometric issues could provide opportunities to increase speeds on truck-only lanes. As described in the interim report, design of a roadway dedicated to trucks could focus on reducing roadway curvature and grades and improving sight-distance geometries, thereby allowing for higher truck speeds while maintaining safety.

Most of the studies reviewed for this project that focus on long-haul corridors show that the alternatives that incorporate LCV operations provide the greatest benefits. There is the potential for significant benefit to motor carriers and shippers from LCV operations (due to substantial productivity enhancements for motor carriers, and associated cost savings for shippers) and there is the potential to capture some of this value and finance the facilities through tolling schemes. If motor carriers can increase revenue without increasing many of their costs or without increasing them in proportion to the increase in payload, then these operations will be very profitable. These benefits are expected to be significant enough to be shared among motor carriers, shippers, and the public-sector providers of the LCV lanes. The analysis conducted in this study provides a framework for the estimation of total productivity benefits of LCV operations, which is based on an enhancement of the basic approach developed by the Reason Foundation, related to data inputs such as congestion and speeds.

5.1.3 Mobility

The opportunity to reduce travel times along general purpose lanes from implementing truck-only lanes appears to be relatively limited in long-haul corridors. Although they may pass through or around congested urban areas, long-haul intercity truck corridors generally are not characterized by high levels of congestion. The analysis suggests that the limited opportunity to reduce travel times on long-haul corridors would include cases in which a high volume route passes through many urban centers such that a typical long-haul trip would make it difficult for trucks to avoid traveling through at least one or more of these congested urban areas during peak periods. Examples would include certain parts of the industrial Midwest (possibly I-70) and the I-95 corridor. The results compiled in the performance evaluation task corroborate this point, with truck-only lanes along long-haul corridors in Georgia estimated to provide around 20% savings in travel times along the general purpose lanes. This can be attributed to savings along corridor segments close to, or along, the periphery of the Atlanta metropolitan area with notable peak period congestion.

One of the deficiencies of current research on travel time benefits of truck-only lanes in long-haul corridors has to do with the inability of existing travel demand models to take into account the operational benefits of separating trucks and autos. To some extent, this could be better captured with a different approach to measuring passenger car equivalents (PCE) and incorporating this in the analysis. For example, the Southern California Association of Governments (SCAG) heavy-duty truck model incorporates variable PCE factors that are calculated for each link in the network during assignment. The PCE factors are adjusted based on road grade, level of congestion, and percent trucks. Taking this approach one step further, it could be useful to develop simulation models of the corridors in question to examine actual travel times with and without auto-truck separation. The American Transportation Research Institute (ATRI) is collecting data on corridor travel times and travel time reliability using GPS data sets from in-use trucks and these data, coupled with other local data sets, can be used to calculate differences in truck speeds and auto speeds with different levels of truck volumes. These can be used to help calibrate simulation models to take into account the flow characteristics of trucks as compared to autos. Using data on crash rates and other random events, the simulations also could be structured to see if there is any difference in recovery times between truck-only lanes and mixed-flow lanes. Thus, the simulations could provide a better picture of the actual travel time benefits of separating autos and trucks under various traffic conditions.

5.1.4 Safety

Given the large amount of truck VMT on certain long-haul intercity corridors, the ability to improve safety by separating trucks from autos appears to be an important issue. Also, safety implications of truck-auto interactions would be a key issue along long-haul corridors with truck driver fatigue issues (due to long hours of driving) and significant nighttime truck traffic.

There have been some studies and historic data from real-world projects that have highlighted the safety benefits of truck-auto separation, namely the Douglas report[50], historic accident data for the New Jersey Turnpike, and the NCTCOG *Truck Lane Pilot Study*[51]. However, these studies and data are more representative of truck-auto separation in an urban corridor environment and, consequently, their discussion is presented under the discussion of urban corridors (Section 5.2). Clearly, there appears to be inadequate research into the safety benefits of truck-only lanes along

[50]J. G. Douglas, *Handbook for Planning Truck Facilities on Urban Highways,* August 2004.
[51]See http://www.nctcog.org/trans/goods/trucklane/.

long-haul corridors. The following sections present some discussion of potential approaches that could be undertaken to account for this research need.

First, with the corridors identified by the Reason Foundation as high priority long-haul corridors for LCV operations as a starting point, it would be useful to conduct a much more comprehensive national assessment of crash data as a function of the level of truck-auto interactions. This analysis would look at correlations between the level of truck-auto interaction as a function of total VMT to understand the relationship between level of truck-auto interaction and accidents. In addition, the analysis would conduct a more detailed examination of the conditions under which truck-involved accidents occur to the extent that this information is available in crash databases. One approach for doing this would be to develop regression models to estimate relationships between accident rates (by type of accident) and key parameters including level of congestion, truck shares of total traffic, grade, and number of lanes. Applications such as the Freeway Performance Measurement System (PeMS) developed by the University of California at Berkeley can be used to obtain incident data (including incidents by time of day and severity), which can be supplemented with other data inputs, such as truck and total traffic counts, to obtain truck shares to feed into a regression analysis framework. With this information it may be possible to predict lower crash rates due to the implementation of truck-only lanes.

5.1.5 Benefit-Cost Evaluation of Truck-Only Lanes on Long-Haul Corridors

The primary objectives of the B-C analysis of truck-only lanes under the long-haul corridor scenario were the following:

- Assessing the B-C performance of truck-only lanes without LCV operations compared to adding mixed-flow capacity on long-haul corridors, and
- Assessing the incremental benefits and costs associated with LCV operations on truck-only lanes, and how these impact the B-C performance of this alternative compared to truck-only lanes without LCV operations and to adding mixed-flow capacity.

As discussed in Chapter 4, a sensitivity analysis approach was used for the B-C analysis. Some of the key conclusions from the B-C analysis are summarized as follow:

- The results suggest that high levels of diversion would be needed for truck-only lanes to be judged a preferred alternative both in terms of getting to a B-C ratio greater than 1.0 and exceeding the B-C ratio of adding more general purpose lanes;
- Given the high levels of diversion required to achieve a high B-C performance for truck-only lanes without LCV operations, which might not be achievable along long-haul corridors, particularly those with relatively lower levels of congestion, truck-only lanes without LCV operations would generally appear to be an inappropriate choice compared to adding mixed-flow capacity under the general conditions described for long-haul corridors.
- Based on the previous observation, it appears that for long-haul corridors, the decision making for corridor investment options primarily would be governed by the relative B-C performance of truck-only lanes with LCV operations compared to additional mixed-flow lanes. Even under the most optimal scenario, a minimum of 30% diversion would be required before the truck-only lane alternative with LCV operations becomes more cost-effective compared to adding mixed-flow capacity. This observation would be useful in analyzing the viability of implementing truck-only lanes with LCV operations along long-haul corridors, based on a market analysis of the diversion potential of truck-only lanes.
- The results from the B-C analysis very likely underestimate the benefits of truck-only lanes because they do not fully account for the safety benefits of truck-only lanes as compared with additional mixed-flow lanes. This shortcoming is unlikely to significantly alter the conclusions

because safety benefits are observed to be a relatively small contributor to overall benefits. Also, the analysis does not take into account potential market diversion from congested rail corridors to the LCV lanes, which could add further benefits without any increase in costs; however, the impact of this to the overall B-C results is not expected to be significant.

