Federal Highway Administration
Office of Freight Management and Operations

Freight Benefit/Cost Study: Phase III - Analysis of Regional Benefits of Highway-Freight Improvements

Final Report

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EXECUTIVE SUMMARY

The Freight Benefit/Cost Study is a multi-year effort originating in the Federal Highway Administration, Office of Freight Management and Operations, supported by HLB Decision Economics (Subsequently HDR|HLB Decision Economics) and ICF International[1]. The Freight Benefit/Cost Study project has gone through three phases of development. Phase I focused on developing the theory and logic. Phase II determined the sensitivity of a firm to infrastructural investment on a national level. This phase, (Phase III) establishes the approach, sensitivities and data inputs required to calculate long-term benefits of highway-freight infrastructural investment on a regional level and will investigate the construction of a tool for state and local entities to estimate additional benefits derived though logistics rearrangements from highway performance improvements.

This Phase III report assesses impacts of improvements beyond traditional travel time savings within the conventional benefit cost analysis framework. That is, the methodology adopted allows for the quantification of the effects of transportation system improvements in relation to (1) immediate cost reduction to carriers and shippers, (2) the impact of improved logistics while keeping output fixed, and (3) additional gains from reorganization such as increased demand and new or improved products.

Methodology

Given results for a national analysis of the reorganization impacts of highway performance improvements from Phase II of the Freight Benefit/Cost Study, this study applies similar methodology to that utilized previously. The previously examined corridors were tested to indicate the robustness of results when segregated into regions of various sizes and constitutions. This analysis indicated that the most reliable results could be obtained using a three region approach consisting of East, Central, and West.

A panel of corridor performance, demand for freight movement, freight prices, and regional economic activity was then constructed for these regions. Regression analysis was applied to this panel in order to develop estimates of performance elasticity of demand.

The following equation was used to develop separate estimates for each region (East, Central, and West) when demand for daily truck traffic is specified as a function of delay and real per capita income growth:

$$Log\left(AADTT_{c,t}\right) = \beta_c + \beta_1 Delay_{c,t} + \beta_2 Income_{c,t}$$

where:

[1] FHWA Freight Benefit/Cost Study Reports are available at http://www.ops.fhwa.dot.gov/freight/

AADTT = Average annual daily truck traffic
Delay = Average delay per mile
Income = Real per capita income growth

t = 1993, 1994, … 2003
c = Corridor

β_c are corridor-specific constant, or fixed effects, where:

c = 1, …, 16 for East,
c = 1, …, 18 for Central,
c = 1,…, 21 for West

Table ES-1. Freight Significant Corridors Assessed in this Report, Three Regions

East Region-18 corridors		Central Region-18 corridors		West Region-23 corridors	
Atlanta-Jacksonville	ATL-JAX	Amarillo-Oklahoma City	AMA-OKL	Barstow-Amarillo	BAR-AMA
Atlanta-Knoxville	ATL-KNX	Billings-Sioux Falls	BIL-SIO	Barstow-Bakersfield	BAR-BAK
Atlanta-Mobile	ATL-MOB	Chicago-Cleveland	CHI-CLE	Barstow-Salt Lake City	BAR-SAL
Birmingham-Nashville	BGH-NSH	Cleveland-Columbus	CLE-COL	Dallas-El Paso	DAL-ELP
Birmingham-Chattanooga	BIR-CHA	Dayton-Detroit	DAY-DET	Dallas-Houston	DAL-HOU
Detroit-Pittsburgh	DET-PIT	Indianapolis-Chicago	IND-CHI	Denver-Kansas City	DEN-KAN
Harrisburg-Philadelphia	HAR-PHI	Indianapolis-Columbus OH	IND-COL	Denver-Salt Lake City	DEN-SAL
Knoxville-Harrisburg	KNX-HAR	Kansas City-St Louis	KNC-STL	Galveston-Dallas	GAL-DAL
Miami-Atlanta	MIA-ATL	Knoxville-Dayton	KNX-DAY	Laredo-San Antonio	LAR-SAN
Miami-Richmond	MIA-RIC	Louisville-Columbus	COL-LOU	Los Angeles-Tucson	LAX-TUC
Mobile-New Orleans	MOB-NOR	Louisville-Indianapolis	IND-LOU	Nogales-Tucson	NOG-TUC
New Orleans-Birmingham	NOR-BIR	Memphis-Dallas	MEM-DAL	Portland-Salt Lake City	POR-SAL
Boston-New York City	NYC-BOS	Memphis-Oklahoma City	MEM-OKL	Portland-Seattle	POR-SEA
New York City-Cleveland	NYC-CLE	Nashville-Louisville	NSH-LOU	San Antonio-Dallas	SAN-DAL
Harrisburg-New York City	NYC-HAR	Nashville-St Louis	NSH-STL	San Diego-Los Angeles	SDG-LAX
Philadelphia-New York City	PHI-NYC	Omaha-Chicago	OMA-CHI	San Francisco-Los Angeles	SFO-LAX
Columbus-Pittsburgh	PIT-COL	St Louis-Oklahoma City	STL-OKL	San Francisco-Portland	SFO-POR
Richmond-Philadelphia	RIC-PHI	St Louis-Indianapolis	STL-IND	San Francisco-Salt Lake City	SFO-SAL
				San Antonio-Houston	SAN-HOU
				Seattle-Billings	SEA-BIL
				Seattle-Blaine	SEA-BLA
				Seattle-Sioux Falls	SEA-SIO
				Tucson-San Antonio	TUC-SAN

Data

Data on heavy-duty vehicle traffic volumes, freight rates, and commodity flows were collected from several different sources, including performance and volume data from the Highway Performance Monitoring System (HPMS), commodity data from the Freight Analysis Framework (FAF), and regional economic activity data from the Bureau of Labor Statistics and the Bureau of Economic Analysis. Data on 30 corridors collected for the national study formed the core of the database constructed for the regional analysis. To these, data for 29 additional corridors were added. The original dataset was also improved by adding an additional three years of observations. In total, 55 corridors were included in the regional analysis with 381 combined observations ranging from 1992 to 2003.

Summary of Empirical Findings

The overall goal of the analysis is to develop regional data points required to estimate additive freight reorganization benefits reflecting the added value of specific highway performance improvement efforts. In order to develop estimates of the additional reorganization benefit, the methodology requires that two types of elasticities be estimated for each region:

- Elasticity of Demand with respect to performance
- Elasticity of Demand with respect to price

The study successfully estimated elasticities of demand with respect to performance for each of the three regions. The elasticities were developed applying a multiple regression approach to an unbalanced panel of performance, volume, and other data for the 55 corridors.

Table ES-2. Estimated Impact of Changes in Highway Performance on Freight Demand, Three Regions

Region	Coefficient on Delay	Implied Elasticity	Interpretation
East	-0.005117	-0.0076	Other things being equal, a 10% increase in delay per mile reduces freight demand by 0.076%.
Central	-0.069076	-0.0175	Other things being equal, a 10% increase in delay per mile reduces freight demand by 0.175%.
West	-0.015586	-0.0070	Other things being equal, a 10% increase in delay per mile reduces freight demand by 0.07%.

Due to lack of data regarding freight rates, however, significant difficulties estimating the price elasticity of demand were encountered at the national level during the previous study. These inputs were developed using a review of the existing literature. A similar approach was applied to developing regional price elasticities. Table ES-3 shows the price elasticities applied to the regional additive freight reorganization benefit estimation.

Table ES-3. Estimated Impact of Changes in Price on Freight Demand: United States and Three Regions

U.S.	Regional Differences When Compared to the National Level (-0.97 = 100%)		Regional Estimate of Elasticity of Demand with Regard to Price	
	East	115.3%	East	**-1.12**
-0.97	Central	99.6%	Central	**-0.97**
	West	86.9%	West	**-0.84**

Additive Freight Benefit Factors

The study estimates total benefits associated with highway investment by establishing a relationship between elasticity of demand with respect to highway performance, elasticity of demand with respect to price, and a set of other region-specific variables. The intent of this work is to establish the approach and basic input data required to develop a tool to establish corridor specific additive reorganization benefit factors in a subsequent task.

The calculation indicates the additional benefit related to reorganizing logistics that may accrue from an estimated performance improvement to be used in benefit-cost analyses (BCAs) that do not independently account for the value of improved freight management.

Table ES-4 provides the implied elasticity of demand with respect to performance by region and the typical additive benefit factors calculated for the corridors represented in the sample used in this study. A subsequent task will involve the development of a calculation tool that can be used to estimate a reorganization benefit specific to the AADTT, performance improvement, and other characteristics of the corridor being assessed.

Table ES-4. Probability Ranges for Elasticity and Additive Benefit Factors

	East	Central	West
Implied Elasticity	**-0.0076**	**-0.0175**	**-0.0070**
Additive Benefit Factor	**16.7%**	**14.8%**	**12.7%**

Regional Commodity Characteristics

A regional analysis of FAF commodity flow data was done. Data available included top commodities by volume (weight) and by value. The data describes regional mixes of similar freight movement. Except for the Central region, finished goods were not significant contributors to freight volume. In the Central region, machinery and motorized vehicles were the ninth and tenth largest categories of shipment by volume. This greater than average volume of finished and semi-finished goods in the Central region may explain the higher than average elasticity of demand with respect to highway performance in the region.

CONCLUSIONS AND RECOMMENDATIONS

This study examines the implications of monetizing the impact of logistical reorganization into the conventional benefit-cost analysis approach at a regional level. As it has been stated previously, by improving the reliability and predictability of transit times, highway capacity investments have a material impact on the business case for firms to invest in advanced production, distribution, and customer service logistics. These logistical technologies and business processes enable firms to operate with greater productivity, thereby enhancing their competitiveness, profitability, and shareholder value. Productivity growth throughout the economy generates improved personal incomes and living standards. Productivity growth is widely regarded to be the single most important means of improving the living standards in the United States. Yet conventional BCA does not account for the value of productivity improvements generated by the adoption of advanced logistics. As a result, the conventional framework understates the economic value of capital investment in highway infrastructure.

This study examines the quantitative significance of this shortcoming in the conventional BCA framework at a regional level. The study finds that the conventional framework underestimates the economic benefits of highway investment by 13-17 percent, depending on the region.

It is recommended that this result and the associated calculations be made available to practitioners in a tool designed to simply elicit project and area specific information and return expected freight logistics benefits achievable through performance improving projects.

1 RESULTS OF THE FOUNDATIONAL NATIONAL ANALYSIS

This report builds on and updates the 2003 report, "Analysis of Benefits of Highway-Freight Improvements, Phase II, Final Report."[2] That paper reports the results of a national analysis of the long-term benefits of highway-freight improvements by examining the dynamic interactions between transportation demand, transportation costs, and the condition and performance of the Nation's highway system. The national analysis assessed these interactions beyond traditional travel time savings within the conventional benefit cost analysis framework. That is, the methodology adopted allowed for the quantification of the effects of transportation system improvements in relation to (1) immediate cost reduction to carriers and shippers; (2) the impact of improved logistics while keeping output fixed; and (3) additional gains from reorganization such as increased demand and new or improved products.

This report relies on the methodology developed under Phase II to construct a regional analysis of freight demand with respect to highway performance with a goal of determining regional differences in the demand structure and ultimately developing regional estimations of the additive value of performance improvements beyond the value of time savings.

The sections below summarize the methodology employed and the results of the national analysis. A comprehensive discussion of the methodology can be found in Appendix 2.

1.1 Methodology

The model initially developed for the national analysis relates the demand for freight transportation to both freight transport charges (the monetary-cost of shipping goods) and highway performance (including the quality of shipping services, such as travel or delivery times and travel time reliability). Freight charges are believed to depend on highway performance since average vehicle speed and speed cycling directly affect carrier's costs and, presumably, shipping rates. The two-equation model examined for the national analysis can be expressed as:

$$\mathbf{D} = f(\mathbf{R}, \mathbf{V/C}, FD1, FD2, \ldots) + Errors_1 \qquad \textit{Equation 1}$$

$$\mathbf{R} = f(\mathbf{V/C}, FR1, FR2, \ldots) + Errors_2 \qquad \textit{Equation 2}$$

Where:

- **D** is the demand for freight (expressed in truck miles or truck daily traffic),
- **R** is the freight rate (money cost charged by carriers),

[2] http://ops.fhwa.dot.gov/freight/freight_analysis/improve_econ/

- **V/C** is the Volume-to-Capacity ratio, or other measures of highway performance,
- FD1, FD2,.. are other determinants of freight demand (independent of both R and V/C),
- FR1, FR2,... are other determinants of freight rates (independent of V/C), and
- $Errors_1$ are independent of $Errors_2$.

Equations 1 and 2 show that highway performance affects the demand for freight transportation both directly and indirectly through its impact on freight charges.

1.2 The Data

Data on 30 corridors located across the Nation were collected for the national analysis. These corridors have significant freight volumes. They vary greatly in length (ranging from 105 miles for Harrisburg-Philadelphia to 734 miles for Salt Lake City-San Francisco), total traffic, and congestion levels.

Truck traffic volumes were used as a measure of freight demand. These traffic volumes were estimated from two primary sources: the HPMS and FAF. Highway performance measures were estimated on the basis of information reported in HPMS. Two principal measures were used: the average Volume-to-Capacity (V/C) ratio (averaged over all HPMS segments), and total delay (aggregated over all sample segments).

Freight rates were collected from a sample of truckload and less-than-truck-load companies (as posted on their Web sites); historical data on freight rates were gathered from a rate bureau[3]. Other determinants or control variables were derived from a variety of sources, including the Bureau of Economic Analysis, the Bureau of Labor Statistics, and the Census Bureau.

Figures 1 and 2 illustrate two important relationships derived from the cross-sectional data used in the national analysis:

1. The relationship between highway performance (measured by the V/C ratio) and freight charges (in dollars per mile); and
2. The relationship between freight charges (in dollars per mile) and freight demand (measured by the average number of trucks passing through the corridor daily).

[3] Historic data on trucking rates were collected from SMC3 (previously known as the Southern Motor Carriers).

Figure 1. Cross-Sectional Relationship between Highway Performance and Freight Charges

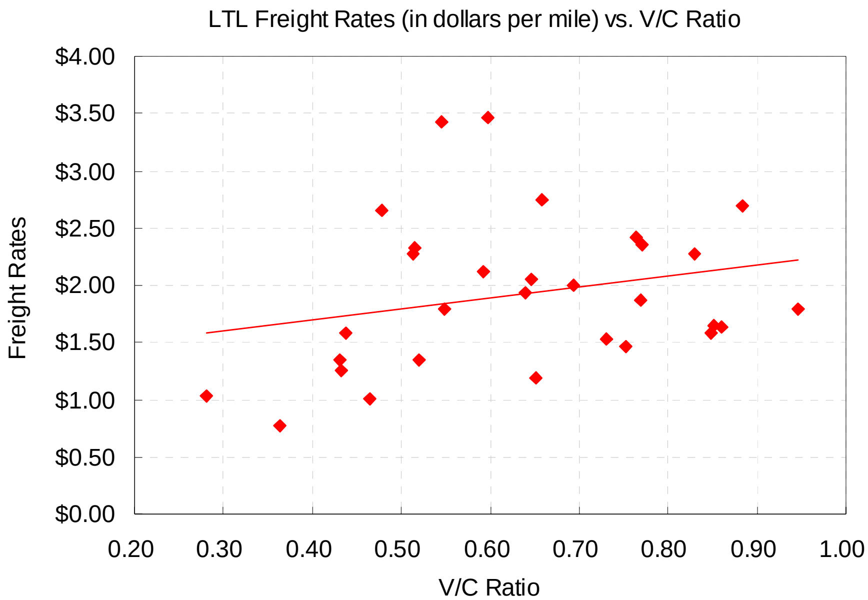
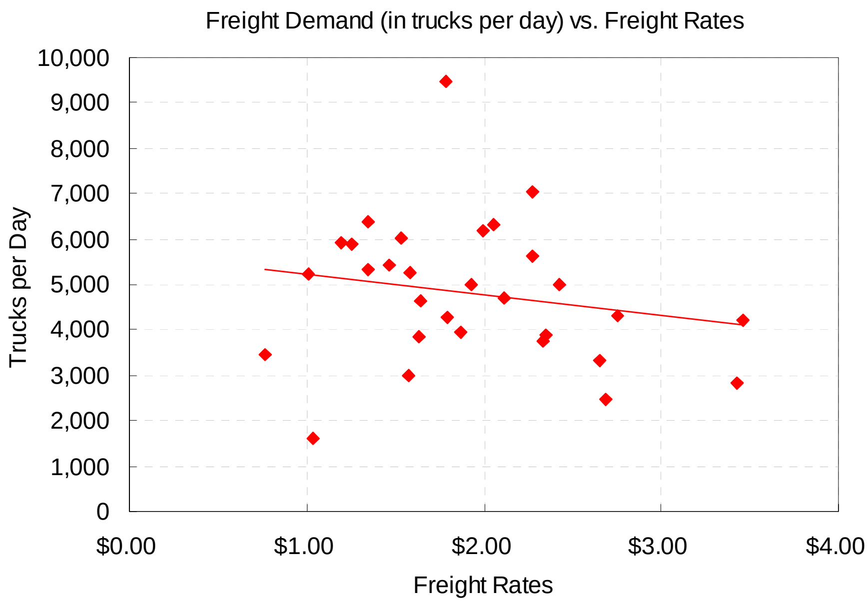


Figure 2. Cross-Sectional Relationship between Freight Charges and Freight Demand



Although Figures 1 and 2 indicate a general relationship with the existing data points, there is not a visible relationship between these variables once the outliers are taken out of the dataset.

