Longer Combination Vehicles on Exclusive Truck Lanes:

Interstate 90 Corridor Case Study

final

report

prepared for

Federal Highway Administration

U.S. Department of Transportation

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September 2009

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1.0 Introduction

Population and economic growth could nearly double the volume of freight moved over the U.S. transportation system by 2035. All freight modes will struggle to increase productivity to accommodate the additional demand, and each freight mode faces its own set of challenges to implement productivity and capacity improvements. Growing concerns over greenhouse gas emissions and energy conservation are applying additional pressure to increase productivity. Due to population growth, passenger travel is also projected to increase. This increase in freight movement and passenger travel must be done safely. Separated truck lanes, in conjunction with the use of longer combination vehicles (LCV), present a potential opportunity to boost transportation productivity and reduce emissions and energy consumption per ton mile of freight moved for the nation's highway commerce while at the same time improving safety through the elimination of conflicts with passenger cars. Recent studies[1] suggest that trucking economics may support the feasibility of truck toll lane development with the provision of opportunities for the trucking industry to realize greater productivity through the expanded utilization of LCVs – double or triple trailers. This would potentially allow LCVs to operate on toll truck ways in states where LCV operations are now allowed[2], or toll truckways to be built in states where they are not allowed provided Federal legislation supports it, permitting such tolls on appropriate portions of the Interstate and, in some cases, using Interstate right-of-way for expansions to accommodate the toll truck ways.

1.1 STUDY OVERVIEW

This study investigates the potential feasibility of exclusive truck lanes (ETL) in a multistate corridor that could potentially benefit from new connectivity of LCV networks. In order to identify the potential issues and impacts of implementation of an ETL allowing LCVs, the FHWA directed the study team to identify the basic construction and operating parameters of the facility; and to provide initial estimates of facility utilization, toll revenue, and other performance metrics to enable the FHWA to determine future follow-up studies or pilot testing programs. This is not a policy study, it is a technical study to examine the various impacts of ETLs that have been raised in recent literature. It

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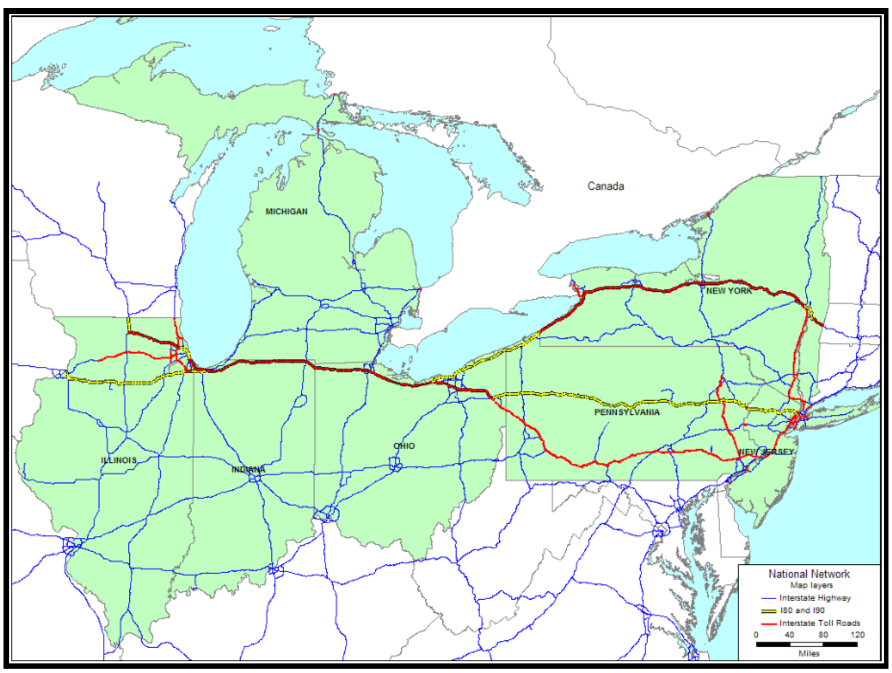
[1] Reason Policy Study 316, Reason Policy Study 294, Corridors of the Future – Phase II Application – I-70 Corridor.

[2] The ISTEA Freeze limited LCV operations to those States that had LCV operating as of June 1991. Currently, 18 states allow LCV configurations on part of their highway networks, but the configurations allowed vary by state.

builds on technical analysis that FHWA has done over the years on this topic including the Comprehensive Truck Size and Weight Study reported to Congress in 2000.

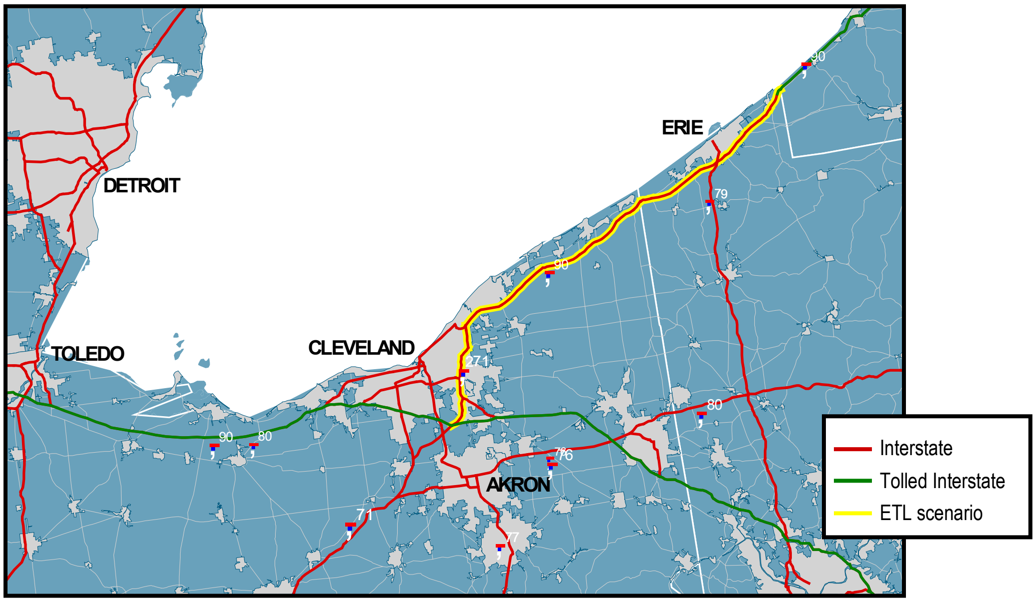
After examining several possible corridors, the FHWA and the study team determined that the Interstate 90 corridor between the Chicago, Boston, and New York City metropolitan areas would serve as a worthy proxy. The I-90 corridor is one of the long-distance routes identified in previous studies and represents a corridor that is often selected as a potential exclusive lane corridor due to the proximity of existing LCV turnpikes. Along with the Interstate 80 corridor, which shares some mileage with I-90 between Illinois and Ohio, the I-90 corridor is the principal east-west freight corridor linking the West, Midwest, and Northeast United States. The "LCV gap" on the study portion of the I-90 corridor occurs between Cleveland, Ohio, and the New York/Pennsylvania State Line. I-80 in Indiana and Ohio allow LCVs and this study tests the impacts of connecting I-80 to the New York Throughway that currently also allows LCVs. The following map shows the extent of the corridor and the LCV gap portion this study tests for exclusive truck lane application.

Figure 1.1 Interstate 90 Corridor With Tolled Sections



Source: FHWA, The Strategic Multimodal Analysis Task 3: Chicago-New York City Corridor Analysis using 2002 HPMS data.

Figure 1.2 Interstate 90 Corridor Exclusive Truck Lane Scenario



Source: National Transportation Atlas Database, 2008.

2.0 Research Approach

With the corridor identified, the study team engaged in three research-oriented activities to build the analysis methodology. Those activities included:

1. Development of an analytical framework to measure the potential utilization and impacts of the ETL corridor;
2. Data collection acquisition and testing of the framework; and
3. Outreach to relevant stakeholders to validate the approach and to deepen the understanding of industry reaction to the ETL corridor scenario, including the potential for LCV deployment.

The following paragraphs provide a brief overview of the research approach. Subsequent sections provide additional detail on the discovery, analysis, and findings.

2.1 Analytical Framework

The analytical framework for this study was developed to estimate the potential divertible freight trips of semi-trailer trucks and rail shipments that would migrate to LCVs. The framework also establishes ranges of potential utilization based on observed and modeled data.

Building off recent truck size and weight studies by the States of Minnesota and Wisconsin, the analytical framework was also developed to estimate impacts of the change in truck or rail travel on a series of performance metrics, including safety, emissions, highway maintenance, and logistics costs.

2.2 Data Collection and Testing

Data was collected on freight movements, highway infrastructure, infrastructure costs, toll rates, and other key elements necessary for the estimates of the study. Data sets included:

- Vehicle classification counts from the study area states (i.e., Indiana, Ohio, Pennsylvania, New York); and from Federal sources, such as Vehicle Travel Information System (VTRIS) and the Comprehensive Truck Size and Weight Study of the U.S. Department of Transportation (DOT);
- The FHWA's Highway Economic Requirements System (HERS), Highway Performance Monitoring System (HPMS) data, and Freight Analysis Framework 2 (FAF2) data;

- Toll rate information by vehicle classification; and
- Attributes of physical facilities and characteristics of proposed or operating truck lanes.

The testing phase utilized several innovative applications, including the use of the FAF2 data assigned to a highway network. This network assignment allowed the study team to conduct 'select link analysis' queries to identify a population of trucks by highway segment. This detail – including origin, destination, payload, and commodity – enabled the study team to test observations.

2.3 OUTREACH

The outreach activities of this study included two industry roundtable events and a series of interviews.

1. **Trucking Industry Roundtable.** In January of 2008, the FHWA convened a group of industry stakeholders to provide this effort with private-sector input, and to help develop the best scenario for testing. This group, comprised of trucking, shipping, rail, and advocacy organizations, met in Tyson's Corner, Virginia, to provide input to the study team. That event helped the study team narrow its focus to the I-90 corridor, and to frame some of the issues and parameters of the study.
2. **Trucking Safety Roundtable.** In May of 2008, the FHWA organized another roundtable event – this time to discuss the safety dimensions of exclusive truck lanes and LCVs. Attendees included representatives of national safety organizations, Federal agencies, and the trucking industry. This event reiterated public concerns about larger trucks, and provided the study with direction on the physical and operational characteristics of the system.
3. **Industry Interviews.** Finally, the study conducted a series of interviews with likely LCV carriers and shippers to further ascertain the potential utilization of the corridor and willingness to pay a toll in exchange for LCV-afforded productivity gains.

This report integrates the findings of these outreach activities into the analytical approach of the study.

3.0 Facility Characteristics

This section outlines the physical and operational characteristics of the potential exclusive truck lane facility examined in this study. The physical characteristics include assumptions on the route, lanes, access, and staging areas. The physical features of the facility provide the basis for construction costs, which this section also estimates. The operational characteristics include assumptions about the types of vehicles, toll technologies, and operating and maintenance costs.

3.1 Highway Physical Characteristics

Route

The proposed exclusive truck lane in this scenario is a 128.1-mile highway section between Cleveland, Ohio, and the New York/Pennsylvania State Line on I-90. The route of the new exclusive truck lanes would commence at a new interchange of the Ohio Turnpike (I-80) and I-271 southeast of Cleveland, and would follow I-271 to I-90 on east side of Cleveland. Moving east, the ETLs would link I-271 to the New York Thruway, traversing a short distance in Pennsylvania near Erie. The primary reason in following I-271, instead of I-90 from its junction with the Ohio Turnpike, is cost savings provided by the existing I-271 highway envelope versus the I-90 right-of-way. Specifically, the I-271 right-of-way is generally more expansive than I-90 in metropolitan Cleveland; slightly reducing the potential land acquisition costs to accommodate the exclusive truck lanes cross section. Figure 3.1 illustrates the geography of the connection.

Figure 3.1 I-90 Corridor Map With Staging Areas and Access Points

Design

The exclusive truck lane facilities developed on this section would consist of the following physical attributes:

- Four exclusive truck lanes total; two lanes in each direction (representing approximately 487 new lane miles).
- Construction in the existing Interstate median, where possible given current highway configuration and right-of-way.
- Follows Interstate design standards for cross section (e.g., 12-foot lanes).
- Adaptation or complete reconstruction of the highway cross section in some segments where current median or lane configuration would not allow the four new lanes, including potential relocation of general traffic lanes. On portions of the I-271 corridor, this would likely include the reconfiguration of the cross section to accommodate ETLs, express lanes, and general purpose lanes.