5.2 Truck-Only Lanes in Urban Corridors

Urban corridor applications of truck-only lanes have been identified in locations with some of the following characteristics:

- Congested corridors with high truck volumes and significant contribution of truck traffic to congestion (e.g., I-710 and SR 60 in Southern California);
- Major through-truck routes that go through metropolitan areas and have high truck volumes and congestion (e.g., the Mid-City Freightway in Chicago and I-5 in Seattle); and
- Congested corridors providing access to major ports or intermodal facilities (e.g., I-710 in Southern California, Miami Tunnel, and Savannah, Georgia).

The primary objectives governing the implementation of truck-only lanes in urban areas are the following:

- Reducing congestion but because many of the urban studies compare truck-only lane alternatives to alternatives that do not provide equivalent capacity expansion with general purpose lanes, it is difficult to draw conclusions about how effective and under what circumstances truck-only lanes would be cost beneficial. Even assuming equal congestion relief benefits for truck-only lanes as compared to general purpose lanes, the choice of truck-only lanes may be driven by the belief that trucks would pay higher tolls to avoid congestion and that this provides a more effective approach to financing capacity needs. Truck driver willingness to pay tolls may be overestimated, however, in many of the studies conducted to date.
- Mitigating impacts of truck traffic in high-truck-volume corridors by diverting trucks to certain corridors, improving flows (thus reducing emissions), and getting trucks off arterials.
- Separating trucks from autos, thus improving safety and providing reliability benefits (due to reduction in incident-related delay).
- Providing improved travel times and reliability for trucks serving ports and intermodal sites to maintain the economic viability and competitiveness of these facilities.
- Complementing innovative freight-oriented land use strategies (e.g., inland ports or freight villages). Truck-only lanes can be constructed to link facilities like inland ports to primary port facilities, making operations more economical. No research was identified where efforts were made to estimate the degree to which truck-only lanes would be beneficial in encouraging these types of freight-oriented land use strategies or making them more cost effective.
- Facilitating the implementation of truck automation (truck platooning) and/or truck electrification strategies, electronic toll collection (ETC) strategies using automatic vehicle identification (AVI) technologies, and improved weight and safety enforcement of trucks.

5.2.1 Feasibility Criteria

The feasibility of implementing truck-only lanes on urban corridors is a direct function of corridor demand and system characteristics, including truck and auto traffic volumes, share of truck traffic of total traffic, time-of-day variations in truck and auto traffic volumes and contribution of truck traffic to peak-period congestion, truck routing and O-D patterns, length of corridor, and number of lanes. An understanding of the various truck-only lane feasibility criteria would be useful in corridor planning projects, particularly in the preliminary alternatives development processes, to determine the viability of including truck-only lanes for detailed alternatives analyses.

The Douglas handbook serves as a compendium on the key quantitative factors to be considered in assessing the feasibility of truck-only lanes, the recommendations of which are summarized as follow:

- Bidirectional daily total traffic volume on the corridor should be at least 15,000 per lane.
- Bidirectional daily total truck[52] volume on the corridor should be at least 20,000 trucks per day.
- Bidirectional daily total truck volume should exceed 20,000 trucks for a minimum distance of 10 mi along the corridor, or the corridor should provide access to major freight generators at the termini.
- The corridor on which truck-only lanes are to be implemented should have at least two general purpose lanes in each direction. Also, truck-only lanes should have at least two lanes in each direction.

There has been limited research on the impacts of variations in time-of-day distributions of trucks and autos on the feasibility of truck-only lanes, which is a key data gap that needs to be addressed in future research. The next section provides further discussion of the impacts of time-of-day differences on the ability of truck-only lanes to provide peak-period congestion reduction benefits.

5.2.2 Mobility

In the evaluation of the mobility benefits of truck-only lanes on urban corridors, it is critical to assess the relative performance and cost effectiveness of truck-only lanes compared to adding mixed-flow capacity. As part of the performance evaluation task of the project, the differences in capacity assumptions between the truck-only lane and mixed-flow lane alternatives, and the omission of the mixed-flow lane alternative in the performance evaluation in some of the reviewed studies, has resulted in the findings being inconclusive or inadequate in assessing the relative performance benefits of truck-only lanes against mixed-flow lanes with similar capacity. The B-C analysis approach undertaken in this study has attempted to address this gap, the key conclusions from which are summarized in a later section of this chapter.

With respect to the application of truck lanes to reduce congestion on urban corridors, most of the analysis has been done with traditional travel demand models. All other features of truck-only lanes versus general purpose lanes being equal, the only way that truck-only lanes would compete favorably with general purpose lanes for congestion relief would be if trucks have a significant impact on congestion during the peak periods (periods with high levels of congestion), and the truck-only lanes are highly utilized during peak periods (by affecting significant truck diversion from the general purpose lanes). This suggests that there are threshold volumes of trucks below which truck-only lanes are not likely to achieve the benefits that could be obtained from additional general purpose lanes. The traffic threshold volumes for assessing the applicability of truck-only lanes typically pertain to total daily truck and total traffic volumes, as suggested by the Douglas report (which are discussed in the previous section).

It should also be noted that much of the analysis of truck-only lanes that has been done to date has been done based on daily models, models which do not consider the differences in time-of-day distributions of trucks and autos, or models in which the time-of-day distribution of trucks is not based on accurate data. It is absolutely critical to not only understand daily demand but to understand peak-period and peak-hour truck and auto travel demand. Trucks tend to favor mid-day operation in urban areas and generally avoid peak periods to the maximum extent possible. This means that demand for truck-only lanes would be highest during the least congested periods of the

[52]Heavy-duty trucks with three or more axles are included in this category.

day. Analysis in the I-710 and SR 60 studies show this in general terms. This could have major implications for the success of tolling concepts based on the accurate estimation of potential toll revenues. To summarize, it is likely that studies that do not take time-of-day distribution of truck activity into account have overestimated the benefits of truck-only lanes.