The dataset used in the regression work was initially developed for a cross-sectional analysis, where variations in freight demand across the 30 sampled corridors were examined at one point in time (1998). In a later stage, the dataset was expanded to accommodate eight extra years of data from 1993 through 2000.

1.3 Summary of Empirical Findings, National Analysis

The cross-section analysis demonstrated that highway performance variables, such as delay and V/C ratio, are positively correlated with freight demand. These estimated correlation coefficients are inconsistent with expectations. Hence, the results of the cross-section analysis of 30 corridors were inconclusive with the existing dataset.[4] In order to understand the true nature of the relationship between highway performance measures and freight demand and freight charges, a panel data analysis was conducted for a similar set of corridors.

Panel data regression results suggested that there is a negative relationship between demand for freight transportation and highway performance measures. Hence, congestion on highways, holding other variables constant, reduces truck traffic over a specific corridor.

Results from the panel data analysis indicated as expected: a negative relationship between measures of highway performance (delay per mile) and truck traffic; and, in most instances, a negative relationship between freight rates (in dollar per mile) and truck traffic. An overview of the results of the national panel data analysis is provided below:

- Regression outcomes were particularly encouraging with a pooled specification (where cross-sectional and time-series data units are pooled together as one dataset; and where cross-sectional variations are not explicitly differentiated from time-series variations). Under such a specification, the coefficient on the delay variable and the coefficient on the freight-rate variable were both significantly different from zero and of the expected sign (negative). There were, however, indications of possible serial correlation problems, limiting the validity of the coefficient estimates.

- In an effort to limit serial correlation problems and improve on the estimation, fixed effects (corridor-specific constants) were used in the estimation. Under most specifications using this approach, the coefficient on highway performance (V/C ratio and delay) was still significant and had the expected sign. The coefficient on truck rates, however, was either insignificant or significant with a sign contrary to expectations.

Table 1 provides a summary of findings regarding the impact of changes in highway performance on freight demand. Again, these results should be interpreted with some caution given the difficulties and data limitations encountered in the course of this project.

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[4] Poor empirical results were probably attributable to the inability to control for all factors affecting freight demand within a cross-sectional framework.

Table 1. Estimated Impact of Changes in Highway Performance on Freight Demand, National Analysis

Model / Reference	Coefficient Estimate (t-stat)	Mean Sample Value	Slope	Implied Elasticity	Interpretation
Pooled Regression[1] Y = LOG(AADTT) X = Delay per Mile	-0.001834 (-4.39)	Y = 8.80570 X = 3.94823	-12.2	-0.0072	Other things being equal, a 10% increase in delay per mile reduces freight demand by 0.07%
Fixed Effects[2] Y = LOG(AADTT) X = Delay per Mile	-0.002575 (-5.19)	Y = 8.80570 X = 3.94823	-17.2	-0.0102	Other things being equal, a 10% increase in delay per mile reduces freight demand by a tenth of a percent.
Fixed Effects[3] Y = LOG(AADTT) X = V/C Ratio	-0.145737 (-6.01)	Y = 8.80570 X = 0.58245	-972.4	-0.0849	Other things being equal, a 10% increase in the V/C ratio reduces freight demand by about 1%

Overall, the estimated impact ranges from 0.07% to 1.00% reduction in freight demand (measured by average daily truck traffic) for every 10% increase in measured congestion. Conversely, a highway improvement leading to a 10% reduction in measured congestion, from a V/C ratio of 0.60 to a V/C ratio of 0.54 for example, would increase truck movements along the improved highway segment by about 1.0 percent.

Freight Rate Equation

The microeconomic framework, developed in Phase I of the Freight Benefit/Cost Study, uses elasticity of transportation demand with respect to both transportation performance measures and the transportation charges (price) in estimating indirect benefits of transportation investments.

Attempts to estimate this price elasticity from the cross-sectional analysis failed. There was not enough evidence to indicate a significant relationship between measures of highway performance and freight charges (in $ per mile). In most of the specifications tested for the national analysis, the coefficient on V/C ratio or delay were found to be positive as expected, but not statistically significant.

Results from the panel data analysis are even less convincing with, in many cases, a negative coefficient on highway performance measures, indicating that other things being equal, increasing levels of congestion would *reduce* freight charges.

Possible explanations for these poor results include:

- *Data availability problems*: Only Less-than-Truck-Load (LTL) rates were available on a time series basis;

- *Data quality problems*: Large and seemingly inexplicable variations in congestion indices were found in HPMS; variations in segment length and segment selection were also found along some of the sample corridors;

- *Specification problems*: The freight-rate equation estimation attempted here does not explicitly account for the supply of truck shipping services in the sampled corridors. The regressions might be capturing the fact that highly traveled corridors are also those where competition among truckers is more intense, leading to lower shipping rates. Various measures of economic activity and truck traffic were used as explanatory variables in an attempt to control for such effects.

Price elasticity estimates were therefore drawn from a meta-analysis of the existing literature. The same price elasticity approach was used for the regional analysis.

1.3.1 Additive Freight Reorganization Benefit

The national analysis estimated total benefits associated with highway investment by establishing a relationship between highway performance measures and freight demand. The additive reorganization benefit calculation captures the impact of highway investments on freight usage and changes in logistics practices. This calculation is used to estimate the total benefits where the existing data allows estimation of only the direct effects. Table 2 summarizes the range of the implied elasticities and additive benefit for the average corridor in our sample. The median implied elasticity is the average of three elasticity figures presented in Table 1. The benefits described below were estimated by using HLB's Benefit Estimation Spreadsheet Model described in Section 3.2.

Table 2: Probability Ranges for Elasticity and Additive Benefit, National Analysis

	Lower	Median	Upper
Implied Elasticity	**-0.0916**	**-0.056**	**-0.02**
Additive Benefit Factor	**14.7%**	**16.0%**	**18.1%**

These results indicate that the benefits of highway investment due to industrial reorganization and associated productivity effects in the real economy add an estimated 16% to conventionally measured freight benefits when assessed from a national perspective.

2 METHODOLOGY FOR MEASURING REGIONAL REORGANIZATION EFFECTS

2.1 Development of Regional Subgroups

The development of a regional analysis focused on applying the analytical framework developed for the national analysis to geographically grouped sets of corridors. A primary task of the regional analysis has been the development of regional groups to analyze the reorganization effects related to highway freight improvements. The project team developed three proposed regional groupings: A five-region model, a three-region model based on FHWA's Federal Lands Program (FLP) regions, and a distributed three-region model.

These regional models were then applied to the corridors used in the Phase II national analysis and a determination was made of the number of corridors available within each model for each proposed region. Table 3 lists the corridors used in the national analysis conducted under Phase II.

Table 3: Corridors Used in National Analysis

Corridor	Code
Atlanta-Jacksonville	ATL-JAX
Atlanta-Knoxville	ATL-KNX
Atlanta-Mobile	ATL-MOB
Birmingham- Chattanooga	BIR-CHA
Birmingham-Nashville	BGH-NSH
Cleveland-Columbus	CLE-COL
Columbus-Pittsburgh	PIT-COL
Dallas-Houston	DAL-HOU
Dayton-Detroit	DAY-DET
Harrisburg-Philadelphia	HAR-PHI
Indianapolis-Chicago	IND-CHI
Indianapolis-ColumbusOH	IND-COL
KansasCity-St. Louis	KNC-STL
Knoxville-Dayton	KNX-DAY
Louisville-Columbus	COL-LOU
Louisville-Indianapolis	IND-LOU
Mobile-New Orleans	MOB-NOR
Nashville-Louisville	NSH-LOU
Nashville-St. Louis	NSH-STL
New Orleans-Birmingham	NOR-BIR
Richmond-Philadelphia	RIC-PHI
San Antonio-Houston	SAN-HOU
St. Louis-Indianapolis	STL-IND
Denver-Kansas City	DEN-KAN
Denver-Salt Lake City	DEN-SAL
San Francisco-Salt Lake City	SFO-SAL
San Francisco-Los Angeles	SFO-LAX
Portland-Seattle	POR-SEA
Boston-New York City	NYC-BOS
Harrisburg-New York City	NYC-HAR

This original set of corridors represented a selection of freight-significant corridors of varying lengths, traffic volumes, and performance characteristics. However, the corridors are concentrated in the Midwest and lack good representation for some parts of the country. This problem was addressed by adding new corridors to the analysis, as discussed later.

Table 4 describes the division of the corridors originally used in the national analysis into the proposed five regions.

Table 4. Original Corridors Incorporated into Five Regions

Region	Corridor	Code
East Coast	Harrisburg-Philadelphia	HAR-PHI
	Richmond-Philadelphia	RIC-PHI
	Boston-New York City	NYC-BOS
	Harrisburg-New York City	NYC-HAR
Southeast	Atlanta-Jacksonville	ATL-JAX
	Atlanta-Knoxville	ATL-KNX
	Atlanta-Mobile	ATL-MOB
	Birmingham-Chattanooga	BIR-CHA
	Birmingham-Nashville	BGH-NSH
	Mobile-New Orleans	MOB-NOR
	New Orleans-Birmingham	NOR-BIR
Midwest	Cleveland-Columbus	CLE-COL
	Columbus-Pittsburgh	PIT-COL
	Dayton-Detroit	DAY-DET
	Indianapolis-Chicago	IND-CHI
	Indianapolis-Columbus, OH	IND-COL
	KansasCity-St. Louis	KNC-STL
	Knoxville-Dayton	KNX-DAY
	Louisville-Columbus	COL-LOU
	Louisville-Indianapolis	IND-LOU
	Nashville-Louisville	NSH-LOU
	Nashville-St. Louis	NSH-STL
	St. Louis-Indianapolis	STL-IND
Southwest	Dallas-Houston	DAL-HOU
	San Antonio-Houston	SAN-HOU
West Coast	Denver-Kansas City	DEN-KAN
	Denver-Salt Lake City	DEN-SAL
	San Francisco-Salt Lake City	SFO-SAL
	San Francisco-Los Angeles	SFO-LAX
	Portland-Seattle	POR-SEA

The five-region model allows for an easily understandable allocation of corridors to regions with which most practitioners would recognize and identify. However, it creates problems of under-representation, particularly in the Southwest and East. Using a five-region model would require significant investment in collecting data for a sufficient number of corridors to cover each region.

Table 5 describes the division of the corridors originally used in the national analysis into the proposed three FHWA FLP regions.

Table 5. Original Corridors Incorporated into FHWA's Federal Lands Program Regions

FHWA Federal Lands Program

Region	Corridor	Code
Eastern Region	Atlanta-Jacksonville	ATL-JAX
	Atlanta-Knoxville	ATL-KNX
	Atlanta-Mobile	ATL-MOB
	Birmingham-Chattanooga	BIR-CHA
	Birmingham-Nashville	BGH-NSH
	Cleveland-Columbus	CLE-COL
	Columbus-Pittsburgh	PIT-COL
	Dayton-Detroit	DAY-DET
	Harrisburg-Philadelphia	HAR-PHI
	Indianapolis-Chicago	IND-CHI
	Indianapolis-Columbus, OH	IND-COL
	KansasCity-St. Louis	KNC-STL
	Knoxville-Dayton	KNX-DAY
	Louisville-Columbus	COL-LOU
	Louisville-Indianapolis	IND-LOU
	Mobile-New Orleans	MOB-NOR
	Nashville-Louisville	NSH-LOU
	Nashville-St. Louis	NSH-STL
	NewOrleans-Birmingham	NOR-BIR
	Richmond-Philadelphia	RIC-PHI
	Boston-New York City	NYC-BOS
	Harrisburg-New York City	NYC-HAR
	St. Louis-Indianapolis	STL-IND
Central Region	Dallas-Houston	DAL-HOU
	Denver-Kansas City	DEN-KAN
	Denver-Salt Lake City	DEN-SAL
	San Francisco-Salt Lake City	SFO-SAL
	San Francisco-Los Angeles	SFO-LAX
	SanAntonio-Houston	SAN-HOU

Using FHWA's FLP regions as the model for sub-national division creates significant concentration in the East. In addition, the West region becomes extremely small, with only one corridor allocated.

Table 6 describes the division of the corridors originally used in the national analysis into the proposed three distributed regions.

Table 6. Original Corridors Incorporated into Three Regions

Three Regions

Region	Corridor	Code
East Coast	Atlanta-Jacksonville	ATL-JAX
	Atlanta-Knoxville	ATL-KNX
	Atlanta-Mobile	ATL-MOB
	Birmingham-Chattanooga	BIR-CHA
	Birmingham-Nashville	BGH-NSH
	Harrisburg-Philadelphia	HAR-PHI
	Mobile-New Orleans	MOB-NOR
	New Orleans-Birmingham	NOR-BIR
	Richmond-Philadelphia	RIC-PHI
	Boston-New York City	NYC-BOS
	Harrisburg-New York City	NYC-HAR
Midwest	Cleveland-Columbus	CLE-COL
	Columbus-Pittsburgh	PIT-COL
	Dayton-Detroit	DAY-DET
	Indianapolis-Chicago	IND-CHI
	Indianapolis-Columbus, OH	IND-COL
	Kansas City-St. Louis	KNC-STL
	Knoxville-Dayton	KNX-DAY
	Louisville-Columbus	COL-LOU
	Louisville-Indianapolis	IND-LOU
	Nashville-Louisville	NSH-LOU
	Nashville-St. Louis	NSH-STL
	St. Louis-Indianapolis	STL-IND
West Coast	Dallas-Houston	DAL-HOU
	San Antonio-Houston	SAN-HOU
	Denver-Kansas City	DEN-KAN
	Denver-Salt Lake City	DEN-SAL
	San Francisco-Salt Lake City	SFO-SAL
	San Francisco-Los Angeles	SFO-LAX

The distributed three-region model reduces the potential variability between regions that would be in a five-region model. It creates regional allocations with which practitioners can identify, but the three-region model reduces the burden of additional data collection to achievable proportions.

The three proposed regional division models are:

Five-Region Model

Regions	Corridors
Midwest	12
East Coast	4
Southeast	7
Southwest	2
West Coast	5

Three-Region FLP Model

Regions	Corridors
Central	6
Eastern	23
Western	1

Three-Region Model

Regions	Corridors
Midwest	12
East Coast	11
West Coast	7

The three-region FLP model was determined as untenable due to the heavy weighting of states included in the Eastern region and the lack of good mapping to freight-significant corridors with the southern half of the West Coast included in the Central region and most of the Midwest included in the Eastern region. As can be seen from the table above, the FLP approach allowed only one of the original corridors to be included in the third (Western) region.