Access and Staging Areas

The hypothetical locations for access points and staging areas are identified in Figure 3.1. These hypothetical locations were chosen to provide linkages to existing highway facilities, and to serve local shipping communities.

3.2 Highway Operations

The following figures (Figures 3.2 to 3.4) illustrate the typical configurations expected on the new exclusive truck lane. Figure 3.2 illustrates a typical semi-trailer combination unit, typically limited to 80,000 pounds gross vehicle weight (GVW), but capable of carrying a heavier load. The double-trailer configurations operate on all sections of the I-90 between Indiana and New York/ Massachusetts, except for the gap in Northeast Ohio and the Pennsylvania Panhandle. The triple-trailer configuration operates exclusively on the Indiana and Ohio Turnpikes. Axle weights on all configurations must conform to Federal Bridge Formula B.

Figure 3.2 Single 53-Foot Tandem
Five-Axle, 63.8 Feet Extreme Axle Spacing: 87,875 Pounds

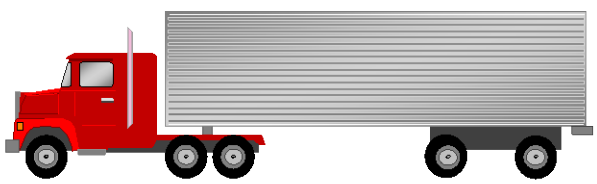


Figure 3.3 Twin 48-Foot (or 53-Foot) Trailers
Nine-Axle, 109.2 Feet Extreme Axle Spacing: 129,000 Pounds

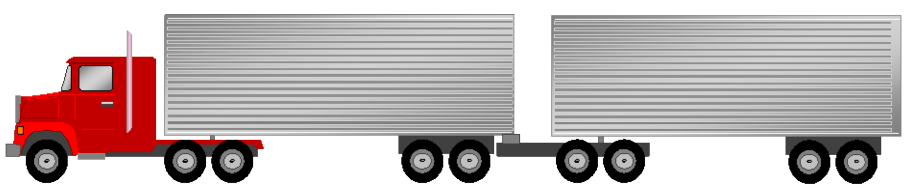
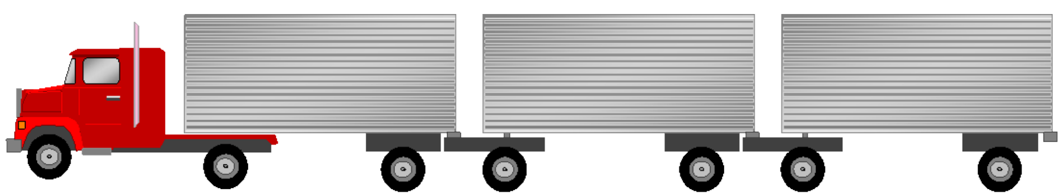


Figure 3.4 Triple 28-Foot Trailers
Seven-Axle, 102.9 Feet Extreme Axle Spacing: 120,000 Pounds



Tolling and Technology Considerations

Tolling

In addition to these LCV configurations, the ETL facility would be open to all commercial vehicle traffic, but would exclude other vehicle traffic. Generally, the facility would convey LCVs and some semi-trailer trucks, especially when congested conditions on the general purpose lanes made the ETLs more attractive. The next section, which provides utilization and toll estimates, includes a scenario in which all commercial vehicles with five or more axles (semi-tractor trailers and LCVs) choose to utilize the ETLs to provide an illustrative upper bound of potential ETL traffic.

Toll collection would likely rely on current and emerging technologies to automatically collect tolls through overhead gantries using existing transponder systems such as E-Zpass.

Safety Technologies

Separation of trucks from the general traffic stream provides safety benefits by reducing the number of potential truck-auto crashes. Section 5.0 estimates the results of these safety performance improvements. The safe operation of the facility could be further enhanced through the requirement of on-board safety technologies. The trucking industry representatives participating in this study extolled the ability of collision detection systems, rollover stability, and other technologies to greatly improve the safety performance of their fleets. The body of research on the safety impacts of technologies for LCVs continues to grow, but does not yet provide any usable factors to estimate the change in crash reductions from shifting loads from semi-trailer to LCV configurations. Based on observed experience, the technologies with the greatest safety mitigation potential for commercial vehicle operations – including LCVs – include at least the following:

- **Collision detection systems** utilize radar-based sensors to engage the vehicle's foundation brakes (which alert the driver), and decelerate the vehicle when a preset vehicle following distance is compromised.
- **Rollover Stability Control (RSC)** systems monitor the vehicle's lateral acceleration to detect and counteract rollover risk. When the system observes a rollover risk, it decelerates the engine and applies tractor and trailer breaking.
- **Lane tracking** systems detect lane boundaries to alert and assist drivers to maintain proper orientation and position within their lane boundaries.

While these technologies show great promise, researchers have not yet developed per-mile rates of crash avoidance and crash reduction for LCV fleets. As such, this study focuses on the crash reduction provided by separating trucks from the general purpose lanes.

Platooning

Another much discussed technology application with respect to truck lanes is "platooning." This study does not estimate the effect of platooning, but the concept has garnered recent attention. Platooning would use connected vehicle technologies[3] to allow a lead tractor combination to simultaneously control or coordinate acceleration, braking, and steering to gain energy and emissions efficiencies by cutting air resistance. Research by Shladover and others indicates platooning could further reduce fuel consumption and tailpipe emissions by 10 to 20 percent beyond the efficiencies already realized by converting semi-trailer trucks to LCVs.

In order for the platooning concept to produce these benefits, the freight corridor would require a critical mass of vehicles with common origins and destinations. Because the potential carriers using the study portion of the I-90 corridor serve a broad mix of origin and destination pairs, this study does not apply the platooning concept because it would affect a relatively small segment of the LCVs using the proposed ETL. Further reducing the likelihood of platooning on this corridor is the relatively short length of the ETL facility relative to the costs (time and labor) to assemble the platoons.

3.3 Capital Improvement Costs

Taking into consideration the physical and operational characteristics of the corridor, this section provides planning-level estimates the capital costs to build the facility. Capital improvement cost data were derived from the FHWA's HERS, and were applied to available highway segment data from the FHWA's HPMS.

- **HERS** is an engineering/economic analysis tool that predicts system condition and user cost levels resulting from a given level of investment. This study utilizes cost estimates from HERS, on a per-mile basis, for pavement and widening improvements.
- **HPMS** data are collected annually by the states and submitted to the FHWA to serve as a clearinghouse of information on highway physical and operational characteristics. HPMS is a valuable tool in developing planning-level estimates of improvements. The following table illustrates some of the ETL corridor's construction-relevant attributes.

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[3] Connected vehicle technologies, formerly known as Vehicle Infrastructure Integration (VII), utilize telematic devices and applications to link some of the operating characteristics of vehicles, and to exchange real-time information between vehicles and roadway infrastructure. In the case of platooning, connected vehicle technologies would enable a string of multiple LCVs to nearly operate as a single vehicle because of linked and synchronized acceleration, steering, and breaking.

Keep in mind that all the costs and assumptions are at the sketch planning level of detail, and would require a more detailed engineering assessment to enhance accuracy. Per-mile cost estimates are based on the following assumptions in Table 3.1 based on HPMS network attributes. The following paragraphs explain the content of the table.

Table 3.1 Corridor HPMS/Cost Assumptions

From	To	Distance (Miles)	Terrain (Flat/ Rolling)	HPMS Widening Feasibility	Added Lanes	Lanes Recon.	Added Lane Miles
NY State Line	PA State Line	46.3	80/20	3+	4		185.2
PA State Line	I-90/I-271	54.7	80/20	3+	4		218.8
I-90/I-271	U.S. 422	12.63	100/0	3+	4	4	50.52
U.S. 422	I-480E	5.42	100/0	5+	4		21.68
I-480E	SR 8	2.97	100/0	5+	4		11.88
SR 8	I-80	6.08	100/0	5+	4		24.32

In Table 3.1, the HPMS attributes include the following:

- **Distance** of the segment expressed in miles.
- **Terrain** characteristics, expressed as the estimated split of flat versus rolling terrain.
- A **Widening Feasibility** code indicating the extent to which an existing facility could be widened within its existing right-of-way, reflecting physical features along the section such as severe terrain, cemeteries, park land, and nonexpendable buildings (large office buildings, shopping centers, etc.). A value of 3+ equates indicates the ability to add 1 lane, while 5+ indicates 3 or more lanes may be added.

Based on these physical design characteristics, the final two columns of Table 3.1 indicate the expected changes to the highway, including the following:

- **Added Lanes** are segments with new exclusive truck lanes in existing right-of-way, typically in the median.
- **Lanes Reconstructed** are segments where reconstruction of existing highway lanes is required to accommodate the exclusive truck lanes. For example, on an urban segment of I-271 between I-90 and U.S. 422, this may require construction of ETLs and the reconstruction of existing Express Lanes.

After identifying the segment characteristics using HPMS data, the study team developed per-mile cost estimates using the HERS model. HERS per-mile cost estimates vary based on improvement definitions for urban and rural segments. For example:

- From the New York State Line to the I-90/I-271 interchange, the HERS improvement type is "Major Widening at High Cost (Rural)."
- For the 12.6-mile segment of I-271 with existing Express Lanes, the HERS improvement type is "Reconstruct and Add High Cost Lanes (Major Urbanized Area)." This improvement type is selected because this section would require complete reconfiguration to accommodate new ETLs while preserving express lane and general purpose lane capacity.
- South of the I-271 Express Lanes to I-80, the HERS improvement type is "Major Widening at High Cost (Small Urbanized)" to reflect and expectation that right-of-way (ROW) acquisition would be minimal, given the existing cross section's wide median.

Based on the assumptions identified above, Table 3.2 presents the total construction costs by applying lane-mile improvement costs from HERS to the HPMS characteristics of the highway segments. The costs include new lanes, ramps, new bridges and bridge upgrades, pavement reconstruction (where identified), and staging areas.

Table 3.2 I-90/I-271 Exclusive Truck Lane Construction Costs by Highway Segment

I-90/I-271		Lane-Mile Costs (2008)		Construction Subtotal	Staging Area Costs	Total Cost 2008 (Millions)
From	**To**	**Flat**	**Rolling**			
NY State Line	PA State Line	$6.02	$7.61	$1,153	$20.40	$1,173
PA State Line	I-90/I-271	$5.11	$6.46	$1,168	$8.40	$1,177
I-90/I-271	U.S. 422	$10.69	$89.46	$1,072	$8.40	$1,080
U.S. 422	I-480E	$21.06	$21.06	$448	$8.40	$457
I-480E	SR 8	$21.06	$21.06	$250	$ –	$250
SR 8	I-80	$21.06	$21.06	$630	$ –	$630
Total				**$4,721**	**$45.59**	**$4,767**

Capital Cost Summary

Based on this analysis, the order-of-magnitude capital costs for this facility are more than $5 billion, consisting of the following major categories, all expressed in 2008 dollars:

- **Highway Mainline.** The costs in Table 3.2 represent 2008 costs adjusted from 2002 cost assumptions from HERS. These adjustments are made through Consumer Price Index factors and state construction cost factors from HERS of 1.257 for Pennsylvania and 1.067 for Ohio. The resulting total corridor cost estimate is **$4.767 billion**.
- **Ohio Turnpike Truck-Only Interchange.** An additional construction cost required for the project recommendation is the development of a truck-only interchange at I-80 (Ohio Turnpike). To develop a cost estimate for the new interchange through use of HERS, the following assumptions are used: 0.5 centerline miles of ramps, 4 structures, rolling terrain, and 10 culverts. These assumptions, accounting for the construction price index and state cost factor, result in a total cost for the interchange of **$83.92 million**.
- **Technology and Toll Collection.** The recently completed Georgia Department of Transportation (GDOT) Statewide Truck Lanes Needs Identification Study[4] developed cost estimates for a system of statewide truck lanes in April 2008. Cost estimates for this study were developed through a statewide project costing tool based on state-specific, regional, and national cost data. To develop a cost estimate for constructing toll collection facilities and Intelligent Transportation System (ITS)/Advanced Traffic Management System (ATMS) equipment in the corridor, per mile cost estimates of $1.1 million from the GDOT study were used. Total cost for this element of the ETL corridor is **$140.47 million**.
- **Staging Areas.** Table 3.2 includes capital costs for the construction of five new staging areas along the corridor. These new staging areas complement the existing staging area at the New York State Line by providing an assembly point for LCV equipment. The new staging areas are situated to serve local shipping communities or at major highway junctions. The estimated cost of developing a staging area is $8.4 million in Ohio and $10.2 million in Pennsylvania (to match the higher HERS construction cost factor for Pennsylvania). The costs were obtained from the U.S. DOT Comprehensive Truck Size and Weight Study and inflated to current year. The total cost for the staging areas is **$45.59 million.**
- **Utilities Relocation.** The average cost per-mile to relocate or reconfigure utilities in the right-of-way is about $1.76 million, translating to **$210.80 million** for the 128.1-mile corridor. This cost is based on the GDOT study assumption that utility relocation is roughly 5 percent of construction cost.