On the other side of the balance sheet, travel demand models may underestimate the average travel time savings benefits to all motorists of having trucks and autos separated based on the way PCEs are calculated. There is evidence from many studies that PCE values vary with congestion conditions and the amount of trucks in the flow when trucks and autos mix. This is related to the acceleration/deceleration characteristics of trucks as compared to autos, and the effects of merging and weaving. It has been further hypothesized that in urban driving conditions trucks may travel at lower average speeds than autos even within the same traffic conditions and thus PCE values need to be recalibrated. The most sophisticated travel demand model in terms of capability to examine this effect is the SCAG HDT model, which does employ variable PCE factors for trucks. However, additional research into how to calibrate variable PCE factors in different flow conditions as well as for situations in which trucks represent the entire flow, as in truck-only lanes would be helpful in improving the accuracy of travel demand models in measuring the travel time savings benefits of truck-only lanes. Based on future improvements in the ability to assess the true mobility benefits of implementing truck-only lanes for autos on general purpose lanes, it could be that the mobility benefits for the general public (autos) potentially turn out to be a stronger selling point to policy makers for the implementation of truck-only lanes compared to the benefits associated with improved operational efficiencies for trucking companies.

5.2.3 Safety and Reliability

The results from the performance evaluation task consistently indicate that truck-only lanes have higher safety benefits compared to mixed-flow lanes. However, the results are inconclusive in understanding the "true" incremental safety benefits of truck lanes because of the differences in capacities between the truck-only and mixed-flow lane alternatives considered in the studies, as well as some key limitations in the approaches used to analyze the safety benefits of truck-only lanes, which are discussed in this section.

It is observed from the review of studies conducted as part of the performance evaluation process that the general approach to estimating the safety benefits of truck-only lanes on urban corridors has been to quantify the reduction in accidents from congestion relief (on the general purpose lanes due to diversion of trucks to truck-only lanes, and to some extent on the truck-only lanes due to improved mobility), without typically accounting for the safety improvements from truck-auto separation. The analysis that was conducted in the performance evaluation task using the data from various studies and presented in Chapter 3 attempts to introduce some assessment of the safety benefits of separating trucks and autos, based on application of post-processing factors to account for safety improvements of truck-auto separation as recommended by the Douglas handbook.

The Douglas handbook recommends a reduction factor of 15% for accidents to account for the safety benefits of truck-auto separation. This factor was derived based on an evaluation of historic crash data on the New Jersey Turnpike, which indicated that total crash rates along the dual-dual roadway sections (sections with auto-only lanes and mixed-flow lanes) of the turnpike reduced by 18% during the first 5 years of dual-dual roadway operations (the dual-dual roadway sections were first implemented in 1966). More recently, in the 1994 to 2003 time period, the dual-dual roadway sections were observed to have accident rates at least 28% lower than the mixed-flow sections of the turnpike. The Douglas handbook concluded that the actual safety benefits of the dual-dual sections (accounting just for the benefits realized from separating autos from the mixed-flow lanes, and not considering the safety benefits from increased capacity on the dual-dual roadway sections) are expected to be closer to the 18% reduction factor, since the impacts of increased capacity on safety are not expected to be significant during the initial phases of implementation. Given the recommendations from the Douglas handbook based on historic data from the New Jersey Turnpike, there still remain, as mentioned under the long-haul corridors section, a number of opportunities to improve the state of knowledge pertaining to the actual safety benefits of truck-only lanes resulting from separation of trucks and autos.

One of the simplest but yet persuasive methodologies for conducting a robust analysis of the safety benefits of truck-only lanes is the application of different crash rates per million VMT for truck-involved and auto-only accidents, which are applied to estimates of auto and truck VMT in truck-only lane configurations to assess the degree to which crashes are reduced. However, there appears to be a lack of available data on the variation in accident rates (by type of accident) as a function of truck shares (truck percent) of total traffic. This is an area of research that should be undertaken in the future to improve data inputs and analytical capabilities to accurately estimate the safety benefits of truck-auto separation. A proposed framework to estimate the dependence of accident rates on truck shares and other corridor characteristics (such as grades and number of lanes) has been presented under the long-haul corridors section. This would be applicable to urban corridors as well.

In future studies, there should be ways to develop simulation models of the operations of truck-auto separations to see the degree to which "near-crash" situations are simulated. Assuming some probability that these would develop into actual crashes, it should be possible to simulate numbers of crashes that could be avoided with truck-auto separations. The application of simulation models in analyzing the safety benefits of truck-auto separation has also been demonstrated from research conducted at the University of Tennessee, Knoxville.[53] Under this research, the approach used to analyze safety benefits involved simulating alternatives (truck-only lanes and no-build) in a VISSIM microsimulation environment, using number of lane changes per hour (lane change rate) as the performance metric for safety analysis, under the assumption that higher lane change rates would result in a higher propensity for accidents and lower safety performance. This research estimated a 47.3% reduction in lane change rate due to truck-auto separation.

One other approach that could be used to develop more data on the safety (and travel time) benefits of truck-auto separation would be to set up experimental truck-only lanes and collect data on different configurations. A basis for conducting these experiments can be found in a recent study conducted by NCTCOG, the Dallas-Ft. Worth Metropolitan Planning Organization (MPO). In this study, NCTCOG was trying to determine the impacts of restricting trucks to the two right-hand lanes. NCTCOG set up short-term experiments that implemented the lane restrictions and then used video and on-site operations to document changes in relative travel speeds by lane, crash rates by lane, frequency of near-miss accidents, and amount of queuing backups on to the freeway or at on ramps. Staff at NCTCOG think it would be difficult to conduct comparable experiments because of the potential for degraded traffic operations without being able to upgrade merge and weave sections and design new interchanges. It would appear that the best opportunities to conduct such experiments would be those where the truck-only lanes could be fully separated with separate interchanges to and from the truck-only lanes. Potential applications could include the conversion of HOV lanes or busways to truck-only lanes for a short period of time for the purpose of this type of analysis.

There were no studies identified in this project that tried to take the estimates of crash reduction benefits of truck-auto separation further and estimate reductions in incident-related delay

[53]A. A. Adelakun, *Simulating Truck Lane Management Approaches to Improve Efficiency and Safety of Highways in Knoxville, Tennessee,* Master of Science thesis, University of Tennessee, Knoxville, December 2008.

and associated reliability improvements. The general estimates of reliability benefits that have been incorporated in a few of the studies suffer because generally they base reliability benefits in terms of savings in incident-related delay on correlations between variables such as VMT, number of lanes, and V/C ratios (i.e., to factors related to general congestion and not to truck-auto separation) to establish the amount of nonrecurrent (incident related) delay. The post-processing effort conducted in this study accounted for this deficiency by applying the accident reduction factor recommended by the Douglas handbook to account for the incremental savings in incident-related delay due to accident reduction from truck-auto separation. It is noted, however, that there is a need for improved analytical methods to better understand the true reliability benefits of truck-only lanes. A more sophisticated approach would be to use simulation models to estimate actual travel times and travel time variability. In this approach, the simulations would examine queue build-up and clearing effects with mixed and nonmixed flows under congested conditions and when accidents occur. Truck-involved crashes generally are more severe and take longer to clear. Thus, queues tend to build up for long periods of time when a heavy-duty truck is involved. The primary difficulty in applying simulation methods is the calibration of simulation models for truck-only conditions. As previously described, there may be some experimental approaches where separated lanes (such as HOV lanes or busways) are temporarily dedicated to truck-only conditions in order to examine changes in crash levels and incident-related delays, and to use these data to calibrate the simulation models to assess safety and reliability benefits of truck-only lanes.