2.2 Testing of Regional Subgroups

The project team tested a selection of the subgroups for performance using the three final equations developed under Phase II: The pooled regression equation, the regression with fixed effects, and the general least squares regression with fixed effects. The objectives of the testing were:

- To estimate the likely minimum number of corridors or observations required per region in order to derive significant results;
- To determine the data collection required in order to develop a robust regional dataset; and
- To use this information to determine which regional definition to use in the final analysis.

In order to estimate the likely minimum number of corridors or observations required, each of the three equations developed for the Phase II national analysis were re-run using the midwestern corridors from the five-region model and the East Coast corridors from the three-region model. In addition, the 23-corridor FLP Eastern region was included in order to improve the estimate of the required minimum number of corridors or observations required. However, as discussed earlier, the FLP model was determined unsuitable for use as a final regional grouping.

Equation 1: Pooled Regression

Equation 1 uses a semi-log functional form with data on freight demand, congestion related delays, and economic variables. In the following model, demand for daily truck traffic is specified as a function of per capita income, GDP growth rate, LTL rates, and delay. Table 7 provides the results from the original national analysis.

Estimating Equation: $LOG(Trucks/day_{r,t}) = ß_0 + ß_1 * Delay_{r,t} + ß_2 * GDP\ Growth_{r,t} + ß_3\ Real\ per\ Capita\ Income_{r,t} + ß_4 * LTL\ Rate_{r,t}$

Table 7. Regression Results for Freight Demand (Pooled Regression)

Variable	Coefficient	Std. Error	t-Statistic	Probability of Non-Significance
Constant	8.162777	0.061204	133.3699	0.0000
Delay	-0.001834	0.000418	-4.388016	0.0000
GDP Growth	0.067249	0.010604	6.342005	0.0000
Real Per Capita Income	6.16E-05	4.67E-06	13.19443	0.0000
Real LTL Rates	-0.004517	0.000296	-15.26863	0.0000
R-squared	0.323195	Mean dependent variable		8.805702
Adjusted R-squared	0.308871	S.D. dependent variable		0.389423
S.E. of regression	0.323743	Sum squared residual		19.80905
Durbin-Watson stat	0.142865			

Method: GLS (Cross-Section Weights)
Total panel (unbalanced) observations: 194

Where:

- Trucks/day — Average number of trucks/day for the corridor
- Delay — Average delay per mile
- GDP Growth — Growth rate for the Gross Domestic Product
- Real Per Capita Income — Average Per Capita income for all counties along the corridors
- LTL Rates/trip — Less-than-truckload rates for 1,000 lb. shipment

For the national analysis, this specification produced coefficients that are of the expected sign. Further estimation also suggested that the coefficient of the delay variable may vary across corridors of various lengths and be higher in absolute terms for long routes (over 400 miles) than for short routes (up to 200 miles) and medium routes (200 to 400 miles). However, the Durbin-Watson (DW) statistic in the above specification was low, at around 0.14. A low DW statistic indicates a potential problem of autocorrelation within and across the individual cross-sections (or other forms of misspecification). This arises from complications with panel data, in particular:

- Errors are not independent between time periods and
- Errors are correlated between corridors.

As such, re-estimating Equation 1 with fewer observations was not expected to produce strong results. Table 8 describes the results of Equation 1 for each of the three regional sub-groups tested.

Table 8: Results for Equation 1 for Three Regional Sub-groups

Three-Region FLP Model	Three-Region Model	Five-Region Model
FHWA Eastern Region	**East (combined)**	**Midwest**
23 corridors with	11 corridors with	12 corridors with
2 no-data corridors	2 no-data corridors	0 no-data corridors
21 corridors for analysis	**9 corridors for analysis**	**12 corridors for analysis**

FHWA Eastern Region

Dependent Variable: **LOG(AADT-Trucks)**
Method: Pooled EGLS (Cross-section weights)
Included observations: 8
Cross-sections included: 21
Total pool (unbalanced) observations: 151

Variable	Coef	Std. Error	t-Stat	Prob.
Constant	8.245	0.127	64.774	0.000
Delay	0.001	0.002	0.243	0.809
GDP Growth	0.040	0.026	1.524	0.130
Real Per Capita Income	0.000	0.000	5.109	0.000
Real LTL Rates	-0.001	0.000	-2.455	0.015

R-squared	0.999	Mean dependent var	13.772
Adjusted R-squared	0.999	S.D. dependent var	7.762
S.E. of regression	0.234	Sum squared resid	7.966
Durbin-Watson stat	0.318		

East (combined)

Dependent Variable: **LOG(AADT-Trucks)**
Method: Pooled EGLS (Cross-section weights)
Included observations: 8
Cross-sections included: 9
Total pool (unbalanced) observations: 65

Variable	Coef	Std. Error	t-Stat	Prob.
Constant	7.873	0.166	47.487	0.000
Delay	-0.006	0.001	-3.874	0.000
GDP Growth	0.039	0.042	0.919	0.362
Real Per Capita Income	0.000	0.000	6.268	0.000
Real LTL Rates	-0.002	0.001	-2.147	0.036

R-squared	0.994	Mean dependent var	10.448
Adjusted R-squared	0.994	S.D. dependent var	2.972
S.E. of regression	0.232	Sum squared resid	3.241
Durbin-Watson stat	0.265		

Midwest

Dependent Variable: **LOG(AADT-Trucks)**
Method: Pooled EGLS (Cross-section weights)
Included observations: 8
Cross-sections included: 12
Total pool (unbalanced) observations: 86

Variable	Coef	Std. Error	t-Stat	Prob.
Constant	8.604	0.149	57.930	0.000
Delay	0.004	0.003	1.568	0.121
GDP Growth	0.037	0.030	1.258	0.212
Real Per Capita Income	0.000	0.000	1.920	0.058
Real LTL Rates	-0.001	0.001	-1.028	0.307

R-squared	0.999	Mean dependent var	13.183
Adjusted R-squared	0.999	S.D. dependent var	5.737
S.E. of regression	0.192	Sum squared resid	2.990
Durbin-Watson stat	0.390		

As expected, each of the regional subgroups performed poorly in terms of the DW statistic, ranging from.0.29 to 0.36. None of the equations achieved significant results for all included variables. The 65-observation Eastern region achieved significant and correctly signed results for the Delay variable, which is the key measure of highway performance included in the equation.

Equation 2: Regression with Fixed Effects

To mitigate the problems associated with Equation 1, the model was re-estimated using the fixed effects method during the Phase II national analysis. The estimating equation was reformulated as

Estimating Equation: $LOG(Trucks/day_{r,t}) = ß_r + ß_1 * Delay_{r,t} + ß_2 * GDP\ Growth_{r,t}$

Where $ß_{r\ (r = 1...28)}$ are corridor-specific constant, or fixed effects.

The results of the estimation developed for the national analysis are provided in Table 9.

Table 9. Regression Results for Freight Demand (Fixed Effects)

Variable	Coefficient	Std. Error	t-Statistic	Probability of Non-Significance
Delay	-0.002575	0.000496	-5.186827	0.0000
GDP Growth	0.073356	0.007632	9.611514	0.0000
Fixed Effects				
Atlanta-Jacksonville	8.716456			
Atlanta-Knoxville	8.918446			
Atlanta-Mobile	8.362351			
Birmingham-Nashville	8.353916			
Cleveland-Columbus	8.605421			
Columbus-Pittsburgh	8.535460			
Dallas-Houston	8.623438			
Dayton-Detroit	8.592172			
Harrisburg-Philadelphia	8.526888			
Indianapolis-Chicago	8.655297			
Indianapolis-Columbus	8.821301			
Kansas City-St. Louis	8.610851			
Knoxville-Dayton	8.807753			
Louisville-Columbus	8.708366			
Louisville-Indianapolis	8.679238			
Mobile-New Orleans	8.325837			
Nashville-Louisville	9.049711			
Nashville-St. Louis	8.086613			
Richmond-Philadelphia	9.035896			
San Antonio-Houston	8.423007			
St. Louis-Indianapolis	8.664829			
Denver-Kansas City	7.441348			
Denver-Salt Lake City	8.156259			
San Francisco-Salt Lake City	7.459972			
San Francisco-Los Angeles	8.343404			
Portland-Seattle	8.794208			
Boston-New York City	8.639654			
Harrisburg-New York City	8.727643			
R-squared	0.924207	Mean dependent variable		8.805702
Adjusted R-squared	0.910804	S.D. dependent variable		0.389423
S.E. of regression	0.116304	Sum squared residual		2.218348
Durbin-Watson stat	1.117309			

Method: GLS (Cross-Section Weights)
Total panel (unbalanced) observations: 194

For the national analysis, the high R-squared value, 0.92 indicated that the variables considered explain changes in freight demand very closely. Delay and GDP growth variables have the correct signs, and they are statistically significant. The DW statistic, 1.11, is significantly higher than that reported in the first model.

Equation 2 was also re-run using the three regional subgroups. Table 10 describes the results for each.

Table 50: Results for Equation 2 for three Regional Sub-groups

Three-Region FLP Model — FHWA Eastern Region

23 corridors with
2 no-data corridors
21 corridors for analysis

Dependent Variable: **LOG(AADT-Trucks)**
Method: Pooled EGLS (Cross-section weights)
Included observations: 8
Cross-sections included: 21
Total pool (unbalanced) observations: 151

Variable	Coef	Std. Error	t-Stat	Prob.
Constant	8.682	0.045	192.020	0.000
Delay	-0.005	0.001	-6.088	0.000
GDP Growth	0.065	0.011	5.685	0.000
Fixed Effects:				
ATL-JAX	0.071			
ATL-KNX	0.270			
ATL-MOB	-0.289			
BGH-NSH	-0.297			
CLE-COL	-0.037			
PIT-COL	-0.115			
DAY-DET	-0.055			
HAR-PHI	-0.104			
IND-CHI	0.007			
IND-COL	0.175			
KNC-STL	-0.013			
KNX-DAY	0.195			
COL-LOU	0.063			
IND-LOU	0.030			
MOB-NOR	-0.320			
NSH-LOU	0.425			
NSH-STL	-0.564			
RIC-PHI	0.397			
STL-IND	0.015			
NYC-BOS	0.026			
NYC-HAR	0.080			

R-squared	0.999	Mean dependent var	12.179
Adjusted R-squared	0.999	S.D. dependent var	4.820
S.E. of regression	0.110	Sum squared resid	1.539
Durbin-Watson stat	1.179		

Three-Region Model — East (combined)

11 corridors with
2 no-data corridors
9 corridors for analysis

Dependent Variable: **LOG(AADT-Trucks)**
Method: Pooled EGLS (Cross-section weights)
Included observations: 8
Cross-sections included: 9
Total pool (unbalanced) observations: 65

Variable	Coef	Std. Error	t-Stat	Prob.
Constant	8.626	0.058	148.596	0.000
Delay	-0.005	0.001	-5.887	0.000
GDP Growth	0.076	0.015	4.958	0.000
Fixed Effects:				
ATL-JAX	0.086			
ATL-KNX	0.285			
ATL-MOB	-0.274			
BGH-NSH	-0.282			
HAR-PHI	-0.093			
MOB-NOR	-0.305			
RIC-PHI	0.412			
NYC-BOS	0.041			
NYC-HAR	0.091			

R-squared	0.999	Mean dependent var	13.535
Adjusted R-squared	0.999	S.D. dependent var	6.478
S.E. of regression	0.137	Sum squared resid	1.009
Durbin-Watson stat	1.176		

Five-Region Model — Midwest

12 corridors with
0 no-data corridors
12 corridors for analysis

Dependent Variable: **LOG(AADT-Trucks)**
Method: Pooled EGLS (Cross-section weights)
Included observations: 8
Cross-sections included: 12
Total pool (unbalanced) observations: 86

Variable	Coef	Std. Error	t-Stat	Prob.
Constant	8.727	0.063	137.923	0.000
Delay	-0.005	0.002	-2.357	0.021
GDP Growth	0.056	0.016	3.534	0.001
Fixed Effects:				
CLE-COL	-0.047			
PIT-COL	-0.125			
DAY-DET	-0.064			
IND-CHI	-0.002			
IND-COL	0.166			
KNC-STL	-0.023			
KNX-DAY	0.177			
COL-LOU	0.052			
IND-LOU	0.022			
NSH-LOU	0.410			
NSH-STL	-0.574			
STL-IND	0.007			

R-squared	0.999	Mean dependent var	10.104
Adjusted R-squared	0.999	S.D. dependent var	3.201
S.E. of regression	0.085	Sum squared resid	0.518
Durbin-Watson stat	1.149		

As with the national analysis, Equation 2 performed well for each of the regional groupings, all with R-squared statistics above 0.99.

Equation 3: GLS Regression with Fixed Effects

The model was also estimated with V/C ratio and "fixed effects." The estimating equation was reformulated as:

Estimating Equation: $LOG(Trucks/day_{r,t}) = ß_r + ß_1 * VC\ Ratio_{r,t} + ß_2 * GDP\ Growth_{r,t}$
$ß_3 * Real\ Per\ Capita\ Income_{r,t} + ß_4 * Real\ LTL\ Rates_{r,t}$

Where $ß_{r\ (r = 1...28)}$ are corridor-specific constant, or fixed effects.

Table 11 describes the results of the original national analysis using Equation 3.

In the original national analysis, this model had a high R-squared value (0.954), indicating that the selected variables are highly correlated with changes in demand for transportation. The VC Ratio, GDP Growth, and Real Per Capita Income variables have the correct signs. The VC Ratio and Real LTL Rate variables are statistically significant. The DW statistic is higher than earlier estimations.

Table 61. GLS Regression Results for Freight Demand with Cross Section Weights (Fixed Effects)

Variable	Coefficient	Std. Error	t-Statistic	Probability of Non-Significance
VC Ratio	-0.145737	0.024236	-6.013214	0.0000
GDP Growth	0.005716	0.004550	1.256128	0.2109
Real Per Capita Income	8.11E-06	4.04E-06	2.006642	0.0465
Real LTL Rates	0.003148	0.000230	13.65898	0.0000
Fixed Effects				
Atlanta-Jacksonville	-0.145737			
Atlanta-Knoxville	0.005716			
Atlanta-Mobile	8.11E-06			
Birmingham-Nashville	0.003148			
Cleveland-Columbus				
Columbus-Pittsburgh	8.343270			
Dallas-Houston	8.671927			
Dayton-Detroit	7.985723			
Harrisburg-Philadelphia	7.827820			
Indianapolis-Chicago	8.331450			
Indianapolis-Columbus	8.187617			
Kansas City-St. Louis	8.232353			
Knoxville-Dayton	8.249458			
Louisville-Columbus	8.055459			
Louisville-Indianapolis	8.262573			
Mobile-New Orleans	8.492228			
Nashville-Louisville	8.111981			
Nashville-St. Louis	8.373134			
Richmond-Philadelphia	8.328012			
San Antonio-Houston	8.378806			
St. Louis-Indianapolis	8.150193			
Denver-Kansas City	8.808472			
Denver-Salt Lake City	7.632464			
San Francisco-Salt Lake City	8.470470			
San Francisco-Los Angeles	8.100525			
Portland-Seattle	8.268212			
Boston-New York City	6.563344			
Harrisburg-New York City	7.438120			
R-squared	0.954116	Mean dependent variable		8.805702
Adjusted R-squared	0.945336	S.D. dependent variable		0.389423
S.E. of regression	0.091048	Sum squared residual		1.342952
Durbin-Watson stat	1.315943			

This model performed well using the entire set of corridors, but sub-division into smaller groupings with fewer observations indicated that the nine- and 12-corridor groupings did not have a sufficient number of observations to generate statistically significant results.

The results of the three regional analyses are described in Table 12.