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[4] Georgia Department of Transportation, Statewide Truck Lanes Needs Identification Study, 2008, http://www.dot.state.ga.us/INFORMATIONCENTER/PROGRAMS/studies/trucklanestudy/Pages/default.aspx.

- **Preliminary Engineering.** The GDOT study also estimates preliminary engineering would constitute at least 10 percent of total construction cost, translating to **$476.7 million**.
- **Total Capital Costs.** Accounting for all subcategories, the total project corridor capital cost in 2008 dollars is **$5.679 billion**.[5]

Financing Costs

To pay for the capital costs of infrastructure, the project would likely require debt service payments to secure at least a portion of the financing. The market rate for toll facilities currently hovers around 5 percent. For example, the New Jersey Turnpike Authority bonds that mature in 2040 are yielding 5.25 percent. The possibility of public financing through the Transportation Infrastructure Finance and Innovation Act (TIFIA) program of the U.S. DOT could provide a lower-than-market rate (currently at 4.25 percent) for a portion of the investment. Assuming a mix of lower interest public financing and market rate bonds, at 5 percent the annual debt service for this investment would be **$365.8 million** (expressed as 2008 dollars). For this estimate a 30-year term is used to match the 30-year bonds traditionally issued by the Ohio Turnpike Commission and the Pennsylvania Turnpike Authority.

3.4 Maintenance and Operations Costs

Another important consideration is the costs associated with continued operations and maintenance of the facility. The estimating procedure from the recent GDOT study assumes annual operations and maintenance costs for a truck-only-toll lane corridor at 0.5 percent of total initial project capital cost plus 3 percent inflation per year. Applying this assumption to the I-90/I-271 corridor results in an average annual maintenance and operations cost estimate of **$45.72 million** from 2010 to 2040.

3.5 Cost Summary

Collectively, the annual capital and operating costs total $411.5 million (2008 dollars). Subsequent sections of this report estimate the potential toll revenues and benefits to public and private stakeholders to offset these costs.

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[5] Note that right-of-way acquisition is not included in these costs as the preliminary analysis of the corridor using HPMS data reveals that the current highway real estate should generally accommodate the conversion or addition of ETLs.

Table 3.3 I-90/I-271 Exclusive Truck Lane Capital and Operating and Maintenance Cost Summary
2008 Dollars (in Millions)

Cost Category	Total Cost ($ Millions)
Capital Costs	
Highway Mainline Construction	4,767
I-80 Truck-Only Interchange	83.92
Technology and Toll Collection	140.47
Utilities Relocation	210.80
Preliminary Engineering	476.70
Subtotal	5,678.9
Operating and Maintenance Costs	45.72
Annual Financing of Capital Costs	365.8
Total Annual Cost	**411.5**

4.0 Demand and Utilization

4.1 Introduction

Utilization of the new exclusive truck lane facility by LCVs largely depends on the degree to which the carriers or shippers choose to move by LCV instead of their current form of transport – either semi-trailer truck or rail. This section estimates the potential shift of freight to LCVs on the new facility from the current and future populations of semi-trailer truck and rail moves on the I-90 corridor. The outcomes of these estimates provide the basis for toll revenue projections and the public/private benefits and impacts presented in Section 5.0.

4.2 Truck-to-LCV Diversion

Baseline Corridor Combination Truck Volumes

To estimate the potentially divertible trucks to the exclusive truck lanes, existing truck flow and count data were evaluated to develop estimates of baseline (2010) and target year (2040) no-build average daily combination truck traffic (ADTT) on I-90 and I-271. The foundation of the baseline estimates is the FAF2 truck flow data assigned to a network. Following the assignment of the FAF2 network flows, the following three count-based data sets were used to scale the FAF2 flows, where FAF2 volumes are either higher or lower than count-based sources.

1. **2006 HPMS**, which includes existing/future AADT, as well as truck share by single unit and combination trucks;
2. **VTRIS** for 2007, which has classification counts on I-90 in Ohio and classification and weight data for I-80 in Pennsylvania (center of State, just west of State College);[6] and
3. **State DOT/FHWA count data**, including truck percentages, and truck counts by classification available for I-90 from Cleveland to Buffalo, including data from the New York Thruway.

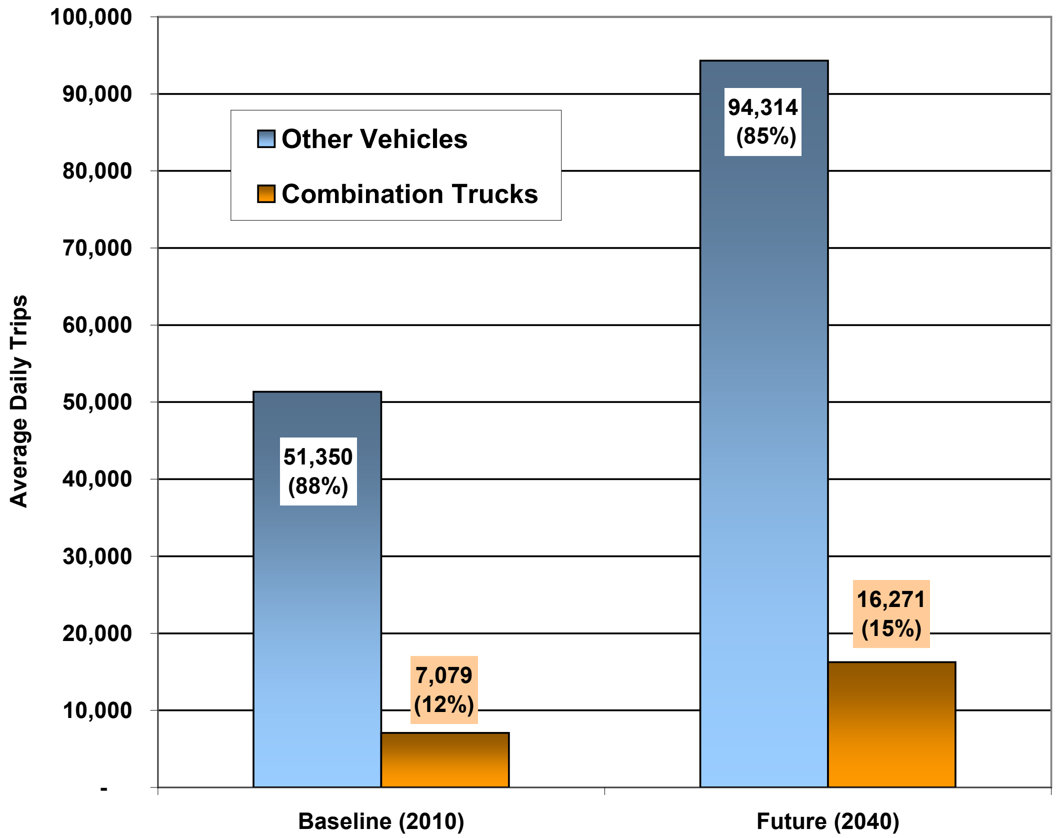
To generate 2040 ADTT, the volume-weighted average FAF2 growth rate for the entire corridor is applied to each segment volume. This value is 3.04 percent annually.[7] Figure 4.1 shows the results of this baseline 2010 and 2040 estimation of total trucks on the corridor versus other vehicle traffic. In this case, trucks are five-axle combination units and greater. The volumes shown in Figure 4.1 are

[6] Note that VTRIS does not include weight data on I-90.

[7] Calculated from FHWA's FAF2 data.

indicated at locations of key interchanges. It reflects AADT (average annual daily traffic) counts to illustrate the magnitude of total traffic (noncommercial and commercial vehicles).

Figure 4.1 Baseline (2010) and Future (2040) Corridor Traffic Profile
Average Daily Combination Truck Trips Versus Other Vehicles



Source: FAF2, VTRIS, State Counts.

Figure 4.1 shows that the proportion of truck traffic will grow over time from 12 percent in 2010 to 15 percent in 2040. This growth trend highlights the need for consideration of truck productivity measures, such as LCVs.

Estimation of Combination Trucks Diverted to LCVs

Given the study parameters and highway operating assumptions, the primary source of utilization in the exclusive truck lane in this study are the single-trailer trucks (STT) that would divert to LCVs to reap higher productivity gains. This initial estimate of LCVs includes both double- and triple-trailer combination units; the following section provides a specific estimate for triples portion.

In order to estimate the share of STTs diverting to LCVs, the following high and low scenario estimates were developed based on observed truck classification count data, where LCVs are currently allowed to operate:

- **High Scenario (10 percent) LCV Share in Selected LCV Corridors.** Vehicle classification counts for combinations on Interstates in four western LCV states (Montana, Nevada, South Dakota, and Utah)[8] indicate that, in those states, 10 percent of all combinations are multiple-trailer trucks with seven or more axles (from 2007 VTRIS data analysis). This estimate is considered "high" because in these states LCVs can travel on a much broader highway network, avoiding the extra operating costs required in limited LCV states for assembling and disassembling configurations.

  High estimates of LCVs diverting from conventional combinations are based on the assumption that 10 percent of the combination trucks in the corridor would be LCVs with the implementation of the exclusive toll lanes. Under this assumption and the payload factor of 1.6, LCV usage is calculated by multiplying baseline traffic by 0.09434 since:

  $$0.09434 / (0.09434 + 1 – 0.09434 \times 1.6) = 10\%$$

  Note that LCV traffic is equal to baseline traffic times 0.09434, and conventional truck traffic following the implementation of the exclusive toll lanes is equal to baseline traffic times (1 – 0.09434 x 1.6).

- **Low Scenario (2 percent) Existing LCV Share on I-90/New York State Thruway.** Vehicle classification counts at the toll plazas on I-90 between Rochester area and the Pennsylvania State Line indicate that an average of 2 percent of all combination trucks are LCVs (seven or more axles) (May 2008, New York State Thruway data). This is an approximate average on the Thruway east through the Rochester area. The share LCVs was highest at the of Buffalo stations; in general none were higher than 2%.

  Low estimates of LCVs diverting from conventional combinations are based on the assumption that 2 percent of corridor traffic would be LCVs with the implementation of the exclusive toll lanes. Under this assumption and the payload factor of 1.6, LCV usage is calculated by multiplying baseline traffic by 0.01976 since:

  $$0.01976 / (0.01976 + 1 – 0.01976 \times 1.6) = 2\%$$

Once estimated, the high and low ranges of STTs diverted (see Table 4.1) were converted to LCV trips based on a payload factor reflecting the change in truck weight from a 5-Axle STT to a 9-Axle LCV. To accomplish this, a payload factor of 1.60 was utilized to convert 5-Axle STT (80,000lbs) to 9-Axle LCV (127,000lbs). The following table shows the results of the high and low potential for truck-to-

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[8] Montana, Nevada, South Dakota, and Utah allow the operation of turnpike doubles and triples on Interstate highways under Grandfather Exemptions to current Federal restrictions on LCV operations. Nevada, South Dakota, and Utah allow turnpike doubles and triples up to 129,000 pounds. Montana allows turnpike doubles at 137,800 pounds and triples at 131,000 pounds.

LCV diversion in the base and future years. The estimates are expressed as daily truck trips.

Table 4.1 Estimate of Daily Single-Trailer Truck Trips Diverted to LCVs
All LCV Configurations

Average Daily Trips	Baseline (2010)	Future (2040)
Combination Trucks	7,079	16,271
Single-Trailer Trucks Diverted to LCVs (High)	708	1,628
Single-Trailer Trucks Diverted to LCVs (Low)	142	326
Resulting LCVs (High diversion with payload factor applied)	443	963
Resulting LCVs (Low diversion with payload factor applied)	89	193

*See formulas above for payload factor information.