5.2.4 Port and Intermodal Terminal Access

In areas around ports and intermodal terminals, the research suggests there can be real benefits to communities—beyond the congestion, safety, and reliability benefits discussed previously—by directing and diverting truck traffic to preferred corridors and routes. Studies such as the *Mid-City Freightway*[54] in Chicago, *Miami Toll Truckway: Preliminary Feasibility Study,*[55] and *I-710 Major Corridor Study*[56] show that new truck routes or truck-only lanes on existing corridors that are designed to serve industrial areas, port and intermodal terminals, and customers in dense urban settings can relieve pressure on mixed-flow freeways by providing alternative routes better aligned with existing and forecast truck flows. This has been demonstrated in most of these connector studies. These studies also show that if main connectors are very congested, truck traffic often spills out onto arterial streets. Truck-only lanes may be more effective in providing relief in these situations than adding general purpose capacity because the truck lanes may be less congested and provide a very beneficial alternative for trucks. They can also be planned with alignments and entry/egress locations that more closely match the routing and O-D patterns of trucks accessing the port and intermodal terminals.

Another benefit of planning truck lanes to serve ports and intermodal terminals is that they tend to exhibit node-to-node travel characteristics that are not otherwise characteristic of urban truck travel. Examples include connections between ports and off-dock intermodal terminals, logistics parks, and other concentrations of warehouse/distribution facilities. This allows for the design of a facility with more limited access and this can be very cost-effective. In more general urban truck corridors, limiting access can have significant impacts on usage levels. Studies such as those on SR 60 and I-710 illustrate this point clearly.

---

[54]Chicago Department of Transportation, *Mid-City Freightway: Evaluation of Alternative Alignments and Tolls,* November 2006.
[55]R. W. Poole, Jr., *Policy Study 365, Miami Toll Truckway: Preliminary Feasibility Study,* Reason Foundation, November 2007.
[56]Los Angeles County Metro, *I-710 Major Corridor Study: Final Report,* March 2005.

Several studies have examined the amount of time savings per trip for average trips between ports and inland warehouses. To the extent that these time savings add up over the course of a day to allow drayage operators to make extra trips and generate extra revenue, they may be able to pass some of these savings on to shippers. However, to date no studies have been able to demonstrate the degree to which these savings increase the competitiveness of ports. Leachman[57] conducted an analysis of modal cost and congestion elasticities for SCAG by examining the impacts of fees on port and distribution channel choices. Leachman's model has been used to examine the effect of spending cargo fees on reducing congestion at the marine terminals as a tradeoff against the economic impact of the fee by itself. The congestion impacts that Leachman examined to date are focused on queues at marine and intermodal terminals and capacity constraints on rail mainlines. His models have not yet incorporated the impacts of delay on access roadways as it affects port and distribution channel choices. It would be possible to build this capability into Leachman's models by conducting simulations of critical access corridors with and without truck lanes in order to establish mean travel times between nodes and standard deviations in these times. It is recommended that the scale of delays associated with roadway congestion be compared to the scale of other delays in the logistics system and the demand elasticities associated with delays to determine whether it would be cost-beneficial to develop this type of analytical capability.

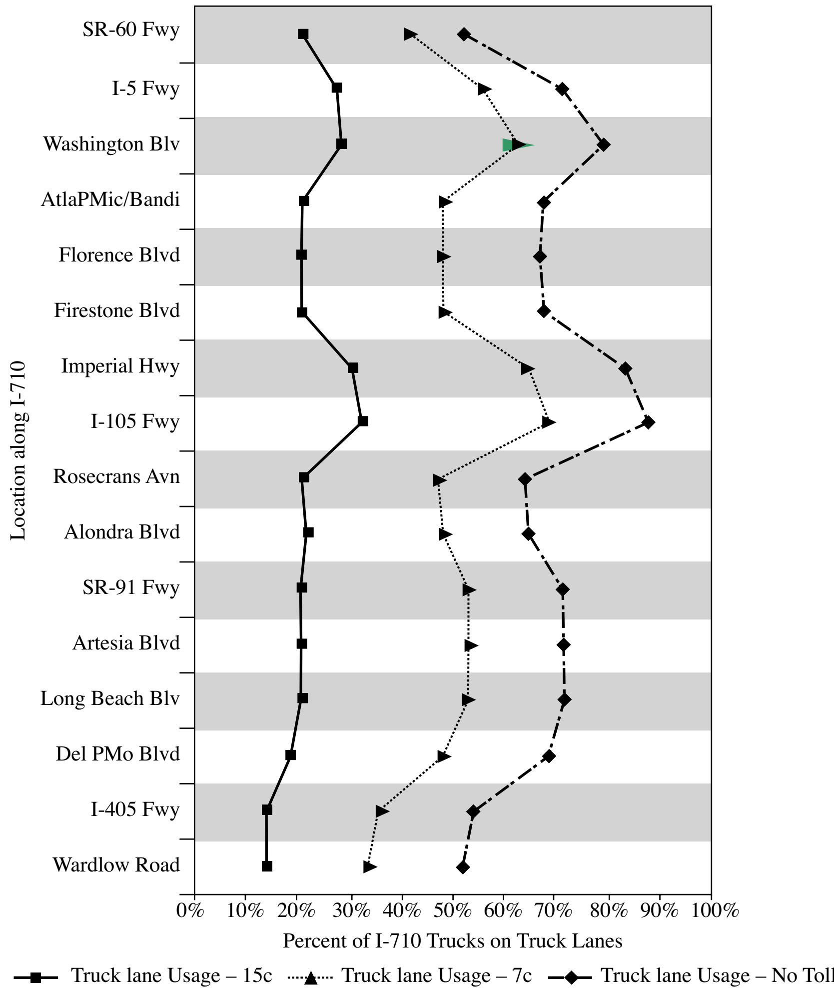
5.2.5 Tolling Urban Truck Lanes

The potential for tolled truckways in urban corridors is controversial and the analysis to date is inconclusive as to how cost-effective this approach may be. However, the *I-710 Major Corridor Study* conducted sensitivity analysis of various toll scenarios to assess the impacts of tolls on diversion potential and utilization of truck-only lanes, which provide some useful insights. The study provides relationships between changes in tolls and diversion to truck-only lanes that can be used to understand how tolls impact the performance of truck-only lanes based on truck and auto volume characteristics on the general purpose lanes, as well as assess the revenue potential of various toll scenarios. Figure 5.1 depicts the results of the sensitivity analysis in terms of the impacts of tolls on utilization of truck-only lanes along the corridor. These results pertain to a truck-only-lane toll scenario with voluntary use of truck-only lanes. It would be important to note that the performance of tolled truck-only lanes would be different under mandatory usage of truck-only lanes (all trucks diverting from the general purpose to truck-only lanes), since the diversion rate in that case would not depend on the magnitude of the tolls.