Table 72: Results for Equation 3 for Three Regional Sub-groups

Three-Region FLP Model — FHWA Eastern Region

23 corridors with
2 no-data corridors
21 corridors for analysis

Dependent Variable: **LOG(AADT-Trucks)**
Method: Pooled EGLS (Cross-section weights)
Included observations: 8
Cross-sections included: 21
Total pool (unbalanced) observations: 151

Variable	Coef	Std. Error	t-Stat	Prob.
Constant	8.223	0.104	78.752	0.000
VC_Ratio	-0.162	0.037	-4.361	0.000
GDP_Growth	0.003	0.009	0.383	0.703
Real Per Capita Income	0.000	0.000	0.867	0.388
Real LTL Rates	0.003	0.001	4.392	0.000
Fixed Effects:				
ATL-JAX	0.095			
ATL-KNX	0.426			
ATL-MOB	-0.264			
BGH-NSH	-0.424			
CLE-COL	0.088			
PIT-COL	-0.060			
DAY-DET	0.001			
HAR-PHI	-0.193			
IND-CHI	0.008			
IND-COL	0.246			
KNC-STL	-0.137			
KNX-DAY	0.129			
COL-LOU	0.081			
IND-LOU	0.131			
MOB-NOR	-0.088			
NSH-LOU	0.567			
NSH-STL	-0.620			
RIC-PHI	0.217			
STL-IND	0.018			
NYC-BOS	-0.184			
NYC-HAR	-0.201			

R-squared	0.999	Mean dependent var	15.836
Adjusted R-squared	0.999	S.D. dependent var	18.020
S.E. of regression	0.090	Sum squared resid	1.020
Durbin-Watson stat	1.1896		

Three-Region Model — East (combined)

11 corridors with
2 no-data corridors
9 corridors for analysis

Dependent Variable: **LOG(AADT-Trucks)**
Method: Pooled EGLS (Cross-section weights)
Included observations: 8
Cross-sections included: 9
Total pool (unbalanced) observations: 65

Variable	Coef	Std. Error	t-Stat	Prob.
Constant	7.796	0.210	37.165	0.000
VC_Ratio	-0.088	0.072	-1.223	0.227
GDP_Growth	0.000	0.016	-0.027	0.979
Real Per Capita Income	0.000	0.000	1.391	0.170
Real LTL Rates	0.002	0.002	1.219	0.228
Fixed Effects:				
ATL-JAX	0.179			
ATL-KNX	0.464			
ATL-MOB	-0.184			
BGH-NSH	-0.251			
HAR-PHI	-0.180			
MOB-NOR	-0.001			
RIC-PHI	0.248			
NYC-BOS	-0.214			
NYC-HAR	-0.206			

R-squared	0.999	Mean dependent var	15.440
Adjusted R-squared	0.999	S.D. dependent var	8.714
S.E. of regression	0.112	Sum squared resid	0.650
Durbin-Watson stat	1.221		

Five-Region Model — Midwest

12 corridors with
0 no-data corridors
12 corridors for analysis

Dependent Variable: **LOG(AADT-Trucks)**
Method: Pooled EGLS (Cross-section weights)
Included observations: 8
Cross-sections included: 12
Total pool (unbalanced) observations: 86

Variable	Coef	Std. Error	t-Stat	Prob.
Constant	8.487	0.132	64.309	0.000
VC_Ratio	0.071	0.122	0.581	0.563
GDP_Growth	0.014	0.016	0.841	0.403
Real Per Capita Income	0.000	0.000	-1.430	0.157
Real LTL Rates	0.005	0.001	4.389	0.000
Fixed Effects:				
CLE-COL	0.039			
PIT-COL	-0.093			
DAY-DET	-0.003			
IND-CHI	0.118			
IND-COL	0.203			
KNC-STL	-0.289			
KNX-DAY	-0.062			
COL-LOU	-0.005			
IND-LOU	0.155			
NSH-LOU	0.522			
NSH-STL	-0.660			
STL-IND	-0.006			

R-squared	0.999	Mean dependent var	14.241
Adjusted R-squared	0.999	S.D. dependent var	19.442
S.E. of regression	0.070	Sum squared resid	0.341
Durbin-Watson stat	1.311		

2.3 Selection of the Regional Groupings

The results of the analysis of the proposed regional groupings indicate that results generating reliability similar to that in the Phase II national analysis require groupings with an estimated minimum of 15-20 corridors. It can not be determined in advance of data collection and re-analysis whether any particular grouping will generate usable results. However, the performance of the test groupings against the three Phase II equations did not demonstrate any particular regional weakness.

Given the need for a regional grouping where every defined region needs at least 15-20 corridors, the project group and FHWA selected the distributed three-region grouping and began the task of collecting data for additional corridors to generate sufficient observations for each region. Having experienced issues related to incomplete data during the Phase II analysis, the project team selected sufficient additional corridors for each region in case a few corridors could not be used. In addition, an attempt was made to include corridors that covered a range of route types, from heavily urban to more rural and from a variety of areas within each region.

The following corridors were selected for addition to the dataset:

- Omaha-Chicago
- Barstow-Bakersfield
- San Francisco-Portland
- Billings-Sioux Falls
- Chicago-Cleveland
- Amarillo-Oklahoma City
- Detroit-Pittsburgh
- Galveston-Dallas
- San Diego-Los Angeles
- Miami-Atlanta
- Seattle-Billings
- Miami-Richmond
- Seattle-Sioux Falls
- New York City-Cleveland
- Portland-Salt Lake City
- Philadelphia-New York City
- Los Angeles-Tucson
- Dallas-El Paso
- Tucson-San Antonio
- Memphis-Dallas
- Barstow-Salt Lake City
- Memphis-Oklahoma City
- Barstow-Amarillo
- Stouts-Oklahoma City
- Nogales-Tucson
- Seattle-Blaine
- San Antonio-Dallas
- Knoxville-Harrisburg
- Laredo-San Antonio

Having added these corridors, a final regional division was made. Table 13 describes the corridors selected for inclusion in each region.

Table 83. Proposed Final Corridors for Three-Region Analysis

East Region-18 corridors		Central Region-18 corridors		West Region-23 corridors	
Atlanta-Jacksonville	ATL-JAX	Amarillo-Oklahoma City	AMA-OKL	Barstow-Amarillo	BAR-AMA
Atlanta-Knoxville	ATL-KNX	Billings-Sioux Falls	BIL-SIO	Barstow-Bakersfield	BAR-BAK
Atlanta-Mobile	ATL-MOB	Chicago-Cleveland	CHI-CLE	Barstow-Salt Lake City	BAR-SAL
Birmingham-Nashville	BGH-NSH	Cleveland-Columbus	CLE-COL	Dallas-El Paso	DAL-ELP
Birmingham-Chattanooga	BIR-CHA	Dayton-Detroit	DAY-DET	Dallas-Houston	DAL-HOU
Detroit-Pittsburgh	DET-PIT	Indianapolis-Chicago	IND-CHI	Denver-Kansas City	DEN-KAN
Harrisburg-Philadelphia	HAR-PHI	Indianapolis-Columbus OH	IND-COL	Denver-Salt Lake City	DEN-SAL
Knoxville-Harrisburg	KNX-HAR	Kansas City-St Louis	KNC-STL	Galveston-Dallas	GAL-DAL
Miami-Atlanta	MIA-ATL	Knoxville-Dayton	KNX-DAY	Laredo-San Antonio	LAR-SAN
Miami-Richmond	MIA-RIC	Louisville-Columbus	COL-LOU	Los Angeles-Tucson	LAX-TUC
Mobile-New Orleans	MOB-NOR	Louisville-Indianapolis	IND-LOU	Nogales-Tucson	NOG-TUC
New Orleans-Birmingham	NOR-BIR	Memphis-Dallas	MEM-DAL	Portland-Salt Lake City	POR-SAL
Boston-New York City	NYC-BOS	Memphis-Oklahoma City	MEM-OKL	Portland-Seattle	POR-SEA
New York City-Cleveland	NYC-CLE	Nashville-Louisville	NSH-LOU	San Antonio-Dallas	SAN-DAL
Harrisburg-New York City	NYC-HAR	Nashville-St Louis	NSH-STL	San Diego-Los Angeles	SDG-LAX
Philadelphia-New York City	PHI-NYC	Omaha-Chicago	OMA-CHI	San Francisco-Los Angeles	SFO-LAX
Columbus-Pittsburgh	PIT-COL	St Louis-Oklahoma City	STL-OKL	San Francisco-Portland	SFO-POR
Richmond-Philadelphia	RIC-PHI	St Louis-Indianapolis	STL-IND	San Francisco-Salt Lake City	SFO-SAL
				San Antonio-Houston	SAN-HOU
				Seattle-Billings	SEA-BIL
				Seattle-Blaine	SEA-BLA
				Seattle-Sioux Falls	SEA-SIO
				Tucson-San Antonio	TUC-SAN

The final regional categorization utilizes a three-region approach. Data availability and quality are the main reasons that a more detailed regional disaggregation has not been pursued.

However, the additive benefit estimation calculator will achieve significantly more specificity to local conditions then the example illustrated herein. This will be achieved though the use of corridor-specific AADTT in the additive benefit calculation and corridor-specific delay characteristics in the transformation of the elasticity estimate.

Additive benefit estimates are provided in this report as an illustration of what the additional reorganization benefit would be for the average corridor in each region. This is not the additional benefit proposed as the addition to every corridor's total benefit estimation. The tool to be developed in a subsequent task will utilize the regional elasticities calculated for this report and corridor-specific data, such as daily truck traffic, current delay, delay reduction, localized cost data, and other locally specific data to develop a corridor-specific additive freight reorganization benefit factor to be applied to calculated freight related benefits.

2.4 Rate, Flow, Commodity, and Performance Data

In addition to adding corridors, the existing dataset was also expanded by adding years of observations. Additional HPMS data collection has occurred since the development of the Phase II dataset. The project team was able to add three years of observations for most corridors, significantly expanding the total number of observations.

Data on heavy-duty vehicle traffic volumes, freight rates, and commodity flows were collected from several different sources. The data used are described below. Note that data on 30 corridors were available from Phase II of this study. Additional years of data were collected for these corridors. Data for 29 new corridors were also collected to enhance the size and regional coverage of our database. Of those 29 corridors, 25 were added to the final sample.

2.4.1 Rate Data

Freight rates for each corridor were obtained from SMC[3]'s Czarlite[5] database. This database serves as the benchmark for thousands of LTL contracts. Rates were obtained for each corridor using an origin and destination zip code. The rates were defined by using a 1,000 pound, class 70 shipment type to estimate an average rate for each corridor for the years 1993-2004.

2.4.2 Commodity Flow Data

The commodity flows in each corridor were characterized using FAF data from FHWA. Both the original FAF and a newly released version (FAF2) were used since the geographic detail and years available were somewhat different between these databases. The FAF2 database has information on commodity flows between major geographic regions, including some metropolitan area city pairs for the year 2002. Data on the tonnage, value, and commodity types being moved in both directions in the study corridors were developed. Since the geographic

[5] CzarLite is a nationwide (48 contiguous states) database of baseline class rates established on a territorial basis.

regions available in FAF2 did not map exactly to the corridor origin and destination cities used in the analysis, the regions most closely matching this study's corridors were utilized to obtain an approximate picture of existing commodity flows. Commodity flows were developed for 58 distinct corridors and captured information on freight moving in both directions along the corridor.

The original FAF database contains county-to-county movements of freight by commodity type for 1998 and forecast years. Commodity flows for each corridor were developed from this database as well. The purpose of the commodity flow analysis was to understand the differences that exist between the corridors and to develop an understanding of how these differences might affect the results of the modeling.

2.4.3 HPMS

The HPMS Sample database was used to develop information on the average V/C ratios for the corridors being studied. The HPMS Sample database was obtained for the years 1993-2003. Each year of sample data contains approximately 110,000 records. Each record represents one segment and includes data on segment ID, state, county, route number, average annual daily truck traffic, peak and off-peak commercial vehicle percentages, V/C ratio, as well as many other items.

FHWA's list of "freight significant corridors" was used to identify many of the corridors used in this study. Additional corridors were added based on expert judgment or the need to increase regional coverage or include corridor types that were not represented. For instance, a number of major international trade lanes were added to increase the coverage of international commodity flows. A number of rural low-volume freight corridors were added to enhance coverage of this corridor type.

For each corridor identified, the relevant highway routes that would be used between a given city pair were identified. The set of HPMS segments representing these highway routes were then determined. One problem encountered was that, in some cases, routes designated in HPMS would change across years or between states. For instance, in one year a route would be identified as 40, and in another year a route would be identified as I40. There were also variations in how routes were designated between states.

In order to work around this, the data for each state were manually inspected to determine the route designations used for each corridor. Based on this analysis, a list of segments that characterized each corridor was developed.

HPMS data for each study corridor defined were aggregated to develop summary information describing average truck volumes and V/C ratios for each corridor. Truck volumes were obtained by multiplying the off-peak truck percentage by the AADTT for each segment. Corridor averages for truck volumes and V/C ratios were obtained averaging all the segments for each corridor, weighted by the segment length.

A number of problems were encountered. Many segments did not have data for all the years in the analysis. In addition, some segments had zero values in the off-peak truck percentage field. In order to compare data across years for each corridor, it was necessary to eliminate segments from the analysis that did not have data across all years or were missing data. For some corridors, data were unavailable for particular years. In order to address this, the years of data used in each corridor was adjusted to include the most segments, while at the same time making available the largest number of years of data available for analysis.

For example, if most segments were missing for a particular year of data, then that year would be omitted. In some cases, there were duplicate records for some segment IDs. These were dropped from the analysis. A number of corridors that were initially examined did not have enough data available for them. An additional 29 corridors to those used in the national analysis had enough information to develop corridor averages. Table 14 shows the total number of segments available and the number of segments used to develop the data for each of the 29 corridors. Also shown are the years of data that were available for each corridor.

Post data cleaning resulted in 55 corridors, representing both the corridors in the Phase II national analysis and newly added corridors, being usable for our sample.

Table 94. Number of Segments and Years Used to Characterize Each Additional Corridor

Corridor Name	Total Segments	Segments Available for Analysis	Years Covered
Dallas-El Paso	147	141	1997-2000
Memphis-Dallas	148	77	1993-1994 & 1996-2004
Memphis-Oklahoma City	230	70	1993-1994 & 1996-2004
Amarillo-Oklahoma City	155	121	1999-2001
Barstow-Amarillo	371	324	1997-2000
Barstow-Bakersfield	55	48	1994-2000
Barstow-Salt Lake City	234	180	1997-2004
Billings-Sioux Falls	186	140	1993-2004
Denver-Kansas City	111	54	1993-2003
Galveston-Dallas	53	50	1997-2000
Knoxville-Harrisburg	272	224	1996-2004
Laredo-San Antonio	36	34	1997-2000
Los Angeles-Tucson	259	244	1997-2000
Miami-Atlanta	205	163	1998-2002
Miami-Richmond	183	63	1994-2004
Nogales-Tucson	117	92	1996-2000
Philadelphia-NYC	55	16	1997-2002
Pittsburg-Detroit	51	30	1998-2003
Portland-Salt Lake City	365	270	1993-2004
San Antonio-Dallas	111	106	1997-2000
San Diego-Los Angeles	49	39	1994 -2000
Seattle-Billings	212	202	1993-2004
Seattle-Blaine	38	38	1993-2004
Seattle -Sioux Falls	375	321	1993-2004
St. Louis-Oklahoma City	205	194	1999-2002
Tucson-San Antonio	316	248	1996-2000
Chicago-Cleveland	44	16	1996-2004
New York City-Cleveland	683	651	1996-2004
Omaha-Chicago	188	108	1996-2004

2.5 Variables for Regional Discrimination

Having settled on a three-region approach, the project team developed improved variables with greater power for regional discrimination for inclusion in the original equations. These included replacement of GDP as the variable used to describe economic growth with Gross State Product (GSP), which was developed by selecting from the states in which the corridors begin and end. Use of GSP allowed for improved discrimination between regions by better tying performance improvements to local economic growth. National Producer Price Index (PPI) inputs, used for discounting income and truck rate variables, were replaced with localized Consumer Price Index (CPI) numbers developed by the Bureau of Economic Analysis.