Alternative Methodology

As an alternative to this observation-based method, this study also estimated potential LCV diversions using a second set of assumptions. A description of this method, which uses a combination of distance, weight, and commodities as filters, is summarized in Section 6.0 appendices of this report. The alternative scenario diverts a higher percentage of single-trailer trucks to LCVs – roughly 20 percent. The study team chose the more conservative observation-based methodology to estimate truck-to-LCV diversion because the utilization trends of long-distance moves in western LCV states have persisted for decades.

Estimation of Triple-Trailer Combinations

While the majority of single-trailer trucks trips diverted to LCVs on the corridor would use a double-trailer combination, a portion of the LCVs diverted would utilize triple-trailer combination units. Currently, triples are allowed on the Ohio and Indiana portions of the corridor. For example, the Ohio Turnpike Commission stipulates triples to between 90 to 113 feet long, and having anywhere between 7 to 9 axles. The maximum gross weight of a triple should not exceed 115,000 pounds. Accordingly, this estimate assumes that the range of triples would extend from the Illinois/Indiana State Line to the Pennsylvania/New York State Line.

To calculate the percentage share of triples among all LCVs, vehicle miles traveled (VMT) shares from the U.S. DOT's Comprehensive Truck Size and Weight Study by state were evaluated. Across the nation, in states where triples are allowed, triples account for anywhere from 2 to 42 percent of the share of total LCV VMT on the states' highways. In Indiana and Ohio, where LCVs are restricted to the Ohio Turnpike and I-90, the VMT share for triples averages **29.9 percent**.

Applying this factor to the estimated population of LCVs on the corridor in 2010 results an average of 132 triple-trailer combinations on the corridor in 2010, assuming the 10-percent diversion of all single-trailer combination units to LCVs. The following table supplements Table 4.1 by illustrating the potential for triple-trailer combinations under high (10 percent) and low (2 percent) diversion scenarios for 2010 and 2040. This estimate does not consider triples on the corridor's New York Thruway or Massachusetts Turnpike, where triples are not currently allowed. Also, this estimate does not consider the effect of tolls on triple utilization.

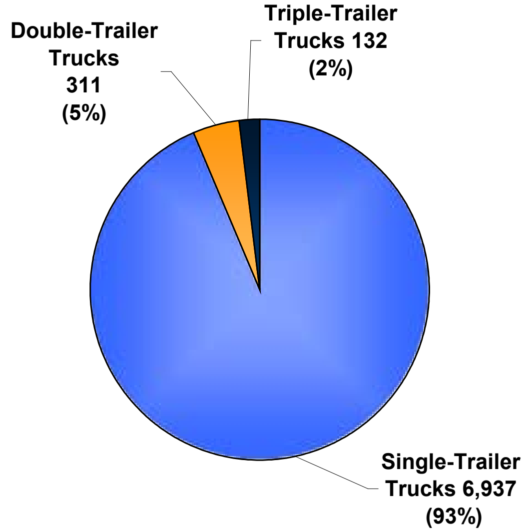
Table 4.2 Estimate of Daily Single-Trailer Truck Trips Diverted to LCVs
Double- and Triple-Trailer Combination Units

Average Daily Trips	Baseline (2010)	Future (2040)
Combination Trucks	7,079	16,271
Single-Trailer Trucks Diverted to LCVs (High)	708	1,628
Single-Trailer Trucks Diverted to LCVs (Low)	142	326
Resulting LCVs (High diversion with payload factor applied)	443	963
Doubles (70.1 percent)	*311*	*675*
Triples (29.9 percent)	*132*	*288*
Resulting LCVs (Low diversion with payload factor applied)	89	193
Doubles (70.1 percent)	*62*	*135*
Triples (29.9 percent)	*27*	*58*

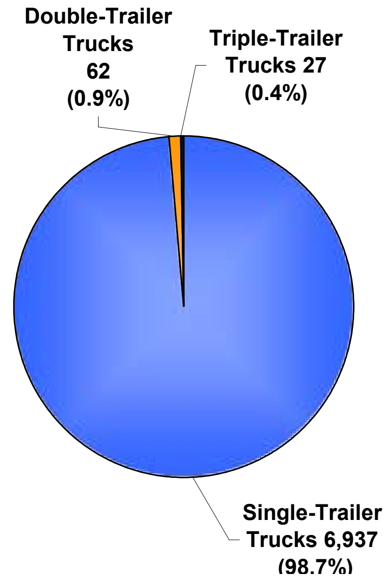
The following figure (Figure 4.2 graphically illustrates the magnitude of resulting doubles and triples under the low and high scenarios for the base year.

Figure 4.2 Truck Traffic Profile with High (10 percent) and Low (2 percent) LCV Diversion Base Year (2010)
Average Daily Combination Truck Trips

High Scenario



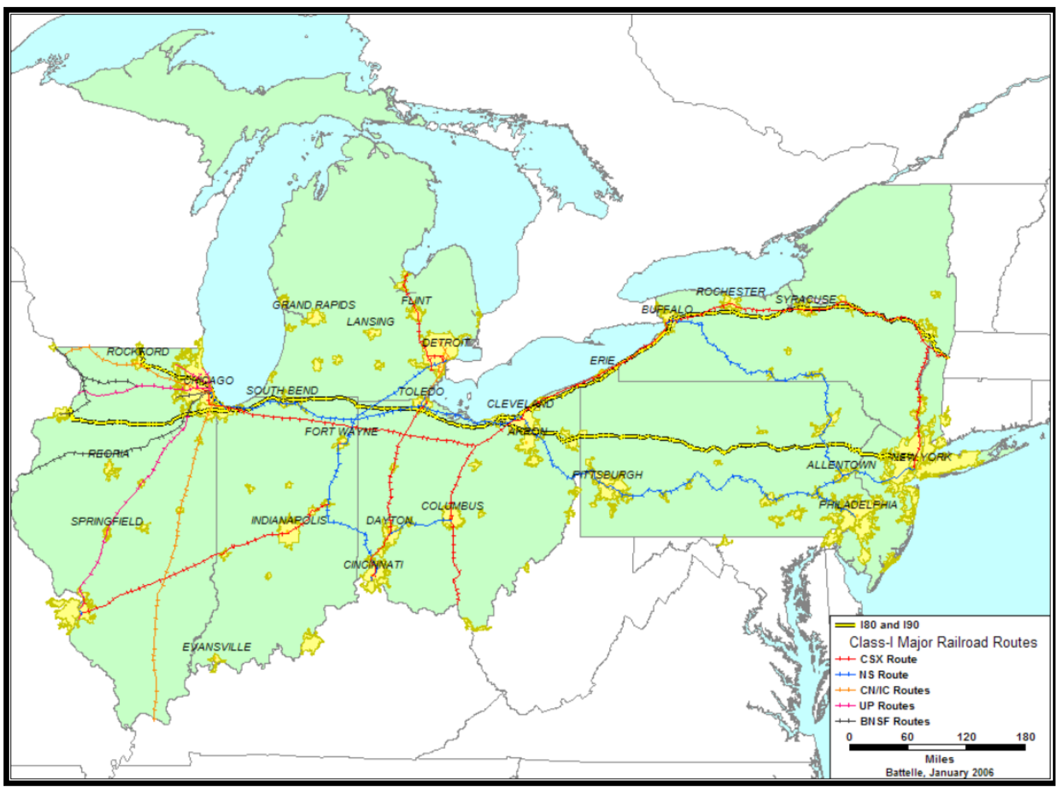
Low Scenario



4.3 RAIL-TO-LCV DIVERSION

With the development of a long-distance LCV route, a share of the freight traffic moving over CSXT and Norfolk Southern (NS) rail lines parallel to the corridor would likely shift to LCVs to realize per-mile cost savings. To estimate the number of railcars diverted to LCVs, the study team identified the LCV cost savings per mile and a cross-elasticity to predict change in rail ton-miles because of changes in trip costs. Using these two factors, high and low diversion estimates were developed. The primary difference between the "high" and "low" estimate is that the methodology for the high estimate does not include costs for assembly and total corridor trip costs. Rail ownership was not considered in this analysis, since both NS and CSXT operations and commodities on this corridor would be similarly affected by any addition of ETLs. The following map (Figure 4.3) illustrates the regional extent of the rail network.

Figure 4.3 Regional Rail and Highway Network



Source: FHWA, The Strategic Multimodal Analysis Task 3: Chicago-New York City Corridor Analysis using 2002 HPMS data.

Corridor Rail Tonnage Estimates

To develop baseline and forecast rail tonnage estimates, the study team applied national FAF2 growth rates to detailed commodity flow data for the CSXT and NS operations at Erie, Pennsylvania. The FAF2 data were also used to identify the share of low-density commodities traveling by rail that would be eligible for diversion to LCV (9.5 percent). The appendices of this report contain a more detailed description of the approach and development of rail tonnage estimates and both scenarios (high and low).

High Rail Diversion Estimate

The high rail diversion estimate is based exclusively on cost savings resulting from expanded eligibility for LCV operations and new ETL tolls in the project corridor. The high diversion effect is estimated by identifying the change in per-mile truck operating costs and by applying a cross elasticity.

Table 4.3 presents the results of this analysis. As demonstrated in Table 4.3, the number of LCVs resulting from rail diversion is relatively low compared to diversion from single-trailer trucks.

Low Rail Diversion Estimate

This estimate takes into account cost difference of operating an STT versus an LCV in the corridor. The corridor evaluated is I-90 from its interchange with I-95 just west of Boston to the Illinois State Line. The STT corridor trip assumes current per-mile toll rates and operating costs. A lower cross-elasticity is applied to identify the number of LCVs that would result from rail-to-truck diversion. Table 4.3 demonstrates the results of this low rail diversion scenario.

Table 4.3 Rail Diversion Estimates

Daily LCV Equivalents Diverted from Rail

	2010		2040	
Diverted to LCVs From	**High**	**Low**	**High**	**Low**
Rail	29	5	58	9

4.4 Combined Truck and Rail LCV Diversion

The result of combined traffic estimates of truck and rail moves diverted to LCVs is summarized below in Table 4.5.

Table 4.4 LCV Equivalents Diverted from Truck and Rail
Corridor Average Daily Trips

	2010		2040	
Diverted to LCVs From	**High**	**Low**	**High**	**Low**
STTs	443	89	963	189
Rail	29	5	58	9
Total	**472**	**94**	**1,021**	**202**

4.5 Exclusive Truck Lane Usage and Toll Revenue Estimates

To determine the exclusive truck lane usage and revenue estimates, three tiers of toll rates were developed – high, medium, and low – to test against the high and low diversion estimates from truck and rail. The change in cost per truck-mile with and without tolls reflects the following:

- Excluding tolls, the per-mile operating costs for LCVs are $1.13 lower than for single-trailer trucks. This assumes a 1.60 payload factor (i.e., 127,000-pound LCV versus 80,000-pound STT).
- When the toll rate is included in the operating costs, the savings per mile can range from as high as $0.83 per mile (with a $0.30 per mile toll) to an added cost of $0.07 per mile with an assumed maximum toll rate of $1.20 per mile.

LCV usage of the ETLs varies linearly with per-mile toll estimates (i.e., 100 percent of all LCVs diverted from STTs use the ETL at the minimum $0.30 per mile toll, 0 percent would use the ETL at the maximum $1.20 per mile toll). The high estimate uses the 10-percent diversion scenario; the low estimate uses the 2-percent scenario.

All rail trips that divert use the toll lanes. The justification for this assumption is that, with increased corridor congestion expected in 2040, the time savings and cost savings of operating LCVs in a corridor with free-flow travel speeds is the primary factor guiding rail-to-truck diversion in the absence of corridor increases in rail capacity to meet future demand.

High Toll ETL Usage/Revenue Estimate

The high toll estimate assumes a toll rate three times higher than the existing per-mile rates for LCVs in New York, Ohio, and Indiana. Higher tolls will assist in supporting capital, operations, and maintenance expenses for the new infrastructure. However, the benefit of higher per-mile tolls is offset by low cost savings of only $0.13 per mile (out of a total possible savings of $1.13 per mile); therefore resulting in lower overall volumes and revenues. Additional travel time savings are expected on the ETLs, and are not considered as a factor in the diversion estimates.

Assuming a $1.00 per mile toll adjusted for inflation from 2010 to 2040 this scenario results in a high cumulative revenue estimate in 2008 dollars of $498 million to a low estimate of $116.3 million.