As expected, the highest diversion occurs under the no-toll scenario, in the range of 50% to 90% of total truck traffic along the corridor. With the application of tolls of $0.07 per mile, the estimated diversion drops to between 30% and 70%. With tolls of $0.15 per mile, the diversion further drops to between 10% and 30% along the corridor.

In deciding on the application of tolls on truck lanes, it is not only important to analyze the revenue potential of tolls to recover the costs of developing truck lanes, but also to look at the impacts of tolls on congestion on the general purpose lanes and the effective utilization of truck lanes. Tolls resulting in low truck diversion from general purpose to truck lanes would not contribute to an effective investment strategy due to substantial underutilized capacity on the truck lanes, as well as marginal reduction in congestion on the general purpose lanes. The diversion potential of tolled truck lanes is also important because some share of the freed-up capacity could potentially be filled up by autos diverting to the general purpose lanes from arterials, as well as some trips outside the region that now use the corridor due to the increased capacity.

[57]R. C. Leachman, et al., *Port and Modal Elasticity Study,* Southern California Association of Governments (SCAG), September 2005 (http://www.ieor.berkeley.edu/People/Faculty/leachman-pubs/PortModal.pdf).



Source: Adapted from Los Angeles County MTA, *710 Major Corridor Study—Final Report,* March 2005.

Figure 5.1. Impact of tolls on truck lane utilization.

Some of the key factors that would impact the decisions related to the application of tolls on truck lanes include, but may not be limited to, the following:

- **Revenue potential of tolls and what share of the costs of developing truck lanes can be recovered through tolls.** The revenue potential of tolls is tied to the diversion potential of tolled truck lanes for a given toll scenario, which is in turn dependent on the congestion and reliability benefits of truck lanes and the value of time distribution of truck traffic along the corridor.
- **Magnitude of truck and auto traffic volumes, congestion along the corridor, and contribution of truck traffic to corridor congestion.** To benefit from truck-only lanes under a toll scenario, there needs to be significant congestion along the corridor and truck traffic needs to be a significant contributor to congestion.
- **Truck traffic with high sensitivity to travel time and reliability benefits.** This factor would be inherently dependent on the value of time and reliability distributions of truck traffic. Typically, urban corridors with significant port truck traffic volumes such as I-710 would have favorable conditions for application of tolls, because a large share of the port truck traffic would be willing to pay tolls to achieve improved travel times and reliability.

- **Variable tolling.** Variable tolling might be a potent approach to maximize the truck diversion, utilization, and revenue potential of truck lanes along corridors with varying congestion, and truck and auto volume characteristics by time of day.

As noted, the benefits that truckers can realize from operating on tolled truck lanes are tied to the congestion conditions on the general purpose lanes. Based on the analysis conducted to date, it is understood that in cases where there are significant differences in time-of-day characteristics of trucks and autos (e.g., trucks predominantly operating in the mid-day period that is less congested), tolled truck-only lanes constructed next to existing general purpose lanes may not provide great enough benefits to truckers to affect diversion from the mixed-flow lanes to the truck lanes. Other studies have suggested that delays while on freeways (especially for short urban goods movement trips) may be relatively small as compared to delays at loading and unloading locations, suggesting that willingness to pay tolls may also be relatively low and potential revenues from tolled truck lanes in urban settings may not generate sufficient revenue to cover much of the cost of the lanes. Staff at SCAG have conducted novel analysis of how taking reliability into account may alter this conclusion.[58] The way that truck owners and shippers deal with unreliability is poorly understood, and the affects of travel time reliability benefits of truck-only lanes on willingness to pay tolls is not adequately addressed in most truck-only toll lane studies.

5.2.6 LCV Operations in Urban Corridors

The benefits of LCV operations in urban corridors are likely to be very limited except in certain limited applications. In urban corridors, trucks will only spend a fraction of their trip time on freeways that might have truck-only lane options while a significant amount of time will be spent off the truck-only lane system accessing local destinations. Off system, trucks will not be able to operate as LCVs. Siting staging areas and absorbing these costs could limit the cost-effectiveness of LCV operations in urban corridors. The one exception could be cases where truck-only lanes provide high-volume connections between two major freight nodes (e.g., between a port and an off-dock intermodal terminal). In these instances, the LCVs will have limited or no time off the LCV truck lanes and the productivity benefits can be applied to many repeated trips. The limited number of urban corridors that have examined LCVs is further evidence of the limitations of this approach.

5.2.7 Applications of Automation Technologies

Automated guidance systems and Cooperative Vehicle Highway Automation Systems (CVHAS) appear to have significant potential benefits on truck-only lanes in urban corridors based on the analysis conducted by Shladover.[59] These systems offer benefits in terms of reduced travel times, increased safety, reduced energy costs (and potential environmental benefits associated with smoother vehicle flows and efficient operations to reduce CO_2 emissions), and increased throughput of the lanes. See Table 2.3 for a demonstration of this conclusion by way of comparison with other alternatives.

The potential for increased throughput in urban areas where right-of-way is often constrained is a major benefit of automated guidance in truck-only lanes. The Shladover work suggests that market timing of advanced technologies to ensure high levels of market penetration is important in determining the cost-effectiveness of the option. In high-truck-volume urban corridors,

---

[58]Southern California Association of Governments, *Goods Movement in Southern California: The Challenge, the Opportunity, and the Solution,* September 2005.
[59]S. E. Shladover, *Advanced Vehicle Technologies and Exclusive Truck Lanes: Research from California PATH Program,* Transportation Research Board Annual Meeting, Washington, D.C., January 2006.

especially those that serve major freight nodes, it may be easier to achieve the levels of demand needed to make automation cost-effective. There are also interesting emerging concepts for phasing new technologies in truck-only lanes and CVHAS technology could be incorporated into these plans. For example, current work on the I-710 corridor in Los Angeles is examining a phased "freight corridor" development that could begin as truck-only lanes on a conventional viaduct structure to be converted to some type of electrified truck option (with wayside power systems or battery power) over time. Incorporating the phased development of CVHAS technology into this kind of evolutionary approach may improve the chances of success with the CVHAS technology.