Rate-data specific to each corridor, traffic flows, and capacity information provide the key corridor-level discrimination. The addition of regional economic variables enhances the ability of the model to distinguish between regions.

Table 15 describes some of the key characteristics of each region given the improved dataset.

Table 105. Descriptive Statistics of Corridors by Region

	Region	Average	Minimum	Maximum
Daily Truck Flows	All Corridors	6,133	642	12,731
	East Coast Corridors	7,113	642	12,433
	Midwest Corridors	6,835	789	12,731
	West Coast Corridors	4,666	1,726	8,338
Population	All Corridors	4,445,071	392,572	16,971,055
	East Coast Corridors	4,554,063	448,948	10,035,145
	Midwest Corridors	2,836,174	392,572	9,154,470
	West Coast Corridors	5,869,570	2,184,897	16,971,055
Per capita income '000 (real)	All Corridors	18.122	12.403	26.079
	East Coast Corridors	19.284	14.571	26.079
	Midwest Corridors	17.617	14.228	20.842
	West Coast Corridors	17.642	12.403	21.056
LTL Rates per mile (real)	All Corridors	0.615	0.165	1.902
	East Coast Corridors	0.749	0.217	1.902
	Midwest Corridors	0.654	0.256	1.368
	West Coast Corridors	0.472	0.165	1.684

2.6 Measuring Highway Performance

A primary requirement of the analysis methodology used to estimate the reorganization effect is to relate the demand for trucking and the rates that carriers charge shippers to a measure of highway performance. Although there are numerous measures that could be employed for this purpose (such as level-of-service indices), prior study suggests that the V/C ratio can serve as a reliable proxy to facility performance.[6]

Consequently, in this study, highway performance variables include V/C ratios and measures of delay along the corridors that are included in this analysis. In HPMS, V/C ratios represent the 30th busiest hour during a given year for a particular segment. V/C ratios for the corridors were estimated by taking the weighted average of the V/C ratios measured along individual segments (the length of the segments was used as the weight). Per-mile delay for a given corridor is the weighted average of all the delays on segments along the corridor.

Delay data were estimated by using the V/C ratios for selected segments and by estimating free flow and congested flow travel times. First, travel time on each segment was estimated assuming free flow of the traffic. Next, travel time with congestion was estimated as follows.

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[6] Cohen, Harry. 1999. "On the Measurement and Valuation of Travel Time Variability Due to Incidents on Freeways." *Journal of Transportation Statistics*. December. http://www.gcu.pdx.edu/download/2cohen.pdf.

The model applies a standard equation to derive actual (congested) speed from information on the V/C ratio and free flow speed. Two equations were considered and tested:

1. The Bureau of Public Roads (BPR) equation:

*Congested Speed = (Free-Flow Speed) / (1 + 0.15 * [volume/capacity] ^ 4)*

2. The Metropolitan Transportation Commission (MTC) equation:

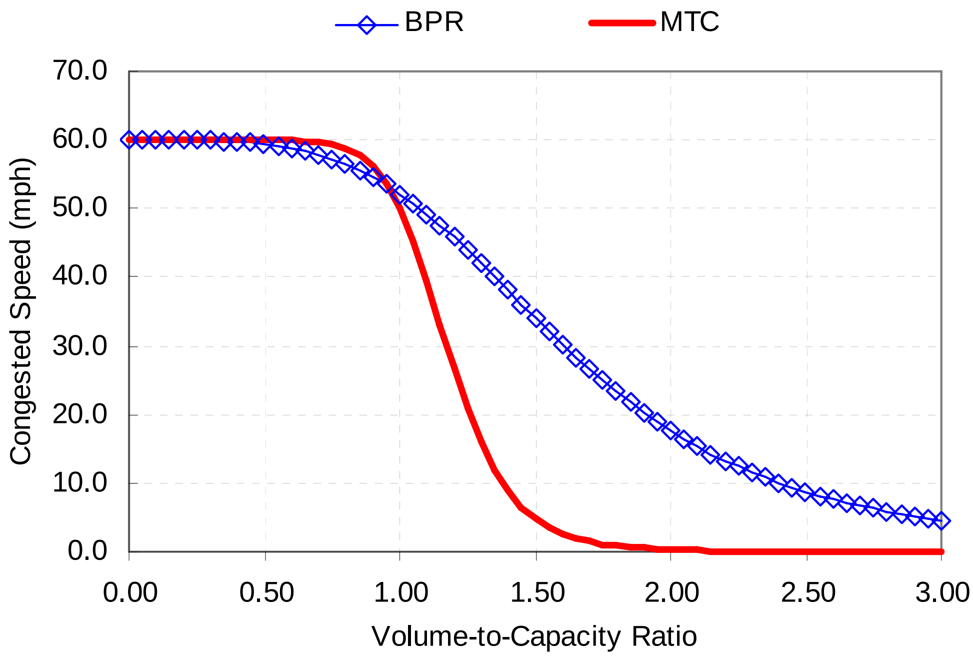
*Congested Speed = (Free-Flow Speed) / (1 + 0.20 * [volume/capacity] ^ 10)*

Finally, the difference between free-flow travel time and congested travel time is assumed to be the delay on this segment. The total delay figures were divided by the total length of the segments to estimate delay per mile as a highway performance measure for these corridors.

One approach considered, and then rejected, was not using a weighted average for delay per mile. A non-weighted approach would have the advantage of emphasizing the degree of delay in the highly congested segments of the corridor.

The weighted average approach is used in an attempt to describe the characteristics of an entire corridor. AADTT is the aggregate of the corridor segments. Therefore a delay factor that is also descriptive of the entire corridor is needed. By not weighting the delay by segment length, one would be vulnerable to accusations of over-valuing the portion of the corridor that is highly delayed and thereby over-valuing the relationship between performance improvements or reductions and demand.

Figure 3. Assumed Speed-Flow Relationships



Note: Assumes a free-flow speed of 60 mph.

3 EMPIRICAL RESULTS

3.1 Estimating Regional Elasticities of Demand

Chapter 2 described tests employed to select a geographic division. Based on the tests and empirical results achieved, the project team selected an approach for estimating the elasticity of demand with respect to highway performance. This section describes and reports the results obtained.

The following equation was estimated separately for each region (East, Central, and West), when demand for daily truck traffic is specified as a function of delay and real per capita income growth:

$$Log\left(AADTT_{c,t}\right) = \beta_c + \beta_1 Delay_{c,t} + \beta_2 Income_{c,t}$$

where:

AADTT	= Average annual daily truck traffic
Delay	= Average delay per mile
Income	= Real per capita income growth
t	= 1993, 1994, … 2003
c	= Corridor

β_c are corridor-specific constant, or fixed effects, where:

c = 1, …, 16 for East,
c = 1, …, 18 for Central,
c = 1,…, 21 for West

The coefficient β_1 from the log-lin specification of the model above might be transformed into the elasticity coefficient. In calculus notation, β_1 can be expressed as

$$\beta_1 = \frac{d\ AADT}{d\ Delay} \times \frac{1}{AADT},$$

And since the elasticity coefficient (elasticity of demand with respect to highway performance-delay) is defined as

$$E = \frac{d\ AADT}{d\ Delay} \times \frac{Delay}{AADT},$$

Therefore

$$E = \beta_1 \times Delay.$$

The regression results are summarized in Tables 16, 17, and 18 for the East, Central, and West regions, respectively. The models explain a high percentage of variability in freight demand measured by average annual daily truck traffic, at about 79% for the East, 95% for the Central, and about 94% for the West.

The coefficients on the delay and income variable have the correct signs and are statistically significant. The only exception is the coefficient on income in the model for the West region (see Table 18), which is insignificant at the 5% level. However, it is significant at the 10% level.

Table 16. Regression Results for the East Region

Dependent Variable: **LOG(AADTT)**				
Method: Pooled EGLS (Cross-section weights)				
Total pool (unbalanced) observations: 114				
Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***p-value***
Constant	8.847002	0.013168	671.8803	0.0000
Delay	-0.005117	0.002344	-2.182555	0.0315
Real Per Capita Income Growth	0.008595	0.004069	2.112079	0.0373
Fixed Effects:				
Atlanta-Jacksonville	0.125424			
Atlanta-Knoxville	0.323139			
Atlanta-Mobile	-0.233984			
Birmingham-Nashville	-0.232907			
Columbus-Pittsburgh	-0.054241			
Harrisburg-Philadelphia	0.012104			
Mobile-New Orleans	-0.259956			
Richmond-Philadelphia	0.44495			
Boston-New York City	0.032609			
Harrisburg-New York City	0.154785			
Detroit-Pittsburgh	-0.104274			
Philadelphia-New York City	-0.106916			
New York City-Cleveland	0.037953			
Miami-Richmond	-0.261302			
Miami-Atlanta	-0.176157			
Knoxville-Harrisburg	0.297654			
R-squared	0.78757	Mean dependent var		8.856317
Sum squared resid	1.534467	Durbin-Watson stat		1.020177

Table 17. Regression Results for the Central Region

Dependent Variable: **LOG(AADTT)**				
Method: Pooled EGLS (Cross-section weights)				
Total pool (unbalanced) observations: 138				
Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***p-value***
Constant	8.745927	0.011244	777.8526	0.0000
Delay	-0.069076	0.019921	-3.467458	0.0007
Real Per Capita Income Growth	0.00866	0.003502	2.473205	0.0148
Fixed Effects:				
Cleveland-Columbus	0.187098			
Dayton-Detroit	0.127923			
Indianapolis-Chicago	0.176353			
Indianapolis-Columbus	0.345631			
Kansas City-St Louis	0.192902			
Knoxville-Dayton	0.322572			
Louisville-Columbus	0.231423			
Louisville-Indianapolis	0.198499			
Nashville-Louisville	0.598196			
Nashville-St Louis	-0.398262			
St Louis-Indianapolis	0.189179			
Omaha-Chicago	0.01184			
Chicago-Cleveland	-0.206494			
Billings-Sioux Falls	-1.651534			
Amarillo-Oklahoma City	0.142811			
Memphis-Dallas	0.373809			
Memphis-Oklahoma City	0.165234			
St Louis-Oklahoma City	-0.349393			
R-squared	0.948179	Mean dependent var		8.744014
Sum squared resid	2.002249	Durbin-Watson stat		1.010586

Table 18. Regression Results for the West Region

Dependent Variable: **LOG(AADTT)**				
Method: Pooled EGLS (Cross-section weights)				
Total pool (unbalanced) observations: 129				
Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***p-value***
Constant	8.370945	0.011247	744.2735	0.0000
Delay	-0.015586	0.00573	-2.720287	0.0076
Real Per Capita Income Growth	0.005534	0.003323	1.665585	0.0987
Fixed Effects:				
Dallas-Houston	0.533012			
San Antonio-Houston	0.335623			
Denver-Kansas City	-0.672123			
Denver-Salt Lake City	0.044107			
San Francisco-Salt Lake City	-0.632347			
San Francisco-Los Angeles	0.247815			
Portland-Seattle	0.668379			
San Diego-Los Angeles	0.544992			
Seattle-Billings	-0.6264			
Seattle-Sioux Falls	-0.867802			
Portland-Salt Lake City	-0.276968			
Los Angeles-Tucson	0.097899			
Tucson-San Antonio	0.557139			
Laredo-San Antonio	-0.06466			
Nogales-Tucson	0.28696			
San Antonio-Dallas	0.669072			
Barstow-Bakersfield	0.257096			
Barstow-Amarillo	0.105583			
Barstow-Salt Lake City	-0.156777			
Galveston-Dallas	0.343733			
Dallas-El Paso	0.198615			
R-squared	0.940778	Mean dependent var		8.377655
Sum squared resid	1.913074	Durbin-Watson stat		0.776213

The semi-logarithmic functional form of the estimated equations requires the coefficients on the delay variable to be transformed in order to interpret them in elasticity terms. Table 19 shows this step and provides a summary of findings regarding the impact of changes in delay on freight demand.

Table 19. Implied Elasticity of Demand for Three Regions

Region	Coefficient on Delay	Implied Elasticity	Interpretation
East	-0.005117	-0.0076	Other things being equal, a 10% increase in delay per mile reduces freight demand by 0.076%.
Central	-0.069076	-0.0175	Other things being equal, a 10% increase in delay per mile reduces freight demand by 0.175%.
West	-0.015586	-0.0070	Other things being equal, a 10% increase in delay per mile reduces freight demand by 0.07%.

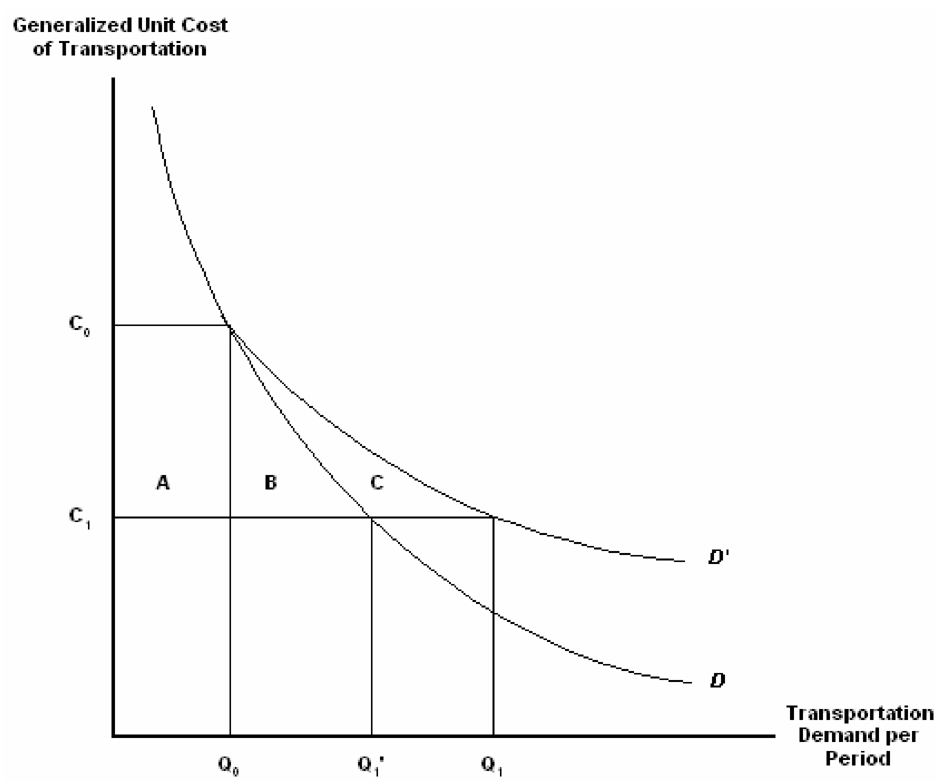
3.2 Calculating Regional Additive Freight Reorganization Benefits

3.2.1 Microeconomic Framework

Figure 4 gives a diagrammatic representation of the microeconomic framework which identifies the benefits of industrial reorganization. Area A represents the immediate benefits of a highway improvement to existing highway users (principally user time savings and reduced vehicle operating costs). Area B represents the immediate benefits accruing to users newly attracted to the highway by virtue of the improvement. Areas A and B together represent the benefits conventionally measured in a CBA.

Area C represents the value of efficiency gains to the economy due to industrial reorganization precipitated by the highway improvement. Industrial reorganization means the adoption of advanced logistics the firm's business case for which depend on the likelihood of a threshold level of reliability in highway performance. Defined as the ratio of area C to the sum of areas A and B namely, C/[A+B] expressed as a percentage, the "additive freight reorganization benefit" gives the percentage by which to increase the value of conventionally-measured benefits to freight traffic in order to approximate total benefits. In other words, the benefits inclusive of the reorganization effect.