Medium Toll ETL Usage/Revenue Estimate

The medium toll estimate assumes a 75- to 100-percent higher toll rate than existing per-mile rates for LCVs in New York, Ohio, and Indiana. Higher tolls will assist in supporting capital, operations, and maintenance expenses for the new infrastructure. Cost savings are high enough ($0.53 per mile) to result in significant diversion from rail and truck. Additional travel time savings are expected on the ETLs, and are not considered as a factor in the diversion estimates.

Assuming a constant $0.60 per mile toll adjusted for inflation from 2010 to 2040, this scenario results in a high cumulative revenue estimate in 2008 dollars of $913.9 million to a low estimate of $195.9 million.

Low Toll ETL Usage/Revenue Estimate

The low toll estimate assumes a toll rate comparable to existing per mile rates for LCVs in New York, Ohio, and Indiana. Cost savings are $0.83 per mile; therefore resulting in significantly higher volumes, which outweigh lower per-mile revenues. Because these tolls are in line with current corridor rates which truckers are accustomed to paying, trips are experiencing additional time and cost benefits from use of the ETL and there is reduced need for assembly and disassembly, it is assumed that 100 percent of LCVs in the corridor will use the ETL. Additional travel time savings are expected on the ETLs, and are not considered as a factor in the diversion estimates.

Assuming a $0.30 per mile toll adjusted for inflation from 2010 to 2040, this scenario results in a high cumulative revenue estimate in 2008 dollars of $687.9 million to a low estimate of $135.3 million.

Table 4.5 summarizes the results of the three toll scenarios by providing the 30-year revenue stream.

Table 4.5 Exclusive Truck Lane Toll Revenue by Diversion Scenario

Cumulative Revenue (2010 to 2040) (2008 Million Dollars)	High (10%)	Low (2%)
High toll at $1.00 per mile	$498.0	$116.3
Medium toll at $0.60 per mile	$913.9	$195.9
Low toll at $0.30 per mile	$687.9	$135.3

Universal Truck Toll Scenario

Because none of the LCV revenue estimates contributes significantly toward the total cost of construction and operation of the exclusive truck lane, this scenario estimates toll revenues if ALL combination units choose to use the facility, but at a discounted rate. This study assumes that a discounted toll rate would attract more STTs than equivalent per-mile tolls on LCVs because the corridor is relatively uncongested, except on some metropolitan Cleveland segments at peak hours. Over time, as levels of delay and congestion increase, the motivation for STTs to utilize the ETL may increase. Table 4.6 illustrates the results of this exercise, assuming that combination units would pay 50 percent of the per-mile toll of LCVs.

Table 4.6 Exclusive Truck Lane Toll Revenue Estimate for All Single-Trailer Trucks

Cumulative Revenue (2010 to 2040) (Million $2008)	**High (10%)**	**Low (2%)**
High toll at $0.50 per mile	$9,802.9	$10,674.4
Medium toll at $0.30 per mile	$5,881.8	$6,404.7
Low toll at $0.15 per mile	$2,904.9	$3,202.3

5.0 Performance Measures

While toll revenue might be the single most important performance measure when making an investment decision in new infrastructure, there are several other quantitative and qualitative impacts worthy of consideration. Among the important impacts of any freight transportation proposal are productivity, congestion, pavement, safety, and air quality. This section estimates these impacts for the exclusive truck lane facility, and monetizes them to serve as an additional consideration against the costs of the project. These benefits – both public and private – may warrant outside investment beyond traditional infrastructure bonding to move exclusive truck lanes forward to development.

5.1 Impact Analysis Methodology

The change in VMT, either by single-trailer trucks or freight-rail, serves as the source of impacts. The impacts are calculated by measuring the difference in cost per unit mile of the following factors:

- Transport cost saving due to more productive trucks;
- Congestion cost savings to both vehicles using the ETL and other vehicles;
- Pavement cost savings;
- Crash cost savings; and
- Savings due to emissions reductions.

Trucking Productivity

LCVs are more productive than conventional trucks, even though they have slightly higher operating costs per vehicle mile. This is because fewer LCV trips are required to carry a given amount of freight.

Impacts on trucking productivity were estimated by updating unit costs from Working Paper 7 of the 2000 U.S. DOT Comprehensive Truck Size and Weight Study. This source provides costs per vehicle mile for selected vehicles by configuration, trailer type, and gross vehicle weight. Costs are separated into the following categories: drivers, vehicle, fuel, tires, repair, and overhead. This source also provides estimates of the costs associated with assembling and disassembling combinations in staging areas.

Pavements

Pavement cost savings on other roads due to the exclusive truck lanes were estimated as follows:

- Calculate Equivalent Single Axle Loads (ESAL) per truck for single-trailer trucks and LCVs at different operating weights;
- Calculate changes in ESAL-miles on other roads using ESALs per truck and predicted changes in truck VMT; and
- Apply an average cost of 2.1 cents per ESAL mile (in 2008 dollars) to calculate pavement cost savings.

The analysis was performed using ESALs for rigid pavements since I-90 in Pennsylvania and both I-90 and I-271 in Ohio are either rigid or composite pavements.

The average cost of 2.1 cents per-ESAL-mile was developed based on the following data sources and assumptions:

- Average rural and urban Interstate highway resurfacing costs per lane mile were taken from the FHWA's HERS model and updated to 2008 dollars;
- Pavements on Interstate highways were assumed to be resurfaced or reconstructed every 15 years;
- Average ESALs per single unit and combination truck on Interstate highways in Ohio, Pennsylvania, and New York were compiled from the FHWA's VTRIS;
- Single unit and combination truck VMT per lane mile in the I-90 corridor was compiled from the FHWA's HPMS database; and
- On Interstate highways, 85 percent of pavement resurfacing and reconstruction costs were assumed to be load-related and 15 percent are not load related, based on the FHWA's 1997 Federal Highway Cost Allocation Study.

The average value of 2.1 cents per ESAL mile developed from the above information is consistent with estimates of cost per ESAL mile from Transportation Research Board (TRB) Special Report 211, Twin Trailer Trucks. Special Report 211 reviewed the literature on pavement cost per ESAL mile, and found plausible estimates for Rural Interstates ranging from 0.7 to 5.0 cents per ESAL mile. An independent estimate of cost per ESAL mile was also developed in that report using nationwide data on pavement costs and ESAL miles on rural Interstates. Their estimate, when updated for inflation and adjusted for differences in pavement types, is about 2.5 cents per ESAL mile, close to the average value of 2.1 cents developed using the data and assumptions listed above.

Congestion

Diversion of traffic from the general purpose lanes will reduce congestion in those lanes and provide time and fuel savings. These impacts were estimated based on the following information:

- Passenger car equivalent (PCE) factors for heavy trucks (by truck type and operating weight) from runs of the FHWA's FRESIM model performed for the 1997 Federal Highway Cost Allocation Study. FRESIM simulates the interaction of individual vehicles on freeways. The model was run under a variety of traffic levels and vehicles mixes, and regression analysis was used to estimate the relative impacts of different types of vehicles on congestion.
- AADT and capacity data for I-90 from the HPMS data set.
- Speed relationships for freeways from the HERS model (in which average speeds are estimated based on the ratio of AADT to capacity).
- An estimated 0.84 gallon of gasoline wasted per vehicle hour of congestion delay.
- A $29.90 per vehicle hour value of time (in 2008 dollars) for all traffic, based on values used in HERS[9].

Safety

Safety benefits result from the shift of single-trailer trucks (STT) to LCVs and the reduced truck vehicle-miles traveled. The benefits were estimated based on the following data sources:

- Average crash rate data compiled by the Federal Motor Carrier Safety Administration;
- Adjustments to crash rates to account for truck type and configuration;
- Adjustments to crash rates to account for reduced vehicle interactions associated with the separation of LCVs and other traffic; and
- Crash cost data updated to 2008 dollars.

To account for the effects of truck type and gross vehicle weight, crash rate adjustment factors from the TRB Special Report 225, Truck Weight Limits: Issues and Options were used. With these adjustments, multiple trailer trucks have crash rates per vehicle mile that are 10 percent higher than those of single trailer

[9] This assumes that congestion savings accrue to all vehicles (not just trucks using the ETL) and so a weighted average for all vehicles ($29.90 in this case) is appropriate. These congestion savings are those experienced by other vehicles on general purpose lanes due to the diversion of truck traffic to LCVs on exclusive toll lanes. The time savings associated with higher operating speeds on the exclusive truck lanes were valued at a higher rate appropriate for only trucks ($39.52 in this case).

trucks, when both are operated under similar conditions. Also, crash rates per vehicle mile increase with gross vehicle weight so that, other things being equal, a 10-percent increase in weight results in a 2.5-percent increase in crash rate. It should be noted, however, that because of the higher payloads carried by LCVs, they have lower crash rates per payload ton-mile than single trailer trucks.

To account for the reduced vehicle interactions associated with the ETLs, an AADT adjustment factor from HERS was used. With this adjustment, crash rates on Interstate highways vary in proportion to AADT 0.155, implying that a 10-percent decrease in volume produces a 1.55-percent decrease in crash rates.

Crash costs were estimated using Unit Costs of Medium and Heavy Truck Crashes, a Pacific Institute report prepared for the Federal Motor Carrier Safety Administration. The report provides estimates of the monetary losses associated with crashes, as well as the nonmonetary losses due to shortened life, pain and suffering, physical impairment, etc. Crash costs from that study, updated to 2008 dollars, are as follows:

- $4,044,000 per fatal crash;
- $221,300 per injury crash; and
- $17,000 per property damage only crash.

Emissions Reductions

Estimates of emissions reductions and associated costs were developed for carbon dioxide, nitrogen oxides, and particulate matter based on fuel consumption. The American Trucking Research Institute (ATRI) report, *Energy and Emissions Impacts of Operating Higher Productivity Vehicles Update 2008*, provides the following estimates of emissions per gallon of fuel consumed:

- Carbon dioxide: 22.2 pounds per gallon of diesel fuel;
- Nitrogen oxides: 23.0 grams per gallon of diesel fuel; and
- Particulate matter: 0.11 grams per gallon of diesel fuel.

Emissions reductions for nitrogen oxides and particulate matter were monetized using information compiled by the FHWA for the HERS model and updated to 2008 dollars. For nitrogen oxides, the damage costs are $4,532 per ton in rural areas and $6,798 per ton in urban areas. For particulate matter, the damage costs are $3,016 in rural areas and $6,033 per ton in urban areas.

Emissions reductions for carbon dioxide was monetized based on Richard S. J. Tol, "The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties." Tol compiled 103 estimates from 38 published studies. The median value from the estimates was $14 per tonne of carbon. Updating to 2008 dollars and converting from metric tonnes of carbon to tons of carbon dioxide produces $4.06 per ton.

5.2 IMPACT ANALYSIS RESULTS

Table 5.1 shows annual benefits of the ETLs for 2010 and 2040. About 70 percent of the benefits accrue from the shift to double-trailer trucks while the remaining 30 percent accrue to triple-trailer configurations.

Table 5.1 Benefits of Exclusive Truck Lanes
Thousands of $2008

	2010		2040	
	High	Low	High	Low
LCV Transport Cost Savings				
Due to larger payloads	$ 80,851	$ 16,170	$ 175,310	$ 34,903
Due to higher speeds on ETL	$ 68	$ 14	$ 2,396	$ 474
Subtotal	$ 80,919	$ 16,184	$ 177,706	$ 35,377
Cost Savings to Other Vehicles				
Due to Less Congestion	$ 2,090	$ 426	$ 83,383	$ 17,093
Safety Benefits	$ 2,811	$ 584	$ 6,233	$ 1,312
Pavement Cost Savings on				
Other Roads	$ 3,131	$ 637	$ 6,852	$ 1,397
Environmental Benefits				
Reduction in CO2 emissions	$ 198	$ 42	$ 551	$ 117
Reduction in NOX emissions	$ 630	$ 132	$ 1,756	$ 372
Reduction in PM emissions	$ 2	$ 1	$ 7	$ 1
Subtotal	$ 830	$ 175	$ 2,314	$ 490
Total Benefits	$ 89,781	$ 18,006	$ 276,488	$ 55,669

An average trip length of 500 miles for LCVs was assumed in developing the estimates of annual benefits shown in Table 5.1. The trip length includes travel on the exclusive truck lanes and other turnpikes (Massachusetts, New York, Ohio, and Indiana) on which LCVs are allowed.

The largest benefit category is transport cost savings, which result from larger payloads. The estimates of transport cost savings take into account 1) the reduction in vehicle miles required to carry a given amount of freight due to the larger payloads per trip for LCVs; 2) the higher per vehicle mile operating costs of LCVs; and 3) the cost associated with assembling and disassembling LCVs in staging areas.