5.2.8 Benefit-Cost Evaluation of Truck-Only Lanes on Urban Corridors

The primary objectives of the B-C analysis of truck-only lanes on urban corridors were to assess the relative B-C performance of truck-only lanes compared to adding mixed-flow capacity based on an analysis of the key factors that drive the relative performance of truck-only lanes compared to mixed-flow lanes and under what conditions might truck-only lanes be a better alternative compared to mixed-flow lanes along urban corridors. The key conclusions from the B-C analysis on urban corridors are summarized as follows:

- Truck diversion rates of 60% to 70% provide the highest B-C ratios for the truck-only lane alternative.
- Very high diversion rates (greater than 80%) may not necessarily improve the performance of the truck-only lane alternative because the truck-only lanes begin to experience congestion and the system does not have optimal capacity utilization (both on the general purpose and truck-only lanes). The importance of this result is significant in analyzing policy issues associated with use of truck-only lanes (e.g., mandatory use of truck-only lanes might not be a feasible policy option because it would not ensure optimal system performance).
- The B-C performance of the truck-only lane alternative is observed to be low under low diversion rates because there is under-utilization of truck-only lane capacity, and low levels of diversion from the general purpose lanes result in a low level of congestion relief from these lanes. This observation is important in understanding the impacts of tolls on truck-only lanes, since higher tolls would impact diversion rates, thus affecting the benefits of truck-only lanes as well as the revenue potential of tolls.
- Comparing the B-C performance of mixed-flow and truck-only lane alternatives, the mixed-flow lane alternative is observed generally to have a better B-C performance compared to the truck-only lane alternative (although there is a range in the graph where the truck-only lane alternative could have a better performance given the uncertainties in the costs and the variations in the diversion rates) under the defined conditions of the representative baseline corridor. This can be explained by the fact that a large share of the benefits for both the alternatives is driven by congestion reduction (travel time savings).
- The B-C results suggest that for truck-only lanes to have a higher B-C performance compared to mixed-flow lanes, in addition to travel time savings, they have to provide significantly higher safety and reliability benefits (compared to mixed-flow lanes).
- Due to a lack of analytical tools, the post-processing approach used for the B-C could potentially be underestimating the true safety and reliability benefits of truck-auto separation. Given the constraints in the current project, it would, therefore, be important to supplement these results with more detailed analyses of the safety and reliability performance of truck-only lanes to understand the magnitude of these benefits in relation with the mobility benefits of truck-only lanes.
- Based on the B-C results, some key insights can be gained on the types of corridor applications under which truck-only lanes could be expected to have a better B-C performance relative to mixed-flow lanes. These include

– Congested urban corridors on which because of terrain such as grades and other system configurational issues, there may be safety problems due to truck-auto operational conflicts. Implementation of truck-only lanes along these corridors would provide significant levels of safety and reliability benefits in addition to travel time savings from diversion of trucks from the general purpose lanes.
– Urban corridors serving as key access routes to major freight facilities (such as seaports) where high truck and auto volumes, in addition to causing congestion, may be leading to reliability problems for international goods movement supply chains relying on the corridor for truck shipments. Along these corridors, the implementation of truck-only lanes would not only relieve congestion on the general purpose lanes (by diverting trucks), but also provide dedicated lanes for port truck traffic, resulting in improved truck freight mobility and reliability.

5.3 Proposed Research Program

Although it would be desirable to have substantially more empirical data from which analyses of different truck-only lane concepts could be assessed, there appear to be opportunities to do additional analysis of these concepts in the absence of real-world applications. A research program to conduct these analyses would have the following three major components:

- **Experimental research.** This research would set up temporary truck-only lane situations in order to collect empirical data that can be used to better calibrate models and conduct safety and travel speed studies.
- **Screening studies, market-based studies, and development of concepts of operation.** This research would use the existing studies to establish screening criteria for identifying high-priority intercity and urban corridors. For several high-priority corridors of each type, detailed procedures would be used to develop concepts of operations and evaluations of performance and cost-effectiveness.
- **Simulation studies.** These studies would use mesoscale traffic simulation models to detail corridor operations and estimate potential benefits of truck-only lanes in terms of improved safety and reliability due to truck-auto separation.

5.3.1 Experimental Studies

One of the biggest disappointments of this study is the extremely limited real-world application of truck-only lanes from which to draw data for performance evaluations and B-C analysis. This is a particular shortcoming with respect to safety and reliability evaluations. This could continue to be a shortcoming until some truck-only lanes are actually built. However, there are some experimental programs/models that could be implemented on a limited scale that could begin to produce the types of data that would greatly improve the state of knowledge.

Experimental work could focus on identifying opportunities to convert existing separated lanes (or lanes on existing roadways that could be run as separated lanes) to truck-only lanes for a limited time and run these lanes within a variety of operational configurations in order to gather evaluation data. Some precedent for how this could be done can be drawn from the U.S.DOT Urban Partnership Agreement[60] (UPA) program, and other congestion pricing experiments. In some of these cases, existing HOV lanes are being converted to HOT lanes or other types of variable pricing configurations. These same lanes, transitways, or new rumble strip separations could be converted to truck-only lanes for short periods of time and data on crash rates, recovery times, speeds,

[60]See http://www.upa.dot.gov/.

and other types of performance issues could be collected. NCTCOG did a study on truck lane restrictions several years ago that could also serve as a model for this type of experimental work. Detailed observations could be made of differences in travel times for trucks and autos operating on mixed-flow and truck-only lanes, differences in crash rates, changes in ramp queues, and changes in near crashes.

The NCTCOG study cost approximately $500,000 and was conducted over an 18-month period in two major corridors. This included agency staff time, an $180,000 consultant analysis for data collection and analysis, and other related services. In discussing the potential application of this concept to a truck-only lane experiment, staff at NCTCOG expressed some concern about how traffic operations would be managed in order to provide access and egress to/from the truck-only lanes. This could present significant safety issues if the lanes are in, or closest to, the median and access was directly from the mainline mixed-flow lanes. Direct dedicated access/egress to/from the truck-only lanes would be much safer but the opportunities for this type of experimental set-up are much more limited.