Figure 4. Change in Consumer Surplus from Changing Demand for Transportation as a Function of Unit Generalized Transportation Cost



To assess the quantitative significance of the additive reorganization benefit, the study amassed quantitative evidence of the following:

Q_0: Initial demand for freight transportation (vehicle-miles (vm));
Q_1: New demand level as a result of highway improvements or policy change;
C_0: Initial unit generalized cost of transportation ($/vm);
C_1: New unit generalized cost of transportation ($/vm) following highway improvement or policy change; and
β_0 β_1 Immediate and post-reorganization slopes of the transport demand curves (respectively) with respect to the generalized cost of transportation, where generalized cost is the linear sum of vehicle operating expenses, delay-related expenses and unreliability-related expenses.

As discussed in the Phase II report on the national analysis, a variable-elasticity form of the present and post-reorganization demand curves (indicating constant returns to scale) provides a reasonable description of the available data. Specifically, the elasticity of demand for transport with respect to generalized cost is found to vary proportionately with generalized cost. This means that the elasticity is smaller when generalized cost is relatively low, and it is higher when generalized cost is relatively high, implying that demand is more sensitive to changes in highway conditions when congestion is high than when congestion is low. The form of the estimated demand curve is:

$$\text{Ln } Q = \beta_0 + \beta_1 * C$$

where Q is the quantity of transportation that would be demanded at a generalized cost of C, and where β_0 and β_1 are constants estimates with least-squares in a fixed-effects model that controls for between-corridor variations.

3.2.2 Additive Benefit Calculation Module

The additive benefit estimation module has been developed to accommodate outcomes from two broad categories of cost benefit analysis models: 1) standard user cost models, where the practitioner focuses on the reduction of user costs to existing highway users (baseline transportation demand, as measured by truck vehicle miles traveled (VMT) or other metrics) and ignore induced demand (additional highway trips brought about by the reduction in transport costs); and 2) consumer surplus models, where the practitioner explicitly accounts for induced demand using standard transportation demand elasticity estimates and estimates the change in consumer surplus resulting from a candidate highway investment.

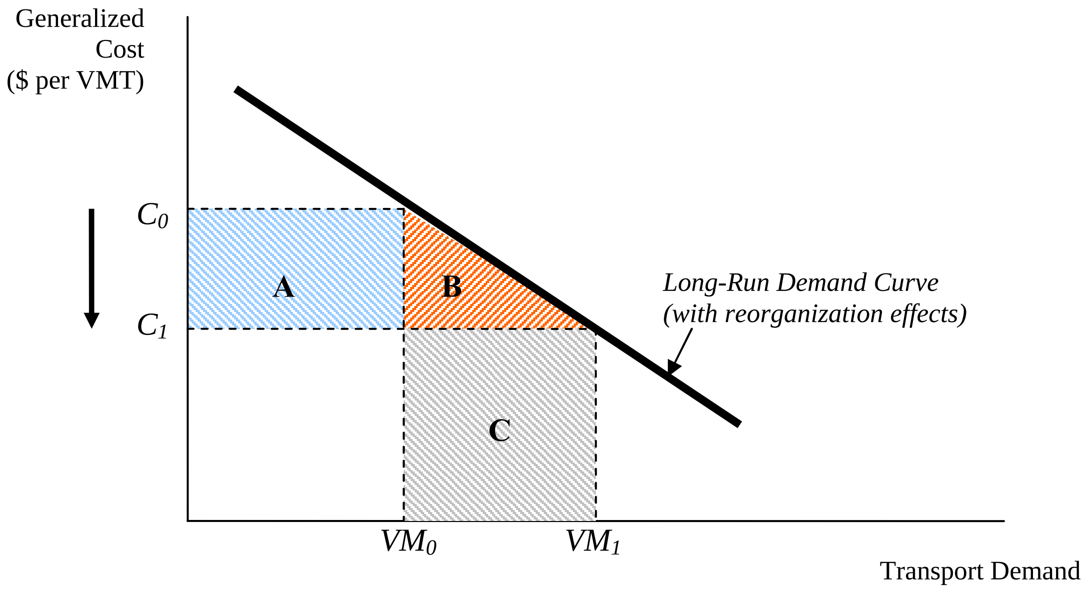
Additive Benefit Estimation with Standard User Cost Models

In Figure 5, the additive benefit would be estimated as the ratio of indirect benefits, represented by the red triangle B (the area between the long run transport demand curve and the C_1 line, and bounded by VM_0 and VM_1), to direct benefits, represented by the blue rectangle A (the area between the C_0 and C_1 lines and to the left of VM_0).

Additive Benefit Factor = Area B / Area A

With the application of the additive benefit factor, direct benefits (or benefits to existing highway users) are augmented to represent total benefits (direct plus indirect benefits). Total benefits within this framework are measured by the change in consumer surplus using the long-run demand curve for freight.

Figure 5. Additive Benefit Estimation with Standard User Cost Models, *An Illustration*



A numerical example of additive freight reorganization benefit estimation is provided in Table 20.

Table 20. Additive Benefit Estimation with Standard User Cost Models, *A Numerical Example*

#	Parameters	Value	Comments
	Unit Generalized Costs ($/vehicle mile)		
1	C_0	$3.8100	Assumption / input.
2	C_1	$3.4351	Assumption (10% reduction).
	Transport Demand (freight vehicle miles)		
3	VM_0	200,000	Assumption / input.
4	VM_1	220,434	Calculated using the nominal elasticity (b).
	Demand Curve		
5	Constant (a = VM_0*C_0 raised to power b)	49,879	
6	Full Price Elasticity (b)	-1.0382	
7	r = 1-(1/b)	1.9632	Estimation of area below demand curve and between VM_0 and VM_1.
8	a^(1/b)	2.98484E-05	
9	a^(1/b) * ((VM_1^r)-(VM_0^r))/r	81,679	
10	Delta VM * C_1	70,191	Estimation of area D.
11	VM_0 * Delta C	74,988	Estimation of area A.
12	Direct Benefits (Row 11)	$74,988	User cost savings.
13	Indirect Benefits (Row 9 minus Row 10)	$11,487	Estimation of area B (triangle).
14	**Total benefits (Row 12 +Row 13)**	**$86,476**	**Area A + B.**
15	**% Indirect / Direct**	**15.3%**	**The additive benefit factor.**

The full price elasticity (b) on row 6 is estimated by considering the combined impact of the elasticity of demand with respect to out-of-pocket costs (direct vehicle operating costs or shipping rate) and a measure of the long-run elasticity of demand with respect to highway performance (transit time and reliability).

For the purpose of this study, the elasticity of freight demand with respect to transportation costs was derived from the literature (-0.97, Tae Oum). The long-run elasticity of demand with respect to highway performance was estimated econometrically, as part of Phase II and Phase III of the study.

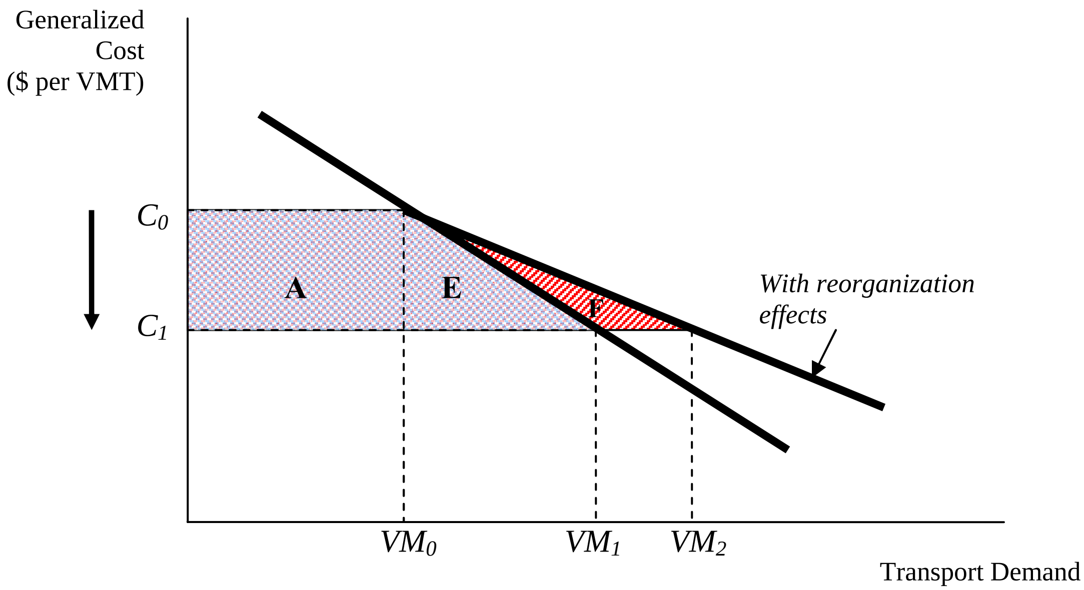
Additive Benefit Estimation with Consumer Surplus Models

In Figure 6, the additive benefit factor would be calculated as the ratio of area F (the area between the long-run transport demand curve "with reorganization effects," the standard short run demand curve, and the C_1 line) to a standard measure of consumer surplus, represented by area A plus area E.

Additive Benefit Factor = Area F / (Area A + Area E)

In other words, the additive benefit factor is estimated as the percentage change in consumer surplus resulting from incremental transport demand along the long-run demand curve. Incremental transport demand is illustrated by the shift from VM_1 to VM_2 on Figure 6.

Figure 6. Additive Benefit Estimation with Consumer Surplus Models, *An Illustration*



A numerical example of additive benefit estimation with consumer surplus models is provided in Table 21.

Table 21. Additive Benefit Estimation with Consumer Surplus Models, *A Numerical Example*

#	Parameters	Standard Consumer Surplus Model Output	Augmented Output and Additive Benefit Estimation
	Unit Generalized Costs ($/vehicle mile)		
1	C_0	$3.8100	$3.8100
2	C_1	$3.4351	$3.4351
	Transport Demand (freight vehicle miles)		
3	VM_0	200,000	200,000
4	VM_1	219,400	220,434
	Demand Curve		
5	Constant (a = VM_0*C_0 raised to power b)	54,642	49,879
6	Full Price Elasticity (b)	-0.9700	-1.0382
7	r = 1-(1/b)	2.0309	1.9632
8	a^(1/b)	1.30602E-05	2.98484E-05
9	a^(1/b) * (($VM_{1\text{ or }2}$^r)-(VM_0^r))/r	77,614	81,679
10	Delta VM * C_1	66,641	70,191
11	VM_0 * Delta C	74,988	74,988
12	Direct Benefits (Row 11)	$74,988	$74,988
13	Indirect Benefits (Row 9 minus Row 10)	$10,973	$11,487
14	**Total benefits (Row 12 +Row 13)**	**$85,962**	**$86,476**
15	**% change in "total benefits"**		**0.60%**
16	**% change in "indirect benefits"**		**4.7%**

Discussion

Both approaches may be developed for the Phase III tool so that analysts not estimating user costs prior to calculator use would still be able to calculate an additive freight reorganization benefit factor. A review of current CBA approaches suggests that most analysts would likely use the Consumer Surplus approach.

In both models, the calculation is sensitive to the difference between current and anticipated demand (AADTT) and user costs, which are items that will vary project to project. It is proposed that the model also calculate the transformation of the elasticity on a project-by-project basis, factoring in the existing delay on the segment being improved. This would also add variability and local specificity to the additive benefit calculation.

Both approaches will be further assessed and refined as part of Phase III-B.

3.2.3 Regional Additive Benefit Factors

The process of computing the additive benefit factor, explained above, was then applied to the three regions of interest. Each region is defined by its elasticities of demand with respect to performance and price.

Table 22 shows the regional elasticities of demand with respect to highway performance estimated through regression analysis in earlier steps.

Table 112. Elasticity of Demand with Respect to Highway Performance

Region	Elasticity
East	-0.0076
Central	-0.0175
West	-0.007

Several difficulties were encountered in Phase II for the development of price elasticity. Both price and demand elasticity are required for the estimation of an additive benefit factor. One acknowledged and accepted value for price elasticity (derived from estimates by Tae Oum in a national analysis is currently used for each of the three corridors. Therefore the value of -.97, as estimated by Tae Oum, is used here. However, an attempt was made to regionalize this value as follows:

Table 123. Elasticity of Demand with Respect to Price

US	Regional Differences* when compared to the national level (-0.97 = 100%)		Regional Estimate of Elasticity of Demand wrt Price	
	East	115.3%	East	**-1.12**
-0.97	Central	99.6%	Central	**-0.97**
	West	86.9%	West	**-0.84**

Note: The regional differences were derived using a proxy variable for which regional data were available. The proxy variable, in this case, is the average V/C ratio. Relating the V/C ratio to the elasticity of demand with respect to price is based upon two assumptions:

1. *The high level of congestion is an indicator of high-level economic activity.*
2. *The demand for transportation with respect to price is more elastic in areas with a higher-level economic activity.*

Using the two elasticities presented above and the computer model described above, sample regional additive benefit factors were calculated, as shown in Table 24. These represent an additive benefit factor for the typical corridor in each regional sample and are provided as an illustration of the additional freight benefits would have been for the average corridor in each region.

Each corridor developing a logistics benefit estimation will derive a unique additive benefit factor based on certain regional and national characteristics:

- Regional elasticity
- Price elasticity

And certain corridor-specific characteristics:

- AADTT
- Delay

- Predicted traffic demand
- User costs
- Calculated freight benefits

Table 134. Regional Additive Benefit Factors

Region	East	Central	West
Additive Benefit Factor	**16.7%**	**14.8%**	**12.7%**

3.2.4 Commodity Flow Data Analysis

Analysis of FAF commodity flow data was conducted for the East, Central, and West regions. Data available included top commodities by volume (weight) and by value. The data describe regional mixes of freight movement that are similar but not the same.

From a value perspective, finished and semi-finished goods rank high in the mix of goods in each region; however, the specific goods vary by region. Except for the Central region, finished goods were not significant contributors of freight volume. In the Central region, machinery and motorized vehicles were the ninth and tenth largest categories of shipment by volume.

Tables 25 and 26 present the top commodities by thousand tons and dollar value. This greater than average volume of finished and semi-finished goods in the Central region may explain the higher than average elasticity of demand with respect to highway performance in the region.

Table 145. Top Commodities Transported in Three Regions (Thousand Tons)

Region	Commodity	Thousand Tons
East	Gravel	7,173.3
	Waste/scrap	5,999.1
	Cereal grains	5,110.0
	Other foodstuffs	4,083.3
	Unknown	3,956.9
	Nonmetal mineral products	3,576.3
	Wood prods.	3,154.3
	Mixed freight	3,024.1
	Base metals	2,916.3
	Nonmetallic minerals	2,322.5
Central	Base metals	2,866.0
	Nonmetal mineral products	2,480.8
	Gasoline	2,013.9
	Other foodstuffs	1,795.7
	Mixed freight	1,621.7
	Unknown	1,587.5
	Waste/scrap	1,471.8
	Gravel	1,385.6
	Machinery	1,164.6
	Motorized vehicles	1,115.2
West	Nonmetal mineral products	14,739.6
	Gravel	7,703.2
	Gasoline	7,593.5
	Coal, n.e.c.	4,344.5
	Mixed freight	3,707.7
	Other foodstuffs	3,488.1
	Unknown	3,415.4
	Wood prods.	3,136.2
	Natural sands	2,623.0
	Waste/scrap	2,491.3

Table 26. Top Commodities Transported in Three Regions ($Million)

Region	Commodity	$M
East	Mixed freight	11,824
	Machinery	10,247
	Motorized vehicles	6,054
	Textiles/leather	5,047
	Pharmaceuticals	4,891
	Other foodstuffs	4,399
	Electronics	3,951
	Printed prods.	3,788
	Unknown	3,690
	Misc. manufacturing products	3,457
Central	Machinery	7,420
	Mixed freight	6,568
	Motorized vehicles	5,306
	Base metals	2,672
	Pharmaceuticals	2,618
	Electronics	2,159
	Articles-base metal	1,907
	Misc. manufacturing products	1,877
	Other foodstuffs	1,826
	Plastics/rubber	1,623
West	Mixed freight	17,672
	Machinery	13,279
	Electronics	13,224
	Motorized vehicles	8,732
	Other foodstuffs	5,366
	Textiles/leather	5,303
	Chemical prods.	4,811
	Articles-base metal	4,807
	Gasoline	4,582
	Misc. manufacturing products	4,322

4 SUMMARY OF FINDINGS

Using the methodology developed under the national analysis of highway performance and demand for freight movement, this study assesses the reorganization impact of performance improvements at a regional level. Panel data analysis indicates that demand for shipping services varies with the expected speed of delivery and that differing levels of variance can be expected in different geographic areas. As highway performance improves, demand for freight movement increases in each region. The impact of improvement is strongest in the Central region. This is possibly due to the greater than average volume of finished and semi-finished goods moved through the Central region.