Transport cost savings due to higher speeds on the exclusive truck lanes are modest in 2010 since most trucks operate at close to free-flow speeds in the general purpose lanes parallel to the exclusive truck lanes. By 2040, however, there will be significant congestion in the general purpose lanes leading to great time savings for vehicles using the uncongested exclusive truck lanes.

Because of the higher congestion levels predicted for 2040, the diversion of truck traffic from the general purpose lanes to the exclusive truck lanes, together with the reduction in total truck miles due to the higher payloads of LCVs will provide considerable time savings to other vehicles. However, construction of the exclusive truck lanes will make it much more difficult to widen the I-90 general purpose lanes in the future. To the extent that construction of the ETL precludes future widening of the general purpose lanes, it has a huge opportunity cost for effective congestion management in the future because most of the traffic (85 percent) will not be eligible for the ETL facility.

Estimates of pavement cost savings on other roads take into account: 1) the net reduction in truck traffic on other roads; and 2) differences between the pavement wear effects of LCVs and single-trailer trucks. The pavement cost analysis included all savings on all general purpose lanes, including those in the corridor itself. Though LCVs have higher gross weights than the vehicles they replace, the weight is spread over more axles so that pavement wear per ton-mile of freight carried is generally less for LCVs.

Estimates of safety benefits take into account: 1) the reduction in truck miles on the highways due to the higher payloads of LCVs relative to single-trailer trucks; 2) the increase in truck miles associated with diversion from rail to truck; and 3) the slightly higher crash rates per mile of LCVs. The first of these three effects is dominant, so that the exclusive truck lanes provide net safety benefits.

Estimates of air quality impacts are of smaller magnitude, but take into account the ability of LCVs to handle higher payloads with fewer vehicles. Any negative air quality impact of shifting freight from rail, which can generate lower emissions on a ton-mile basis, is compensated by higher positive gains from consolidating single-trailer trucks to LCVs.

Appendix A of this report provides additional insight on the impact findings using several sensitivity tests for distance, mix of doubles versus triples, empty backhauls, and fuel costs.

5.3 COST-EFFECTIVENESS

A critical measure of project success is the projected return on investment. Cost-effectiveness assesses the cost of a project with respect to corridor usage and related transportation system benefits. Cost-effectiveness is quantified as cumulative benefits and cumulative costs for the corridor through 2040. The only direct revenue source is tolls, but other offsetting benefits – including productivity, delay, safety, and air quality benefits – may help shape the debate over the public role in exclusive truck lane development.

Capital Cost

The capital cost estimate for the corridor is **$5.679 billion**. The annual average capital cost in 2008 dollars over a 30-year period (2010 to 2040) is $189.3 million per year. With financing at a market rate of 5 percent interest, the annual average cost would be $365.8 million per year over 30-years.

Toll Revenue and Maintenance and Operations Cost

All diversion and tolling scenarios result in cumulative (2010 to 2040) revenues that are less than cumulative operations and maintenance costs during the same period (Table 5.2). The medium toll, high diversion scenario shows the highest cumulative revenues at $914.36 million. This cumulative revenue is $489 million or 35 percent short of breaking even with cumulative operations and maintenance costs.

Table 5.2 I-90/I-271 Exclusive Truck Lane Net Revenues
Millions of 2008 Dollars

Scenarios		2010-2040		
Toll	Volumes	Revenue (Millions)	O&M (Millions)	Difference (Millions)
High	High	$497.98	($1,403.66)	($905.68)
High	Low	$116.29	($1,403.66)	($1,287.38)
Medium	High	$914.36	($1,403.66)	($489.30)
Medium	Low	$195.93	($1,403.66)	($1,207.73)
Low	High	$687.86	($1,403.66)	($715.80)
Low	Low	$135.26	($1,430.66)	($1,268.40)

Rate of Return

Combining annualized capital cost, maintenance and operations cost, and revenue through 2040 results in estimates of annual rate of return. In all tolling and diversion scenarios, the annual corridor toll revenue is less than annual operations and maintenance costs.

When including annualized costs to pay back $5.679 billion in capital costs, the annual rate of return remains negative. In 2015, it is $(381.3) million; in 2040 it has only marginally improved to $(380.6) million. This assumes that operating costs are increasing at an average rate of three percent annually while per mile toll rates remain constant. Excluding maintenance and operating costs, the total revenue of $914.4 million in the medium toll/high volume scenario would only pay back 8.3 percent of the total 30-year debt service on the project.

Other Factors

The greatest offsetting factor for the low revenue-to-cost assessment is the potential for long-term public and private benefits. This report monetized the benefits for 2010 and 2040 under high and low scenario estimates. The total benefits for the high diversion scenario (10-percent diversion) over the 25-year analysis period are $5.164 billion, while the low scenario (2-percent diversion) generates $1.036 billion; both expressed in 2008 dollars. Table 5.3 presents the costs, revenues, and benefits of the proposed ETL facility over the 30-year financing period of the project.

Table 5.3 Rate of Return Summary Table

Category	Cumulative (2010 to 2040) (Million $2008)		LCV Utilization High	LCV Utilization Low
Costs	Capital Costs	$5,678.9		
	Capital Financing Costs	$5,295.9		
	Total Capital Costs	$10,974.8		
	Operating and Maintenance Costs	$1,403.7		
	Total Costs	**$12,378.5**		
Offsets	Total Benefits		$5,163.5	$1,035.5
	Total Revenue*		$913.9	$195.9
	Total Offsets		**$6,077.4**	**$1,231.4**
Rate of Return			($6,301.1)	($11,147.1)
			49%	10%

* Revenues reflect the Medium Toll ($0.60 per mile) because that scenario produced the highest revenues under both high and low LCV utilization categories.

Potential Return from Universal Truck Toll Scenario

While this study focused on the potential for LCVs, the other opportunity to increase the revenue stream depends on the utilization of STTs on the ETL facility. The "Universal" scenario in Section 4.0 provides an illustrative example of revenue potential *if* all combination units utilized the ETL. Under that scenario, STTs could push the rate of return closer to a 1:1 ratio. Specifically, the high toll estimate ($0.50 per mile) under the "Universal" scenario would push revenues to a range of $9.8 billion to $10.7 billion over the 30-year study period. The high toll estimate combined with the high LCV diversion estimate might yield the most favorable return from a public policy standpoint by balancing high toll revenue with from STT diversion *and* high utilization of LCVs on the facility. This combination could reduce overall VMT by preserving a 10-percent share of LCVs, which in turn would produce logistics, safety, highway maintenance, and environmental benefits.

5.4 CONCLUSION

Examination of a hypothetical LCV exclusive truck lane facility on a high-volume interstate truck corridor shows that costs exceed expected revenues and benefits by a margin of at least 2 to 1. While the joint deployment of LCVs and exclusive truck lane facilities holds theoretical promise as a means of increasing freight productivity, the test application to this corridor demonstrates that exclusive truck lanes may not provide a full return on investment – even accounting for significant positive benefits. Despite these findings, this study should not persuade the U.S. DOT and states to abandon the exclusive truck lanes concept as it may have better fit a different corridor or with a different mix of traffic or operating assumptions. For example, ETLs might provide a better rate of return on higher-density urban corridors that connect major port facilities with inland distribution clusters. Finally, with significant diversion of single-trailer trucks to the new facility, the prospects of financial return are heightened.

Appendix A. Alternative Estimation of Candidate Trucks Diverted to LCVs

Three factors support estimates of the candidate trucks for diversion: 1) truck weight; 2) commodity data; and 3) shipment origin-destination data from the FAF2. The U.S. DOT's Comprehensive Truck Size and Weight Study identified commodities and trip distances most likely to support LCV use. The study recognizes that short-haul (under 200 miles) five-axle single-trailer truck operations tend to be affected by increases in truck weight more than truck size because they handle high-density materials, and thus are less likely to divert to LCVs.[10] The remainder of five-axle tractor semi trailers operations are long-haul (more than 200 miles), and tend to be impacted by increases in truck size more than truck weight, as packaged finished goods are low density. In addition, if a shipment is destined for more than 200 miles, the costs of delaying to obtain a full load and costs of coupling and decoupling the LCV are overcome. While there are exceptions for some shippers and commodities, shipments less than 200 miles generally will not utilize LCVs.

I-90/I-271 Candidate Truck Approach

A 'select link' analysis method was utilized with an FAF2 network assignment to select the candidate vehicles based on trip length, commodity type, and vehicle weight. The select link locations included the following:

- I-90 east of I-79 in Pennsylvania; and
- I-271 south of the I-90 interchange in Ohio.

With the data obtained in the select link queries, the three filters were applied (distance, commodity, and weight) to identify the candidate truck trips for diversion:

1. **Distance Filter.** Trip lengths of 200 miles or more are a source of potentially divertible trucks as per-mile shipping costs typically decrease with trip distance, making LCV operations more attractive to longer-haul shipments.
2. **Commodity Filter.** Low-density commodities, including plastics, metals, machinery, transportation, equipment, and miscellaneous commodities. These represent aggregated groups from FAF2 commodity data.

[10] U.S. DOT Comprehensive Truck Size and Weight Study, Volume 3, August 2000.

Applying these two filters to the select links, the following candidate truck trips were captured (for all the trip length is greater than 200 miles):

a. 46.5 percent of combination trucks on I-90 in Pennsylvania carry low density commodities in 2002;

b. 55.6 percent of combination trucks on I-90 in Pennsylvania carry low density commodities in 2040;

c. 45.6 percent of combination trucks on I-90/I-271 in Ohio carry low density commodities in 2002; and

d. 52.8 percent of combination trucks on I-90/I-271 in Ohio carry low-density commodities in 2040.

3. **Weight Filter (using maximum gross vehicle weight (MGVW)).** The third filter isolates the share of combination trucks traveling at an MGVW range that would benefit from an increase in truck size and weight limits. This data is from the FHWA VTRIS W5 reports on I-80/Pennsylvania Turnpike near State College, Pennsylvania. The W5 report shows the number of trucks weighed in various gross weight ranges, total average vehicles weighed, and total average vehicles counted.

   The I-80 truck size and weight VTRIS data in Pennsylvania is used as a surrogate value for I-90 given the proximity, potential for similar trip characteristics and some overlaps in origin-destination pairs. There is no readily available truck size and weight data for the I-90 corridor in Ohio, Pennsylvania, or New York. Using this data, 43.5 percent of trucks are at or above 80 percent of the maximum gross vehicle weight (80,000 pounds for 5+ axle trailer combinations).

   The result is 20.2 percent of thru truck trips on I-90 in Pennsylvania and 19.9 percent of all truck trips on I-90 and I-271 in Ohio meeting the three filters.

I-90 Pennsylvania Origin/Destination Candidate Truck Adjustment

FAF2 zonal geography makes precise truck origins and destinations in the I-90 corridor in Pennsylvania difficult to ascertain (i.e., the FAF2 zone encompasses all of the State outside of Pittsburgh and Philadelphia). To overcome this challenge, the share of combination truck trips originating or terminating in the Erie portion of the FAF2 Zone is estimated using Pennsylvania DOT classification counts and ramp counts. The result of this analysis shows that **39 percent** of class 5+ trucks on I-90 in Pennsylvania have a trip end in the Erie region. To identify the candidate trucks from the total I-90 trucks with Pennsylvania trip ends, the following filters were applied:

- **Distance Filter.** Excludes all trucks to/from adjacent FAF geographies (Pennsylvania Remaining, Pittsburgh, Cleveland, and Buffalo; all of which have a trip distance of 200 miles or less).

- **Commodity Filter.** Excludes high-density commodities (Stone, Mineral, petroleum products, chemicals).
- **Weight Filter.** Same method described above.

The result is **8.6 percent** of the Pennsylvania origin/destination truck trips on I-90 meeting the three filters.

Candidate LCV Summary

The estimated corridor ADTT is multiplied by the percentage filters to obtain total candidate trucks for LCV diversion by corridor segment. Table A.1 shows the candidate STTs for diversion. The share of candidate trucks is slightly lower in Pennsylvania as a result of the adjustment to account for truck trips with a Pennsylvania origin or destination (i.e., 16.7 percent in Pennsylvania compared to 19.8 percent in Ohio in 2010).