5.3.2 Long-Haul Corridor Program

At the time of this writing, an ongoing study[61] undertaken on behalf of FHWA is conducting research on long-haul intercity corridors that addresses many of the ideas for future research presented earlier in this chapter. This study did return to the initial list of priority corridors developed by the Reason Foundation and developed its own criteria for selecting a corridor that would be able to fill gaps in an existing LCV network. The analysis in this study will include a more detailed evaluation of potential markets for LCV operation, estimates of potential toll revenues, truck/rail diversion estimates, and an initial B-C evaluation. The market for LCV operations used Freight Analysis Framework (FAF) commodity flow data, HPMS data, and other local data sources to identify the types of commodities and O-D patterns of trucks in various corridors that were logical candidates for LCV operations. Based on this analysis, the study selected the I-80/I-90 corridor from Chicago to Boston as a high potential candidate corridor. FTN. 61

The FHWA study represents a logical next step in the analysis of potential truck-only LCV corridors. If the FHWA study corroborates the findings of this study that truck-only LCV operations in intercity corridors do have potential positive net benefits compared to the costs, additional research should be conducted focusing on the following elements:

- Using similar screening methods as those used in the FHWA study, select multiple corridors for more in-depth analysis. These corridors would include varying levels of investment needed to close gaps in the existing LCV network, different types of commodity flow patterns, and different levels of movement through urban areas.
- Using FAF and potentially other commodity flow data sources, supplemented with detailed interviews of shippers and motor carriers, develop a much more detailed analysis of the types of commodities and markets that would be served with an LCV network. These data and HPMS would be used to develop a more refined estimate of potential usage levels.
- With the selected corridors, develop detailed concepts of operations to determine the most economical truck configurations to serve the selected markets, identify market nodes along the corridor, and develop a concept for consolidation/deconsolidation of loads and managing off-system movements of commodities. This would be useful in helping to refine concepts for locating a limited number of access/egress locations, as well as estimating the costs associated with off-system infrastructure and operations.

---

[61]FHWA, *Technological Challenges and Policy Implications for LCVs on Exclusive Truck Facilities: I-90 Gap Closing Scenario, Draft Evaluation Results.*

- Using mesoscale simulation models and national crash databases, estimate potential safety, reliability, and operational benefits of truck-auto separation. This would be used to make more accurate estimates of the impacts of truck-auto separation on travel times, reliability (e.g., variability in travel times), and crashes.
- Develop more refined estimates of truck-rail diversion by providing estimates of commodities and O-D pairs in the corridor for which rail and truck compete and applying rail-truck cross-price elasticities to estimate diversion based on estimates of total logistics costs by mode.
- Develop more detailed estimates of toll revenues by conducting routing/costing simulations.

5.3.3 Urban Corridors

The potential benefits of truck-only lanes in urban corridors have much to do with the congested nature of these corridors, which also lead to safety and reliability issues. The demand for capacity within limited rights of way makes throughput a much more critical consideration than in long-haul intercity corridors. The analysis conducted for this study suggests that many of the studies of truck-only lanes that have been done to date have been unable to evaluate some of the critical differentiators of truck-only lanes as compared to other approaches to increasing capacity. This study did conclude that linkages between major nodes in a freight system, such as links between ports and off-dock intermodal yards or concentrations of warehouse and distribution centers, are the most likely to generate sufficient demand to support limited-access truck-only lanes, and at the same time result in significant performance benefits of truck-only lanes (including congestion mitigation as well as efficiency and reliability benefits for international truck freight shipments).

The FHWA study chose not to conduct an evaluation of truck-only lane concepts in urban areas and the focus on LCV operations is less critical in urban corridors. The study team recommends that future research conduct a more in-depth analysis of benefits and costs of urban truck-only corridors, focusing on the following key areas:

- A detailed time-of-day analysis of demand that includes both peak period and peak-period analysis of level of service to understand the impacts of differences in time-of-day distributions between auto and truck traffic on the viability of truck-only lanes.
- A traffic simulation of the operations of the facility to provide for more reliable estimates of travel time savings benefits of truck-auto separation. This analysis should be supplemented with improvements in applications of travel demand models to analyze truck-only lanes with regard to accounting for the variability in PCE factors as a function of truck mix (truck percent of total traffic volume), and corridor configurational issues (grades and number of lanes).
- Use of traffic simulation to estimate the reliability (variability in travel times) benefits of truck-only lanes.
- Revised estimates of crash rates under varying truck-traffic conditions (truck percent of total traffic), based on simulation modeling and historic crash rates.

References

Adkins et al., *Value of Time Savings of Commercial Vehicles,* Highway Research Board, Washington, D.C., 1967.

Adelakun, A. A., *Simulating Truck Lane Management Approaches to Improve Efficiency and Safety of Highways in Knoxville, Tennessee,* Master of Science thesis, University of Tennessee, Knoxville, December 2008.

Anderson, R. M., D. Walker, J. A. Scherocman, and L. E. Epley, *Kentucky's Experience with Large Size Aggregate in Bituminous Hot Mix,* Journal of the Association of Asphalt Paving Technologists, Vol. 60, Seattle, Washington, 1991.

Button, Joe W., Emmanuel G. Fernando, and Dan R. Middleton, *Synthesis of Pavement Issues Related to High-Speed Corridors,* Texas Transportation Institute, Research Report 0-4756-1, September 2004.

Center for Urban Transportation Research, *The Potential for Reserved Truck Lanes and Truckways in Florida,* Research Report 21-17-422-LO, May 2002.

Chicago Department of Transportation, *Mid-City Freightway, Evaluation of Alternative Alignments and Tolls,* November 2006.

Code of Federal Regulations, Title 23, Section 658.23.

Cothron, A. Scott, Douglas A. Skowronek, and Beverly T. Kuhn, *Enforcement Issues on Managed Lanes,* Texas Transportation Institute, January 2003.

David, J. and Jim March, "Issues in the Financing of Truck-Only Lanes," Forkenbrock, *Public Roads,* September 2005.

Dorothy, Paul W., *The Potential for Exclusive Truck Facilities in Ohio* as presented at Ohio Transportation Engineering Conference, 2007.

Douglas, James G., *Handbook for Planning Truck Facilities on Urban Highways,* August 2004.

FHWA, *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries,* FHWA-HRT-05-051, October 2005.

FHWA, *Technological Challenges and Policy Implications for LCVs on Exclusive Truck Facilities, I-90 Gap Closing Scenario, Draft Evaluation Results.*

Georgia Department of Transportation, *Truck Only Lane Needs Analysis and Engineering Assessment,* April 2008.

Georgia State Road and Tollway Authority, *Truck Only Toll Facilities: Potential for Implementation in the Atlanta Region/Atlanta TOT Facilities Study,* July 2005.

Gilroy, Leonard C., Robert W. Poole, Jr., Peter Samuel, and Geoffrey Segal, *Building New Roads Through Public-Private Partnerships: Frequently Asked Questions,* Reason Foundation Policy Brief No. 58.

Holguin Veras, Jose, David Sackey, Sajjad Hussein, Victor Ochieng, *On the Economic and Financial Feasibility of Toll Truckways,* TRB 2003 Annual Meeting.

HNTB and Wilbur Smith Associates, I-35 Trade Corridor Study, Recommended Corridor Investment Strategies, Texas Department of Transportation, September 1999.