Table 27 provides a summary of findings regarding the impact of changes in highway performance on freight demand for the three studied regions.

Table 27: Implied Elasticity of Demand for Three Regions

Region	Coefficient on Delay	Implied Elasticity	Interpretation
East	-0.005117	-0.0076	Other things being equal, a 10% increase in delay per mile reduces freight demand by 0.076%.
Central	-0.069076	-0.0175	Other things being equal, a 10% increase in delay per mile reduces freight demand by 0.175%.
West	-0.015586	-0.0070	Other things being equal, a 10% increase in delay per mile reduces freight demand by 0.07%.

Overall, the estimated impact ranges from 0.07% to 0.175% reduction in freight demand (measured by average daily truck traffic) for every 10% increase in measured congestion.

These results should be interpreted with some caution, however, given the important difficulties and data limitations encountered in the course of this project. In particular, a relatively short period of eleven years and various problems with publicly available data (on highway performance, truck rates, and corridor-specific control variables) affected the reliability of regression results.

This study estimates total benefits associated with highway investment by establishing a relationship between highway performance measures and freight demand. An illustrative additive freight reorganization benefit factor was estimated to capture the reorganization impact of highway investments for a typical corridor in each region. This factor is used to estimate the total benefits where the existing data allows estimation of only the direct effects. The additive benefit factor is sensitive to the level of demand and the level of delay. As such, a small rural road without predicted demand post-improvement would have a negligible additional benefit. Moreover, as the additive benefit factor is applied to AADTT travel time savings, non-freight-trafficked roads could be expected to apply a negligible benefit factor to a minimal AADTT savings. Table 28 summarizes the range of the implied elasticities and example additive benefit factors for each region.

Table 28. Probability Ranges for Elasticity and Additive Benefit Factors

Region	East	Central	West
Additive Benefit Factor	**16.7%**	**14.8%**	**12.7%**

These results suggest there will be 13% to 17% of indirect benefits in addition to estimated direct freight benefits of highway improvements for a typical corridor, depending on the region of interest.

APPENDIX 1. SUPPLEMENTARY DATA TABLES

Summary statistics for the dataset are presented in this Appendix.

Table 29. Summary Statistics for Panel Data

Variable	Mean	Standard Deviation	Minimum	Maximum
Length of Haul	384	284	69	1,535
Total Personal Income (‘000)	114,590,393	99,285,394	9,186,566	414,643,541
Farm Income (‘000)	276,674	329,236	19,937	1,842,296
Population	4,039,128	3,375,173	376,082	16,167,324
Per Capita Income	26,850	4,076	19,978	40,136
Employment	2,522,866	2,003,806	210,800	8,593,668
Gross State Product (‘000,000)	374,003	261,472	20,640	1,113,965
Annual Change in Consumer Price Index	2.49%	0.08%	2.41%	2.62%
LTL Rates ($/trip)	298.2	72.8	159.1	488.0
LTL Rate ($ per mile)	1.04	0.60	0.32	3.08
Volume to Capacity Ratio	0.53	0.20	0.16	1.03
Average Annual Daily Truck Traffic	6,388	2,174	1,286	10,999

APPENDIX 2. ECONOMIC FRAMEWORK

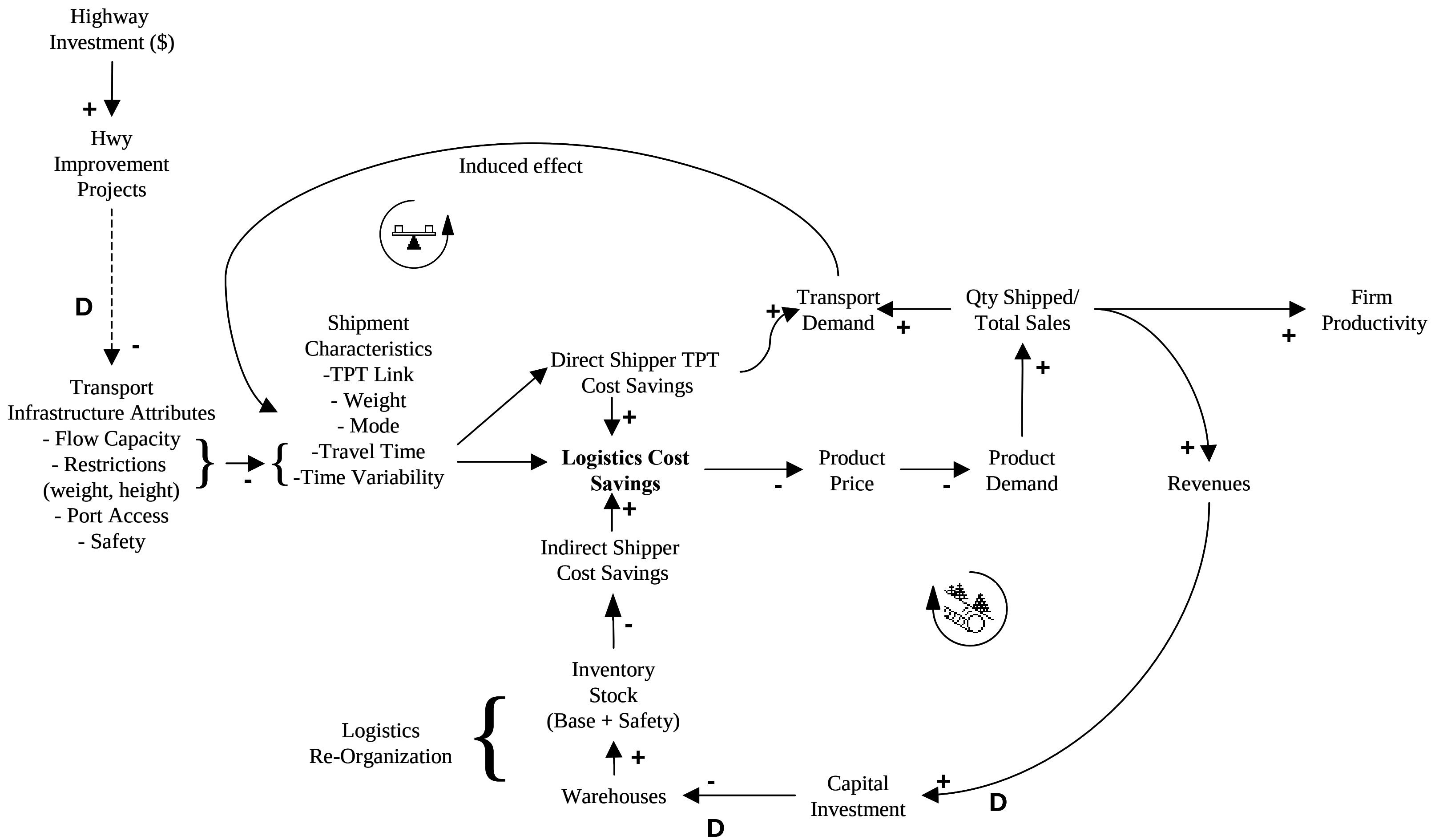
Appendix 2 provides an overview of the microeconomic framework developed in previous study within which the freight-related economic benefits and costs of transportation improvements can be measured. A key objective of the framework is to ensure that BCAs recognize the gains in economic welfare that follow from the propensity of industry to adopt productivity-enhancing “advanced logistics” in response to transportation infrastructure improvements.

Framing the Problem

The term logistics pertains to the way firms organize themselves in relation to transportation, warehousing, inventories, customer service and information processing. The phrase “advanced logistics” is shorthand for technologies and business processes that permit firms to reduce costs by substituting transportation, e-commerce, and just-in-time deliveries for large inventories, multiple warehouses, and customer service outlets. Firms can reorganize in response to transportation infrastructure improvements to reap the rewards of advanced logistics.

Investment in highway improvement projects, both infrastructure and info-structure, will affect attributes of links within the U.S. freight transportation system. For example, flow capacity may be increased by the addition of more lanes, increases in speed limits, limited access highways, and operational/ITS improvements. There also may be fewer restrictions on truck weights and improved bridge clearances. Further improvements could be made to ports/customs processes that lead to increases in net system traffic flow. These types of improvements result in travel-time savings and increased reliability. These and other downstream effects are shown diagrammatically in Figure 7. Productivity gains occur within industries at the level of the firm. The potential for firms to reorganize their logistics systems and policies will occur according to specific trade-offs between logistics components.

Figure 7. Freight Economics Influence Diagram



Nature of Reorganization

Logistics systems are key enablers of economic development. Governments can adopt policies that will encourage overall logistics efficiency. In some instances, logistics costs can amount to 30% of delivered costs. In efficient economies, these costs can be as low as 9.5%.[7] Transportation charges account for nearly 40% of all logistics costs. Trucks also serve as the access and egress mode for maritime, air, intermodal, and many rail trips. Short haul trips are therefore an essential component of the economy.

Logistics costs are driven by activities that support the logistics process. Trade-offs are possible among the elements of logistics costs in order to minimize total costs given customer service level objectives. The main components of logistics costs are:

- Transportation costs
- Warehousing costs
- Order processing/information systems costs
- Lot quantity costs
- Inventory carrying costs

These elements are inter-related, and various trade-offs exist. It is worth noting that some of these trade-offs are not realized in a continuous way. Consolidation of warehouses occurs at a discrete point in time and will be different for various firms based on their decision to invest in new logistics systems. The primary goal of a firm in developing its logistics strategy is to provide customer service while reducing costs, thereby increasing profits and competitiveness.

Changes in Logistics Network Infrastructure

A firm could re-organize its logistics in many ways as a result of lower transportation costs. For example, it could reduce the number of warehouses and increase the use of transportation services. Four factors influence the number of warehouses a firm chooses to maintain: 1) cost of lost sales, 2) inventory costs, 3) warehousing costs, and 4) transportation costs.

- **Cost of Lost Sales**. The cost of lost sales is the most difficult to quantify. It generally decreases with the number of warehouses and varies by industry, company, product, and customer. The remaining cost components are more consistent across firms and industries.

- **Inventory Costs**. Inventory costs increase with the number of warehouses because firms maintain a safety stock of most or all products at each facility.

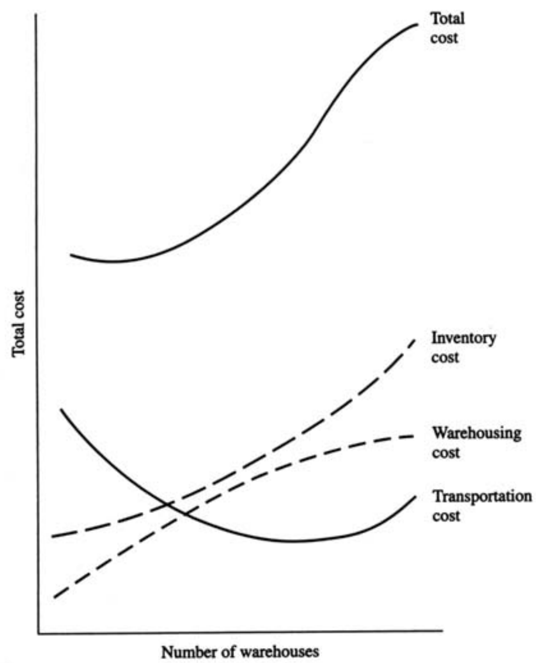
- **Warehousing Costs**. More warehouses mean more space owned, leased, or rented. Fixed costs across many facilities are larger than the marginal variable costs of fewer locations.

- **Transportation Costs**. Transportation costs initially decline as the number of facilities increases due to proximity. Costs eventually increase when a firm maintains too many warehouses due to the combination of inbound and outbound transport costs.

[7] Roberts, P.O. *Logistics Supply Chain Management: New Directions for Developing Economies*, on behalf of the World Bank, Feb. 1999.

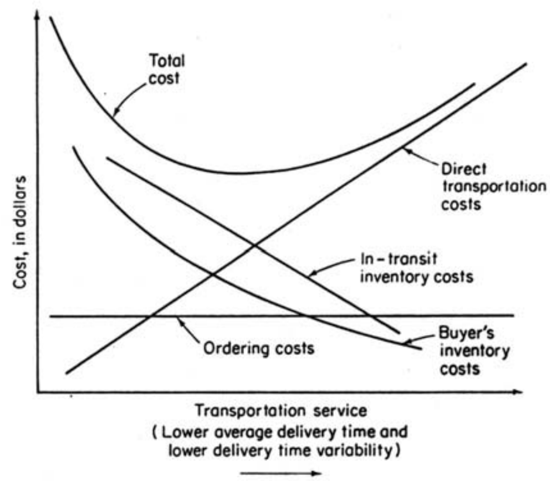
A firm seeking to minimize total costs, which is the sum of the above components, could balance all cost components by solving a multi-facility location problem (as depicted in Figure 8). As transportation costs decline, possibly due to highway infrastructure investment, the minimum total cost generally will be achieved by maintaining fewer warehouses. The nature and timing of reorganization will occur at different points for each firm. Sufficient potential gains will need to be realized before an investment hurdle rate is exceeded.

Figure 8. Relationship between Total Logistics Cost and Number of Warehouses Due to Changes in Inventory Policy



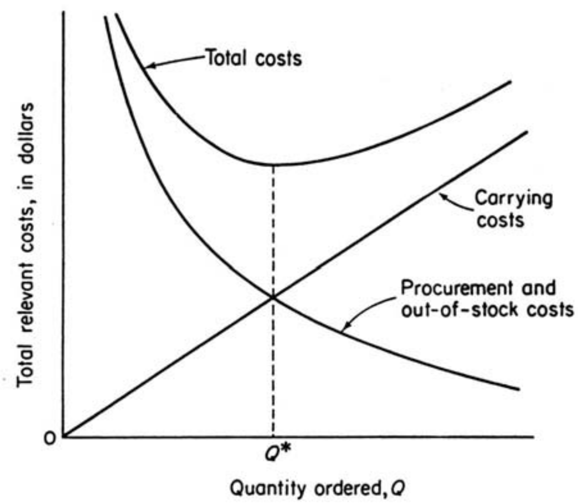
A simpler, more rapid response to lower transportation costs, improved transit times, and reduced delivery time variability is a change in a firm's inventory policy. To demonstrate the direct relevance of travel time and travel-time variability on total logistics costs, consider a simple example where a firm has a central production plant and a single warehouse located within its market area such as in Figure 9.

Figure 9. Generalized Cost Trade-offs for Transportation Services



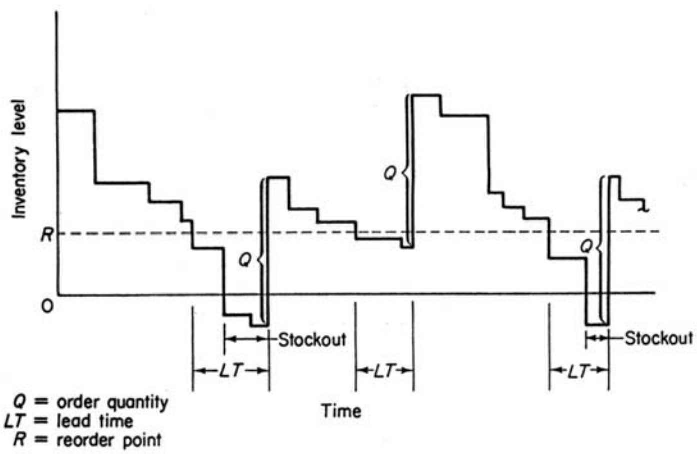
As direct transportations costs decrease, the minimum total logistics cost point moves to the right. A profit-maximizing firm would increase the demand for transportation services. An increase in travel time and variability can be costly. Money tied up in inventory isn't earning interest. The longer it takes to ship perishable goods, the more they depreciate. It's the near elimination of travel-time variability that makes just-in-time inventory management possible. Figure 10 presents the basic inventory cost trade-offs.

Figure 10. Basic Inventory Cost Trade-offs



Stockout and backorder costs[8] are a function of the lead-time distribution of supply. Lead times are a function of travel-time and travel-time variability (i.e., reliability) as shown in Figure 11. Reductions in either travel-time and/or travel-time variability will directly impact various logistics cost components and may trigger reorganization at the level of the firm. Shorter and more predictable lead times can enable firms to reduce their reorder points and average stock levels while maintaining the same level of service. This reduces logistics carrying costs.

Figure 11. Inventory Levels Under A Fixed Order Quantity-Variable Order Interval Policy.



A paper by Mohring and Williamson[9] provides a formal analysis of "reorganization effects," the adjustments in logistical arrangements that shippers make in response to lower costs of freight movement. Typically, these adjustments involve fewer warehouses and more miles of truck movement as shippers take advantage of lower freight costs to consolidate storage facilities and reduce inventory costs. These effects are the principal source of benefits not captured in the conventional approach to BCA.

The ability of a firm to exploit manufacturing scale economies can be limited by the cost of transporting its products to market. A reduction in unit transportation costs can yield two types of benefits. First, it provides "direct" benefits by reducing the costs of distributing the outputs of existing manufacturing facilities. Second, a transport-cost reduction can make it more efficient to expand the outputs and marketing areas of individual production facilities and take greater advantage of manufacturing scale economies. This use of more transportation-intensive means

[8] Stockout periods occur when a product is not available. A key element of customer service, stockout periods can lead to out-of-stock costs incurred when an order is placed but cannot be filled from inventory. These costs can be classified as lost-sales costs and back-order costs. Back-orders often generate additional order processing as well as transportation costs when they are not filled through the normal distribution channel.

[9] Mohring, H., Williamson, H.F. "*Scale and Industrial reorganization economies of transport improvements*," Journal of Transport Economics and Policy, Sept. 1969.

of production and distribution in response to reduced transportation costs generates "reorganization" benefits.

Logistics management continues to evolve with the adoption of e-business practices and various forms of JIT delivery. E-commerce and e-business will increase trade. Growing trade means more freight movements. Note that the nature of these movements may evolve to more single-package deliveries requiring additional transport services. New information technologies also enable JIT logistics systems that rely on dependable and inexpensive transportation. E-business may affect the nature and extent of transportation demand as well as the rate of industrial reorganization, but the logistics principles remain the same.

Microeconomic Framework

The framework developed is general in the sense that it captures benefits of any highway improvement.[10] The introduction of ITS, for instance, to manage congestion would translate into reduced travel times and enhancing reliability. Benefits of any initiative affecting overall logistics costs,- such as vehicle operating limits, could be considered within the context of the framework that is presented in this sub-section.

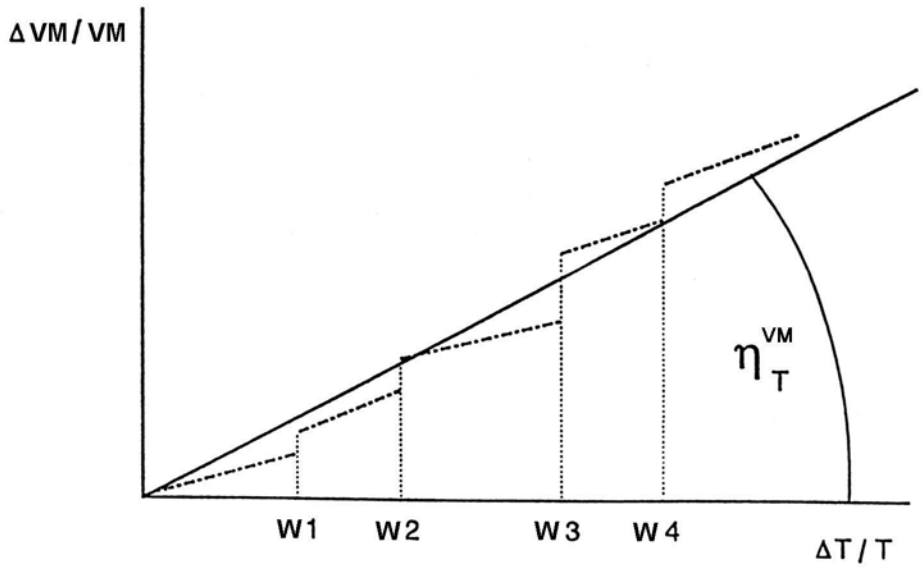
Approach

In *Measuring the Relationship between Freight Transportation and industry Productivity*,[11] a method was developed to estimate the elasticity of logistics cost with respect to travel-time savings, call it η_T^C. This quantity was derived from a sample of firms' responses (cost savings) to travel-time improvements. A similar approach can be used to determine a firm's elasticity of demand for transportation as a result of travel-time savings and changes in logistics, call it η_T^{VM}. This last quantity encapsulates the firm's response to highway improvements in terms of new transportation demand as a result of possible substitutions. The quantity is shown in Figure 12 for a sample of several firms. The points at which reorganization occurs, W_i, may be specific to individual firms. The trend will allow the inference of effects (slope of the curve) over a range of firms.

[10] Both infrastructure and info-structure changes.

[11] NCHRP 2-17(4), *Measuring the Relationship between Freight Transportation and industry Productivity, Final Report*, HLB Decision Economics Inc., June 1995.

Figure 12. Aggregate Relative Change in Transportation Demand



To calculate benefits of road improvements, the elasticity of transportation demand with respect to transportation cost η_C^{VM} is required. A simple relationship can be established between these two elements as follows:

$$\eta_C^{VM} = \frac{\Delta VM / VM}{\Delta C / C}$$

$$= \frac{\dfrac{\Delta VM / VM}{\Delta T / T}}{\dfrac{\Delta C / C}{\Delta T / T}}$$

$$= \frac{\eta_T^{VM}}{\eta_T^{C}}.$$

This expression is the ratio of the elasticity of transport demand with respect to travel time η_T^{VM}, and the elasticity of transportation cost with respect to travel time η_T^{C}. Both of these might be estimated using a suitable sampling methodology within various industries.

Estimation of transportation user costs should not present a problem. For instance, assuming that wages accounted for 30% of transport operating costs, a 20% decrease in travel time could result in a 6% decrease of direct transportation cost per vehicle mile. In reality, other substitutions could also take place.

The fundamental determination of the demand curve for transportation services involves two quantities, price and vehicle miles used/traveled. The change in each of these components was derived as a function of some third dimension,- travel time and/or travel time variability. This third dimension is a function of highway investment. Once time savings are known or estimated, logistics cost savings estimation can be carried out at the firm level to include logistics reorganization effects. Each firm is different, but with a representative sample, the general response trend can be quantified over specific industries. Note that the third dimension could also include changes in vehicle capacity or service hours, thereby increasing freight throughput. This approach has the added advantage that the demand for transportation services can be aggregated across markets or commodities and therefore facilitating benefits estimation for highway-network improvements. Aggregation using a product demand curve may be difficult due to the varying nature of products.

Changes in Output/Product Demand

The demand for freight services is derived from the demand for final products carried. Because freight transport is closely related to land-use patterns, it is also important to consider influences affecting industrial location and distribution. Transport demand could thus increase due to two effects. First, logistics reorganization may result in substitution of additional transport for inventory and holding locations. Second, savings from lower transportation and overall logistics costs may be passed on to consumers and result in an increase of consumer product demand. This increase in demand is embodied in increases in transportation services required. Both these components must be part of the effective demand upon which net benefits are derived.

Competitive Market

The benefits of infrastructure investment can be derived from the change in consumer surplus for transportation demand. In general form, it is possible to write:

$$\begin{aligned} Ben_{Net} &= \Delta CS \\ &= CS_1 - CS_0 \\ &= \left(\int_0^{q_1} p(q)dq - p_1 q_1 \right) - \left(\int_0^{q_0} p(q)dq - p_0 q_0 \right). \\ &= \int_{q_0}^{q_1} p(q)dq - p_1 \Delta q \;\; + q_0 \Delta p \end{aligned}$$

In this case, price $p(q) = C(VM)$ is the cost of transport per vehicle mile at a level of demand $q = VM$. This general expression encapsulates the net benefit of the infrastructure improvement in the absence of marginal cost pricing.

One approach to evaluating the integral above would be to assume constant elasticity of demand near the present demand level. A general expression for a constant-elasticity-of-demand schedule is $Q = a / P^{b}$ where Q is the quantity sold at a price of P and where a and b are constants.

$$Ben_{Net} = \Delta CS$$
$$= \left(\frac{a}{q_0 q_1} \right)^{1/b} \left(\frac{2(b-1)q_0^{(1+1/b)} + q_1 q_0^{1/b} - (2b-1)q_1^{1/b} q_0}{(b-1)} \right)$$

Monopoly

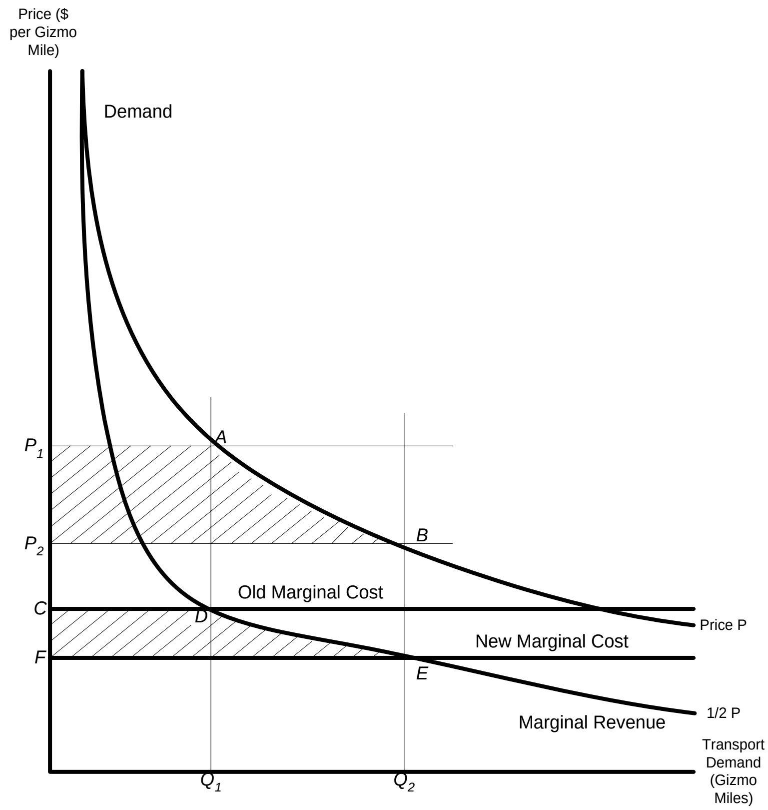
In the case of a monopoly, it was shown that net benefits involve both a consumer's gain as well as a producer's gain. This is true for transportation and other markets.

$$Ben_{Net} = \Delta CS + \Delta CS'$$

The consumer's gain is ΔCS. The producer's gain $\Delta CS'$ has the exact same form, except that the price is replaced by marginal revenue $\frac{\partial R}{\partial q}$. The new price, which maximizes the monopolist's profit, can be approximated as $B = A - \Delta C_{Log}$. These two areas are illustrated graphically below. In the case of a monopoly, two areas must be considered, but the overall procedure for each is the same. The expression is:

$$Ben_{Net} = \Delta CS + \Delta CS'$$
$$= \left(\frac{2b-1}{b} \right) \left(\frac{a}{q_0 q_1} \right)^{1/b} \left(\frac{2(b-1)q_0^{(1+1/b)} + q_1 q_0^{1/b} - (2b-1)q_1^{1/b} q_0}{(b-1)} \right)$$

Figure 13. Benefits in the Presence of Monopoly



Accounting for Non-Marginal Cost Pricing

A simple adaptation of the cost-benefit methodology can be used to correct for non-marginal cost pricing. If TC is the total cost of providing a road with N trips made along it per unit time, then this total cost can be defined as:

$$TC = N \cdot C(N,K) + f(K)$$

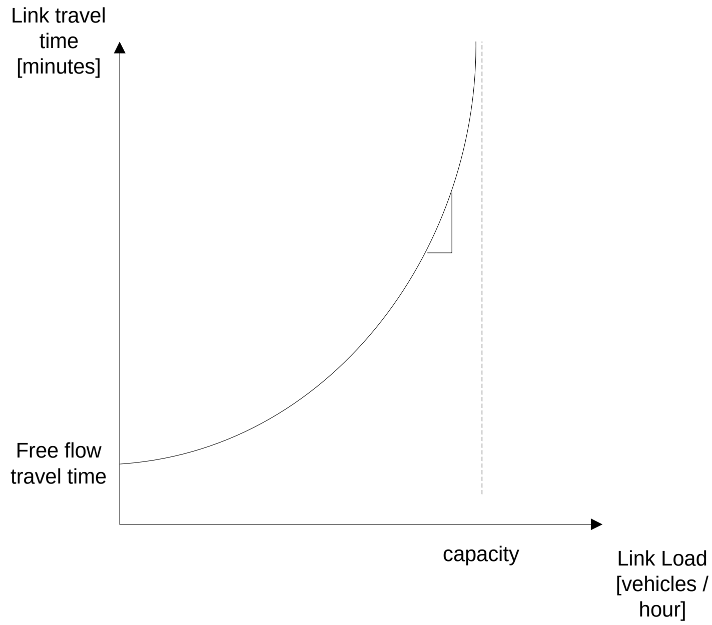
where C is the cost of one trip to a vehicle and $f(K)$ is the cost per time period of providing K units of road capacity. The short term marginal cost becomes:

$$\frac{\partial TC}{\partial N} = C(N,K) + \frac{N \cdot \partial C}{\partial N}$$

The N^{th} vehicle then incurs a cost itself and imposes a cost on other users. This is demonstrated graphically in Figure 14.

The CBA could be revised with estimated marginal social cost prices for the use of transport services at a given level of use. These estimated price adjustments could have a wide margin of uncertainty. However, if a highway improvement option remains justified and highly ranked compared to other competing alternatives in the presence of approximate marginal cost pricing, then there is good confidence that the option valuations are robust to underlying assumptions. The actual estimation of marginal cost prices is work to be carried out as part of a follow-on task.

Figure 14. Typical User Link Travel Time Graph and Marginal Cost.



Approach Summary

In summary, the microeconomic framework rests on estimating the change in consumer surplus reflected in the 'shift' in the demand curve for freight transport that follows the improvement. This provides significant added value to previous research such as the 'shift' in the demand curve now reflects increasing output as well as trade-offs between transportation spending and total logistics costs.

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16. Abstract

The Freight Benefit/Cost Study is a multi-year effort originating in the Federal Highway Administration, Office of Freight Management and Operations, supported by HDR|HLB Decision Economics and ICF International . The Freight Benefit/Cost Study project has gone through three phases of development. Phase I focused on developing the theory and logic. Phase II determined the sensitivity of a firm to infrastructural investment on a national level. This phase, (Phase III) establishes the approach, sensitivities and data inputs required to calculate long-term benefits of highway-freight infrastructural investment on a regional level and will investigate the construction of a tool for state and local entities to estimate additional benefits derived though logistics rearrangements from highway performance improvements.

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