Table A.1 Candidate Truck Trips for LCV Diversion

			Candidate STTs	
			Commodity, Distance, and 80% MGVW	
	ADTT (2010)	ADTT (2035)	2010	2035
I-90 at NY State Line	5,258	11,123	880	2,168
I-90 W. of I-86	5,238	11,081	876	2,159
I-90 Between U.S. 19 and I-79	5,388	11,399	901	2,221
I-90 at OH State line	6,551	13,858	1,096	2,701
I-90 at SR 11	7,584	16,045	1,269	3,127
I-90 at I-271	9,679	20,476	1,921	4,700
I-271 N. of U.S. 422	11,219	23,734	2,227	5,448
I-271 S. of I-480	7,375	15,601	1,464	3,581
I-271 Near I-80	5,416	11,457	1,075	2,630

Rail-to-LCV Diversion Details

The main body of this report summarizes the estimation technique and results for potential rail-to-LCV diversion to the new ETL facility. This appendix section supplements the Section 4.3 of the report with additional detail on the rail diversion approach.

Corridor Rail Tonnage Estimates

There are two sources for corridor rail tonnage. The first data source evaluated was the FAF2 database for selected origin/destination pairs that presumably use the I-90 corridor in Pennsylvania and Ohio (for example, New England states to the Midwest/North Central/Great Lakes region). These rail O/D pairs were identified in part from the origin and destination pairs from the highway select link analysis. From the evaluation of those FAF2 O/D pairs, the estimates are as follows: for 2010, 10.97 million tons annually with an estimated rail tonnage mode share of 18.4 percent in the corridor study area.

The other source of data for rail tonnage in the corridor is from the Erie County 2030 Transportation Plan, approved by the Erie Metropolitan Planning Organization (MPO) in July 2007.[11] The plan's existing conditions report presents data regarding the two Class I freight railroads in Erie County: CSX and NS. The CSX and NS rail lines run parallel to each other along Lake Erie, north of I-90. CSX's Chicago line and Lakeshore subdivision meet at Erie; and this portion of the line carries 113 million gross tons annually, generating approximately 70 trains per day over the Erie line. The NS' line carries 27 million gross tons annually, and generates approximately 25 trains per day through Erie.

The CSX and NS data are 10 times greater than the FAF analysis indicates. Due to the macro level of analysis generated with FAF data and uncertainties in origin-destination pairs that use the corridor, this study used the Erie MPO data to set a baseline rail tonnage estimate. To develop the growth to 2040, the FAF2 data for the corridor was used to increase in corridor rail tonnage between 2010 and 2040. This growth percentage is applied to the baseline data to obtain an estimate of 2040 rail tonnage.

The rail diversion results for both the high and low diversion estimates assume that the baseline rail tonnage data at Erie is 93 percent through-trips (i.e., low trip origin or destination activity between Cleveland and the New York State Line). This assumption is based on the following information about local (study area) rail trip ends.

1. The major rail shipment origins in the corridor between Buffalo and Cleveland are the Port of Erie (Pennsylvania), Port of Conneaut (Ohio), and Port of Ashtabula (Ohio). In total, according to data from the Waterborne Commerce Statistics Center for 2006, these three ports handle 15.3 million short tons of freight annually.[12]

2. According to the Erie County 2030 Transportation Plan, in 2006 O-N Minerals, the current operator of the Mountfort Terminal at the Port of Erie imported approximately 1,200,000 tons of aggregates, sand, salt, shingles,

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[11] Erie County 2030 Transportation Plan, Erie Metropolitan Planning Organization, July 2007, http://www.eriecountyplanning.org/index.php?page=long-range-transportation-plan.

[12] 2006 Waterborne Commerce of the United States, U.S. Army Corp of Engineers, http://www.iwr.usace.army.mil/ndc/wcsc/pdf/wcusgl06.pdf.

steel beams, and heavy lift items through the Port. Of these products, 1,130,000 tons (94 percent) were distributed by truck and the balance (6 percent) by rail.

3. The Ashtabula and Conneaut Ports primarily handle coal (58 percent of total traffic). According to FAF2 data, coal is shipped by rail two times as often as by truck. Using this relationship for these Ports results in an estimate of 5.42 million tons of coal distributed by rail.

4. Based on the above data, 67 percent of coal and 6 percent of all other commodities transferred at the Ohio and Pennsylvania Lake Erie Ports use rail. This results in an estimate of 5.9 million tons, or about 7 percent of total rail tonnage through the corridor with a trip origin or destination at these three ports.

5. Gross tons from the Erie MPO are converted to net annual 87.5 million tons.

National FAF2 data for rail indicates 9.5 percent of all rail tonnage is low-density commodities (same commodities as defined for trucks). For this analysis, it is assumed that these are the candidate rail shipments for diversion to LCV.

High Rail Diversion Estimate

The high rail diversion estimate is based exclusively on cost savings resulting from expanded eligibility for LCV operations and new ETL tolls in the project corridor. The high diversion effect is estimated by identifying the change in per-mile truck operating costs and by applying a cross elasticity.

To develop changes in per-mile truck costs in order to estimate the magnitude of the rail-to-truck diversion, three primary assumptions are utilized:

1. LCV (127,000 pound) cost per mile = $3.90;
2. STT (80,000 pound) cost per mile = $3.13; and
3. A 1.60 payload factor.

The cost per-mile estimates exclude costs associated with tolls, assembly, and empty return.

This savings per loaded truck mile of operating a LCV versus an STT is calculated by multiplying the STT cost per mile ($3.13) by the 1.60 payload factor, and subtracting the average LCV cost per mile. The result is:

- Total cost savings per mile of approximately $1.13 per loaded truck mile for the LCV at 127,000 pounds vs. 80,000 Five Axle STT; and
- Which represents a savings of about 22 percent ($5.02 per mile to carry LCV freight in STTs).

All costs are from Working Paper 7 of the U.S. DOT Comprehensive Truck Size and Weight Study, updated to 2008 costs (CPI Factor from 1988 to 2008 = 1.83, Diesel Factor = 7.07).

Three ranges of per mile tolls are tested for the exclusive toll lanes. The maximum per mile toll is $1.20, which would have completely offset the cost benefits of converting from a STT to a LCV. The low-end range of tolls is $0.30 per mile, which is commensurate with current New York State Thruway and Ohio Turnpike tolls per mile for LCVs. The results of the toll on per-mile LCV operating costs are:

- $1.00 per mile toll – $0.13 savings per mile
  (2.6 percent reduction from STT cost per mile);
- $0.60 per mile toll – $0.53 savings per mile
  (10.6 percent reduction from STT cost per mile; and
- $0.30 per mile toll – $0.83 savings per mile
  (16.5 percent reduction from STT cost per mile).

Rail Ton-Mile Cross Elasticity = 0.52[13]

This elasticity was applied to the three LCV trip cost saving scenarios identified above. To convert from rail tons to the number of LCVs, the empty weight of a nine-axle LCV is 50,000 pounds, thus the average load is (127,000 – 50,000) = 77,000 pounds per LCV.

Table A.2 High Rail Diversion Estimates
Daily LCV Equivalents Diverted from Rail

Scenario	STT-LCV Cost Savings	2010 LCVs	2040 LCVs
$1.00 per mile	2.6%	9	18
$ 0.60 per mile	10.6%	36	73
$ 0.30 per mile	16.5%	56	115

Low Rail Diversion Estimate

This estimate takes into account cost difference of operating a STT versus a LCV in the corridor. The corridor evaluated is I-90 from its interchange with I-95 just west of Boston to the Illinois State Line. The STT corridor trip assumes current per-mile toll rates and operating costs. These costs are compared to LCV toll rates, including the proposed ETL in the corridor, plus LCV operating costs and current costs (2008 dollars) for assembling and disassembling twins (projected based on 1988 costs from Working Paper 7 of the U.S. DOT Comprehensive Truck Size and Weight Study).

[13] *A Guidebook for Forecasting Freight Travel Demand*, NCHRP Report 388, Exhibit G.2, TRB 1997.

Change in Corridor Total Costs

Total 2010 STT trip cost estimate (ETL no-build):

Route assumes STTs bypass Cleveland via I-480.

Toll Costs:

1. Massachusetts Turnpike Toll (Class 9, five-axle) = $29.50 (120.4 miles);
2. New York Thruway Toll (Class 5H) = $68.98 (387.4 miles);
3. Ohio Turnpike Toll (Class 8) = $21.00 (149.1 miles); and
4. Indiana Toll Road (five-axle) = $27.25 (157 miles).

Total Trip Toll Cost Estimate = $146.73.

Total STT Operations Cost = $4,793.60 (955 miles at $5.02 per mile).

Total 2010 LCV trip cost estimate (ETL build):

Total cost to an LCV with the proposed ETL system in place informs an estimate of total corridor trip cost savings. The cost difference includes LCV operation savings of $1.13 per mile compared to STTs. There are also increases in tolls on the existing toll facilities in the corridor for LCV operations versus STT operations. In addition, the cost of one assembly and one disassembly is assumed.

Toll and Assembly/Disassembly Costs:

1. Assembly (Massachusetts Turnpike Exit 14 – I-95 at I-90 interchange) = $27.49;
2. Massachusetts Turnpike Toll (nine-axle tandem assumed) = $29.50 (120.4 miles);
3. New York Thruway Toll (Class 7H assumed) = $118.42 (387.4 miles);
4. Proposed I-90 ETL = $127.70 ($1.00/mile) – $38.31 ($0.30 per mile) (127.7 miles);
5. Ohio Turnpike Toll (Class 11 assumed) = $70.25 (170.5 miles);
6. Indiana Toll Road (less than seven axles assumed) = $59.60 (157 miles); and
7. Disassembly at Illinois line = $27.49.

Total Trip Toll/Assembly Cost Estimate = $460.75 – $371.06.

Total LCV Operations Cost = $3,764.28 (965 miles at $3.90 per mile).

Table A.3 Corridor Trip Cost Estimates
2008 Dollars

Scenario	Tolls	Assembly/ Disassembly	Operating Cost	Total
TST – No Build	$146.73	$ –	$4,793.60	**$4,940.33**
LCV ($1.00 ETL Rate)	$405.77	$54.98	$3,764.28	**$4,225.03**
LCV ($0.60 ETL Rate)	$354.39	$54.98	$3,764.28	**$4,173.65**
LCV ($0.30 ETL Rate)	$316.08	$54.98	$3,764.28	**$4,135.34**

*TST represents tractor semi-trailer combination unit.

The reduction in total costs ranges from 14.5 percent with a $1.00 per mile ETL toll to 16.3 percent with a $0.30 per mile ETL toll. The cost savings for trips between ports in Boston or New York/New Jersey to Chicago and the Midwest were made significantly lower by providing LCV access between the New York Thruway and Ohio Turnpike near Cleveland. Rail tonnage that would divert to LCV operations as a result of this cost savings are estimated below based on a rail ton-mile cross elasticity.

Because the above evaluation only applies to long-distance corridor trips (i.e., Boston to Chicago) to estimate rail diversion, the focus will be on rail shipments of a similar length. Through the analysis of FAF2 data for the corridor, in 2010 it is estimated that 25 percent of all rail tons in the corridor have trip ends in New York and the remainder of New England or Illinois and other Midwestern states.

Rail Ton-Mile Cross Elasticity = 0.35[14]

This lower cross elasticity, as compared to the high rail diversion elasticity, was applied to the three LCV trip cost scenarios in Table A.4. To convert from rail tons to the number of LCVs, the empty weight of a nine-axle LCV is 50,000 pounds, thus the average load is (127,000 – 50,000) = 77,000 pounds per LCV.

Table A.4 Low Rail Diversion Estimates
Daily LCV Equivalents Diverted from Rail

Scenario	TST-LCV Cost Savings	2010 LCVs	2040 LCVs
$1.00/mi	5.1%	8	17
$0.60/mi	5.4%	9	18
$0.30/mi	5.7%	9	19

[14] *A Guidebook for Forecasting Freight Travel Demand*, NCHRP Report 388, Exhibit G.3, TRB 1997.

Additional Considerations

This study provides a sketch planning level of analysis to estimate order-of-magnitude costs, impacts, and benefits. A detailed engineering study would be required to develop more detailed assumptions to guide final determination of costs, impacts, and benefits. During the course of this investigation, the study team identified several issues worthy of additional consideration in future study of ETL feasibility on this or other corridors.

- **I-271 Characteristics.** This study does not take into account the recent investments of the Ohio DOT on the southern end of I-271 (near the junction with I-80), including:
  - The I-271 Cuyahoga River Bridge, which is currently being rebuilt with completion planned in 2009; and
  - Parallel added capacity to SR 8 from I-80 to I-271 is underway through an Ohio DOT project to relieve traffic demands in this corridor segment.

  Finally, I-271 in this area bisects portions of Cuyahoga River National Park. Any major addition to I-271 could generate community opposition to widening as well as NEPA issues.

- **STTs.** This study focuses on LCV utilization of the proposed ETL. The study does not estimate the share of STTs that would divert to the new ETL facility because of the assumed low likelihood of diversion. Because the corridor has low level of delay and congestion, the number of STTs that would divert would be limited, but could increase over time if congestion worsened. If all trucks were required to use the new ETLs, this could force trucks to divert to routes that might not be as safe for trucks to operate. Recent experience by the Ohio Turnpike Authority shows that lowering tolls and increasing speeds can increase STT utilization of toll facilities.

Impact Analyses Sensitivity Tests

Supplementing the Section 5.0 discussion of Impact Analysis Results, the following tables and text summarize findings of several sensitivity analyses conducted to show a range of outcomes to the impact measures.

Average Trip Distance

Tables A.5 and A.6 show sensitivity analyses in which estimates of benefits are developed using average trip lengths of 300 and 700 miles, respectively. Comparison of Tables A.5 and A.6 indicates that total benefits vary roughly in proportion to the assumed average trip length.

Mix of LCV Configurations: Doubles versus Triples

Based on observations of utilization on the Indiana and Ohio Turnpikes, triples were assumed to account for 30 percent of LCV VMT in developing the estimates of annual benefits shown in Table 5.1 and all other tables, except Tables A.4 and A.5. The remaining 70 percent of LCVs were assumed to be turnpike doubles with nine axles. Tables A.7 and A.8 show sensitivity analyses in which estimates of benefits are developed assuming 10 percent and 50 percent triples, respectively. Comparison of Tables 5.1, A.7, and A.8 indicates that total benefits do not vary greatly with changes in the assumed percent triples; and that the shift from single-trailer trucks to LCVs (regardless of the mix of doubles versus triples) is a more important factor in generating benefits.

Empty Backhaul

Empty backhaul travel was assumed to account for 20 percent of LCV VMT in developing the estimates of annual benefits shown in Table 5.1. Tables A.9 and A.10 show sensitivity analyses in which estimates of benefits are developed assuming 10 percent and 30 percent empty backhaul, respectively. Comparison of Tables 5.1, A.9, and A.10 indicate that total benefits do not vary greatly with changes in the assumed percent empty backhaul.

Fuel Costs

Average fuel prices for 2008 were used in the analysis. Tables A.11 and A.12 show sensitivity analyses in which 30 percent higher and 30 percent lower fuel prices are assumed. Changes in fuel prices affect transport cost savings and congestion cost savings.

Table A.5 Sensitivity Test: 300 Miles Average Trip Distance

LCV Volumes on Exclusive Truck Lanes (vehicles per day)

	2010		2040	
Diverted to LCVs from	High	Low	High	Low
Single trailer trucks (STT)	443	89	963	193
Rail	29	5	58	9
Total	472	94	1021	202

Average Trip Length for LCVs Using ETL (miles) 300

Benefits of Exclusive Truck Lanes
(in thousands of 2008 $ per year)

	2010		2040	
	High	Low	High	Low
LCV Transport Cost Savings				
Due to larger payloads	44,838	8,968	97,222	19,356
Due to higher speeds on ETL	68	14	2,396	474
Subtotal	44,906	8,981	99,618	19,830
Cost Savings to Other Vehicles				
Due to Less Congestion	1,771	359	70,396	14,285
Safety Benefits	1,806	375	4,001	839
Pavement Cost Savings on				
Other Roads	2,475	501	5,403	1,094
Environmental Benefits				
Reduction in CO2 emissions	119	25	359	76
Reduction in NOX emissions	381	80	1,144	241
Reduction in PM emissions	1	0	4	1
Subtotal	501	105	1,508	318
Total Benefits	51,460	10,321	180,925	36,366

Table A.6 Sensitivity Test: 700 Miles Average Trip Distance

LCV Volumes on Exclusive Truck Lanes (vehicles per day)

	2010		2040	
Diverted to LCVs from	High	Low	High	Low
Single trailer trucks (STT)	443	89	963	193
Rail	29	5	58	9
Total	472	94	1021	202

Average Trip Length for LCVs Using ETL (miles) 700

Benefits of Exclusive Truck Lanes
(in thousands of 2008 $ per year)

	2010		2040	
	High	Low	High	Low
LCV Transport Cost Savings				
Due to larger payloads	116,864	23,373	253,398	50,450
Due to higher speeds on ETL	68	14	2,396	474
Subtotal	116,932	23,386	255,793	50,924
Cost Savings to Other Vehicles				
Due to Less Congestion	2,408	494	96,371	19,901
Safety Benefits	3,815	794	8,466	1,785
Pavement Cost Savings on				
Other Roads	3,786	772	8,301	1,701
Environmental Benefits				
Reduction in CO2 emissions	276	58	742	158
Reduction in NOX emissions	880	185	2,368	503
Reduction in PM emissions	3	1	9	2
Subtotal	1,160	244	3,120	663
Total Benefits	128,102	25,691	372,051	74,973

Table A.7 Sensitivity Test: 10 Percent Triples Share of LCVs on ETL

LCV Volumes on Exclusive Truck Lanes (vehicles per day)

	2010		2040	
Diverted to LCVs from	High	Low	High	Low
Single trailer trucks (STT)	443	89	963	193
Rail	29	5	58	9
Total	472	94	1021	202

Average Trip Length for LCVs Using ETL (miles) 500

Benefits of Exclusive Truck Lanes
(in thousands of 2008 $ per year)

	2010		2040	
	High	Low	High	Low
LCV Transport Cost Savings				
Due to larger payloads	80,611	16,122	174,789	34,799
Due to higher speeds on ETL	68	14	2,396	474
Subtotal	80,679	16,136	177,184	35,273
Cost Savings to Other Vehicles				
Due to Less Congestion	2,097	428	83,678	17,159
Safety Benefits	2,813	585	6,239	1,314
Pavement Cost Savings on Other Roads	3,956	803	8,649	1,759
Environmental Benefits				
Reduction in CO2 emissions	194	41	544	115
Reduction in NOX emissions	619	130	1,734	368
Reduction in PM emissions	2	0	7	1
Subtotal	816	172	2,284	485
Total Benefits	90,360	18,123	278,034	55,990

Table A.8 Sensitivity Test: 50 Percent Triples Share of LCVs on ETL

LCV Volumes on Exclusive Truck Lanes (vehicles per day)

	2010		2040	
Diverted to LCVs from	High	Low	High	Low
Single trailer trucks (STT)	443	89	963	193
Rail	29	5	58	9
Total	472	94	1021	202

Average Trip Length for LCVs Using ETL (miles) 500

Benefits of Exclusive Truck Lanes
(in thousands of 2008 $ per year)

	2010		2040	
	High	Low	High	Low
LCV Transport Cost Savings				
Due to larger payloads	81,092	16,218	175,831	35,007
Due to higher speeds on ETL	68	14	2,396	474
Subtotal	81,160	16,232	178,227	35,481
Cost Savings to Other Vehicles				
Due to Less Congestion	2,083	425	83,089	17,026
Safety Benefits	2,809	584	6,228	1,310
Pavement Cost Savings on Other Roads	2,305	470	5,055	1,036
Environmental Benefits				
Reduction in CO2 emissions	201	42	558	118
Reduction in NOX emissions	642	135	1,779	376
Reduction in PM emissions	2	1	7	1
Subtotal	845	177	2,343	496
Total Benefits	89,202	17,888	274,942	55,349

Table A.9 Sensitivity Test: 10 Percent Empty Backhaul

LCV Volumes on Exclusive Truck Lanes (vehicles per day)

	2010		2040	
Diverted to LCVs from	High	Low	High	Low
Single trailer trucks (STT)	443	89	963	193
Rail	29	5	58	9
Total	472	94	1021	202

Average Trip Length for LCVs Using ETL (miles) 500

Benefits of Exclusive Truck Lanes
(in thousands of 2008 $ per year)

	2010		2040	
	High	Low	High	Low
LCV Transport Cost Savings				
Due to larger payloads	80,950	16,190	175,524	34,946
Due to higher speeds on ETL	68	14	2,396	474
Subtotal	81,018	16,204	177,920	35,419
Cost Savings to Other Vehicles				
Due to Less Congestion	2,120	433	84,610	17,351
Safety Benefits	2,856	594	6,333	1,333
Pavement Cost Savings on Other Roads	3,507	713	7,675	1,565
Environmental Benefits				
Reduction in CO2 emissions	196	41	548	116
Reduction in NOX emissions	624	131	1,748	371
Reduction in PM emissions	2	1	7	1
Subtotal	822	173	2,303	489
Total Benefits	90,322	18,116	278,840	56,157

Table A.10 Sensitivity Test: 30 Percent Empty Backhaul

LCV Volumes on Exclusive Truck Lanes (vehicles per day)

	2010		2040	
Diverted to LCVs from	High	Low	High	Low
Single trailer trucks (STT)	443	89	963	193
Rail	29	5	58	9
Total	472	94	1021	202

Average Trip Length for LCVs Using ETL (miles) 500

Benefits of Exclusive Truck Lanes
(in thousands of 2008 $ per year)

	2010		2040	
	High	Low	High	Low
LCV Transport Cost Savings				
Due to larger payloads	80,752	16,150	175,096	34,860
Due to higher speeds on ETL	68	14	2,396	474
Subtotal	80,821	16,164	177,492	35,334
Cost Savings to Other Vehicles				
Due to Less Congestion	2,059	420	82,157	16,835
Safety Benefits	2,766	575	6,133	1,291
Pavement Cost Savings on Other Roads	2,755	560	6,029	1,230
Environmental Benefits				
Reduction in CO2 emissions	200	42	553	117
Reduction in NOX emissions	637	134	1,765	373
Reduction in PM emissions	2	1	7	1
Subtotal	839	176	2,325	492
Total Benefits	89,240	17,895	274,136	55,181

Table A.11 Sensitivity Test: 30 Percent Higher Price for Fuel

LCV Volumes on Exclusive Truck Lanes (vehicles per day)

	2010		2040	
Diverted to LCVs from	High	Low	High	Low
Single trailer trucks (STT)	443	89	963	193
Rail	29	5	58	9
Total	472	94	1021	202

Average Trip Length for LCVs Using ETL (miles) 500

Benefits of Exclusive Truck Lanes
(in thousands of 2008 $ per year)

	2010		2040	
	High	Low	High	Low
LCV Transport Cost Savings				
Due to larger payloads	86,799	17,360	188,208	37,471
Due to higher speeds on ETL	68	14	2,396	474
Subtotal	86,868	17,373	190,603	37,945
Cost Savings to Other Vehicles				
Due to Less Congestion	2,136	436	85,239	17,473
Safety Benefits	2,811	584	6,233	1,312
Pavement Cost Savings on Other Roads	3,131	637	6,852	1,397
Environmental Benefits				
Reduction in CO_2 emissions	198	42	551	117
Reduction in NOX emissions	630	132	1,756	372
Reduction in PM emissions	2	1	7	1
Subtotal	830	175	2,314	490
Total Benefits	95,776	19,205	291,242	58,618

Table A.12 Sensitivity Test: 30 Percent Lower Price for Fuel

LCV Volumes on Exclusive Truck Lanes (vehicles per day)

	2010		2040	
Diverted to LCVs from	High	Low	High	Low
Single trailer trucks (STT)	443	89	963	193
Rail	29	5	58	9
Total	472	94	1021	202

Average Trip Length for LCVs Using ETL (miles) 500

Benefits of Exclusive Truck Lanes
(in thousands of 2008 $ per year)

	2010		2040	
	High	Low	High	Low
LCV Transport Cost Savings				
Due to larger payloads	74,903	14,981	162,412	32,335
Due to higher speeds on ETL	68	14	2,396	474
Subtotal	74,971	14,994	164,808	32,809
Cost Savings to Other Vehicles				
Due to Less Congestion	2,043	417	81,527	16,712
Safety Benefits	2,811	584	6,233	1,312
Pavement Cost Savings on Other Roads	3,131	637	6,852	1,397
Environmental Benefits				
Reduction in CO_2 emissions	198	42	551	117
Reduction in NOX emissions	630	132	1,756	372
Reduction in PM emissions	2	1	7	1
Subtotal	830	175	2,314	490
Total Benefits	83,786	16,807	261,734	52,721

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