Hsing-Chung Chu, *Implementing Truck-Only Toll Lanes at the State, Regional, and Corridor Levels: Development of a Planning Methodology,* Georgia Institute of Technology, December 2007.

Indiana Department of Transportation, *I-70 Corridor of the Future Phase II Application,* 2007.

Kawamura, Kazuya, *Commercial Vehicle Value of Time and Perceived Benefit of Congestion Pricing,* University of California Berkeley, PhD Dissertation, 1999.

Leachman, R. C., et al., Port and Modal Elasticity Study, Southern California Association of Governments, September 2005 (http://www.ieor.berkeley.edu/People/Faculty/leachman-pubs/PortModal.pdf).

Los Angeles County MTA, *I-710 Major Corridor Study Final Report,* March 2005.

Mahboub, K., and E. G. Williams, "Construction of Large-Stone Asphalt Mixes (LSAMs) in Kentucky," *Transportation Research Record 1282,* Transportation Research Board, Washington D.C., 1990, pp. 41–44.

Mason, J. M., Middleton D. R., and Petersen H. C., *Operational and Geometric Evaluation of Exclusive Truck Lanes,* Texas Transportation Institute, Research Report 331-3F. pp. 18–23, May 1986.

McDevitt, C. F., "Basics of Concrete Barriers," *Public Roads,* March 2000.
Middleton, Dan, Steve Venglar, Cesar Quiroga, Dominique Lord, and Debbie Jasek, *Strategies for Separating Trucks from Passenger Vehicles: Final Report,* Research Report 0-4663-2, September 2006.
Middleton, Dan, *Truck Accommodation Design Guidance: Policy Maker Workshop,* Texas Transportation Institute, Research Report 4364-3, October 2003.
Parsons Brinckerhoff Quade & Douglass, Inc., *Truck Only Toll Facilities: Potential for Implementation in the Atlanta Region,* July 2005.
Poole, Robert W., Jr. and Peter Samuel, *Corridors for Toll Truckways: Suggested Locations for Pilot Projects,* Policy Study 316, Reason Foundation, February 2004.
Poole, Robert W., Jr. and Peter Samuel, *Toll Truckways: Increasing Productivity and Safety in Goods Movement,* PowerPoint Presentation.
Poole, Robert W., Jr., *Miami Toll Truckway: Preliminary Feasibility Study,* Reason Foundation, Policy Study 365, November 2007.
Poole, Robert W., Jr., *Reducing Congestion in Atlanta: A Bold New Approach to Increasing Mobility,* Reason Foundation and Georgia Public Policy Foundation, Policy Study 351, November 2006.
Poole, Robert W., Jr., *Safeguarding and Modernizing America's Highway Infrastructure,* Reason Foundation, PowerPoint Presentation.
Poole, Robert W., Jr., *The Private Sector's Growing Role in Highway Infrastructure,* Reason Foundation Presentation to the National Surface Transportation Policy and Revenue Study Commission, October 2006.
Reich, Stephen, Janet Davis, Martin Catala, Anthony Ferraro, and Sisinnio Concas, *The Potential for Reserved Truck Lanes and Truckways in Florida,* Center for Urban Transportation Research, Research Report 21-17-422-LO, May 2002.
Samuel, Peter, Robert W. Poole, Jr., and Jose Holguin Veras, *Toll Truckways: A New Path Toward Safer and More Efficient Freight Transportation,* Reason Foundation, Policy Study 294, June 2002.
Shladover, Steven E., *Advanced Vehicle Technologies and Exclusive Truck Lanes: Research from California PATH Program,* Transportation Research Board Annual Meeting, January 2006.
Shladover, Steven E., *Improving Freight Movement by Using Automated Trucks on Dedicated Truck Lanes: A Chicago Case Study,* California PATH Intellimotion, Volume 12, No. 2, 2006.
Smalkoski, Brian, and Levinson, D. (2005), *Value of Time for Commercial Vehicle Operators,* Journal of the Transportation Research Forum 44:1 89–102.
Southern California Association of Governments, *Goods Movement in Southern California: The Challenge, the Opportunity, and the Solution*, September 2005.
Southern California Association of Governments, *I-15 Comprehensive Corridor Study,* SCAG, December 2005.
Southern California Association of Governments, *SR 60 Truck Lane Feasibility Study Final Report,* February 2001.
Texas Department of Transportation/I-35 Steering Committee, *I-35 Trade Corridor Study—Recommended Corridor Investment Strategies,* September 1999.
Texas Transportation Institute, *The Feasibility of Exclusive Truck Lanes for the Houston-Beaumont Corridor,* Research Report 393-3F, pp. 72–76, March 1987.
Thompson, M., F. Gomez-Ramirez, and M. Bejarano, *ILLI-PAVE Based Flexible Pavement Design Concepts for Multiple Wheel Heavy Gear Load Aircraft,* Proceedings, 9th International Conference on Asphalt Pavements, Copenhagen, Denmark, August 2002.
U.S. Department of Transportation, 2004 Status of the Nation's Highways, *Bridges, and Transit: Conditions and Performance,* U.S. Department of Transportation, Report to Congress (www.fhwa.dot.gov/policy/2004cpr).
U.S. Department of Transportation, *Western Uniformity Scenario Analysis: A Regional Truck Size and Weight Scenario Requested by the Western Governors' Association,* April 2004.
U.S. Government Accountability Office (GAO), *Highway Finance: State's Expanding Use of Tolling Illustrates Diverse Challenges and Strategies,* U.S. Government Accountability Office (GAO) Report to Congressional Requesters, June 2006 (http://www.gao.gov/new.items/d06554.pdf).
VanderWerf, Joel, Steven Shladover, and Mark A. Miller, *Conceptual Development and Performance Assessment for the Deployment Staging of Advanced Vehicle Control and Safety Systems,* California PATH, 2004.
VDOT, *I-81 Corridor Improvement Study, Tier 1 Draft Environmental Impact Statement,* 2005.
Woudsma, C., T. Litman, and G. Weisbrod, *A Report on the Estimation of Unit Values of Land Occupied by Transportation Infrastructures in Canada,* Transport Canada, 2006.
Yin, Yafeng, Mark A. Miller, and Steven E. Shladover, *Assessment of the Applicability of Cooperative Vehicle-Highway Automation Systems to Freight Movement in Chicago,* Transportation Research Board Annual Meeting, January 2004.

APPENDICES

Appendices A through D are available on the TRB website at www.TRB.org by searching for "NCHRP Report 649/NCFRP Report 3". Titles of Appendices A through D are as follows:

Appendix A: NCHRP Project 03-73 Separation of Vehicles—CMV-Only Lanes Task 7—Interim Report
Appendix B: Performance Evaluation
Appendix C: Benefits Monetization Factors and Unit Costs
Appendix D: Net Present Value Calculations for Benefit-Cost Analysis

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation