Metropolitan Mobility Alliance

Northeast Corridor Greater Cincinnati Transit Benefit-Cost Analysis

Technical Report

MARCH 25, 2002

Metropolitan Mobility Alliance

Northeast Corridor–Greater Cincinnati Transit Benefit-Cost Analysis

Technical Report

Prepared By:
HLB DECISION ECONOMICS INC.
1010 Wayne Avenue, Suite 300
Silver Spring, MD 20910

March 25, 2002
HLB Reference: 6650
File Name: TechnicalReport.doc

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

1.1 Purpose

This is the technical report accompanying the summary report "Moving Forward, The Economic and Community Benefits of Transportation Options for Greater Cincinnati." It includes all the graphs, tables and discussions presented in the summary report. It also includes a detailed description of the methodology and assumptions used by HLB to derive the estimates of light rail costs and benefits.

1.2 Plan of the Report

After this introductory chapter, Chapter 2 explores various transportation investment options aiming at reducing congestion in the I-71 Corridor. Chapter 3 describes the criteria used by the Federal Transit Administration to evaluate New Starts projects for discretionary funding. The Chapter also reviews the New Starts submittals for the Ohio-Kentucky-Indiana Regional Council of Governments and provides recommendations for improving the results of the I-71 Corridor project evaluation. Chapters 4 through 6 describe the methodology used for the estimation of congestion management benefits, affordable mobility benefits and community development benefits. The chapters also present the outcomes of the estimation process. Chapter 7 is a summary chapter showing total light rail benefits over the life cycle of the project. Light rail costs are presented in Chapter 8. Chapter 9 explores the economic impacts of constructing and operating a light rail system in Cincinnati. The potential for infrastructure cost avoidance associated with a more compact development is analyzed in Chapter 10. The net present value and rate of return of the project are estimated in Chapter 11. The Appendices at the end of the report provide supporting materials and references.

2. BACKGROUND AND PERSPECTIVE

This chapter explores various transportation investment options aiming at reducing congestion in the I-71 Corridor. The options considered in this chapter are:

- Base Case: this is an option with low cost capital improvements to the existing transportation system option that mainly consists of bus system improvements as part of the Transportation System Management (TSM);

- Adding a New Lane: this option consists of adding one new driving lane to each direction of the current I-71 throughout the Minimum Operable Segment (MOS); and

- Light Rail Transit: this option consists of the construction and operation of a 38-mile fixed-guideway system, starting first with a MOS of 19 miles.

The chapter analyzes the traffic analysis and induced travel under the new lane option and the ridership forecast uncertainty associated with the light rail option. The analysis can be considered as the preliminary screening needed to get to the options to be considered for subsequent analysis. In other words, this chapter paves the ground for the benefit cost analysis by defining the "Base Case" and accounting comprehensively for alternative investments.

2.1 Scope of Alternative Solutions for the I-71 Corridor

2.1.1 The I-71 Corridor

2.1.1.1 Corridor Overview

The I-71 Corridor in the OKI region is a bi-state corridor that extends from Kings Island in southern Warren County, Ohio, to two legs south of I-75 in north central Boone County, Kentucky. One leg extends along I-71/I-75 to Florence (35 miles long), the other leg connects to the Cincinnati/Northern Kentucky International Airport (39 miles long).

The I-71 corridor passes through 15 cities. From north to south, these cities include Mason in Warren County, Ohio; Montgomery, Blue Ash, Deer Park, Madeira, Silverton, Norwood, and Cincinnati all within Hamilton County, Ohio; Covington, Park Hills, Fort Wright, Fort Mitchell, Crescent Springs, and Erlanger within Kenton County, Kentucky; and, Florence in Boone County, Kentucky. Several established neighborhoods also lie within the corridor. These neighborhoods include Pleasant Ridge, Kennedy Heights, Oakley, Evanston, Walnut Hills, North Avondale, Avondale, Mt. Auburn, and Over-the-Rhine within Cincinnati; King Mills and Twenty Mile Stand within Warren County; Sixteen Mile Stand, Brecon, Highpoint and Rossmoyne within Hamilton County; and, the Peaselburg neighborhood in Covington.

A number of high trip generators exist along the corridor:

- Two Central Business Districts (Downtown Cincinnati and Covington) and convention centers (Greater Cincinnati Convention Center and Covington Convention Center);

- Two universities (University of Cincinnati with 33,000 students and Xavier University with 6,500 students);
- Two sports facilities (65,000-seat Paul Brown Stadium and 45,000-seat Great American Ballpark);
- Eleven hospital/health care facilities (including The Christ Hospital with 3,000 employees);
- An international airport (Cincinnati/Northern Kentucky International Airport attracting 14 million passengers annually);
- Several retail and office centers including Florence and Kenwood Malls; and
- A list of amusement and cultural centers such as the Paramount's King Island Amusement Park, the Beach Water Park, the Cincinnati Art Museum and the Main Public Library of Cincinnati and Hamilton County.

2.1.1.2 Socioeconomic Conditions

The local economy is characterized by a strong manufacturing sector, especially the motor vehicle industry with Ford, Toyota and Mitsubishi. Since 1990, the Gross Regional Product (GRP) has increased on average by 3.8 percent annually, while the Gross Domestic Product (GDP) has increased on average by 3 percent annually. As a result, in 1999 the local unemployment rate was only 3.4 percent as compared to a national unemployment rate of 4.2 percent.

2.1.1.2.1 Population

The population in the I-71 Corridor numbers about 23 percent of the region's total population of 1,851,000[1] and is expected to drop to 20 percent by 2020. While Kings Mills and Mason in Warren County, Erlanger in Kenton County and Florence in Boone County are expected to see some growth; urban areas such as Covington, Cincinnati and Norwood in Hamilton County are expected to experience a decrease in population growth. Furthermore, population density in the central city is expected to drop from 1995 to 2020 while it is expected to increase in suburban areas. The number of households is projected to grow faster than population in the corridor. Between 1995 and 2020, Hamilton County is expected to experience a 7 percent growth in households and a 3 percent growth in population.

2.1.1.2.2 Employment

Major employers are concentrated in downtown Cincinnati and the northern part of Hamilton County. Several major international firms are established within the limits of the corridor. Procter & Gamble alone currently employs about 15,000 persons. In 1999, 10 foreign companies such as Lafarge Corporation and Isuzu Motors relocated to the OKI region.[2]

---

[1] *Existing and Future Conditions Report*, Burgess & Niple Ltd. and BRW Inc., November 1997.
[2] *1999 Growth Report*, Greater Cincinnati Chamber of Commerce, 2000

The corridor's employment in 1995 was about 41 percent of the region's 952,340 jobs. By the year 2020 this percentage is expected to decrease to about 39 percent of the region's 1,057,040 expected jobs. This employment growth from 1995 to 2020 is expected to occur mostly in the outlying suburban regions. Employment growth of more than 10 percent is expected in the Mason/Kings area in Warren County and in areas around the airport in Boone County. In areas surrounding Cincinnati, employment is expected to drop anywhere from 10 percent to 20 percent.

2.1.2 The Base Case

2.1.2.1 Overview

Recent research and practice indicates that failure to establish the proper basis for comparison in evaluating major transportation policies and investments can result in misleading information about the economic performance of alternative courses of action.

A major corridor improvement may have a "rate of return" of 20 percent, or may promise a "net present value" of $200 million, which represents the economy's gain with the corridor improvement. But what would have happened in the absence of the investment? Would other measures be found to improve the performance of the road system? How would traffic and the pattern of economic activity change as result?

Sound economic decisions in investment planning necessitate that major new policies, programs and investments be approved only if they can be justified after accounting for the impact of developments and actions that lead to the most efficient use of existing facilities. Rarely is it the case that "nothing happens" to improve the current system, in the absence of major investment. Therefore, the base case of a benefit cost analysis cannot be defined as a "nothing happens" or "do nothing" option.

The base case option, unlike the "nothing happens" alternative, can involve capital and operating expenditures and will certainly generate economic benefits. These costs and benefits need to be explored in the same depth as those associated with major policy and investment initiatives, and used as the base against which the expected returns on major initiatives are compared. At least four initiatives have been found effective in improving the productivity of congested systems, short of major capital expansion:

- Smaller-scale infrastructure modifications designed to enhance traffic handling capacity of existing systems. Examples include improvements at key intersections or interchanges, and lane widening along critical road segments;

- Electronic traffic control technology (Intelligent Transportation Systems) designed to obtain additional capacity from existing roadway networks;

- Traffic control procedures that secure additional capacity through modified rules of traffic flow and control; and

- Demand management techniques, such as congestion pricing, designed to allocate scarce capacity to users who value facilities most highly (as indicated by their willingness to pay the congestion fees). Other travel demand management techniques include programs that promote carpooling and telecommuting, and parking management strategies.

More than one base case option can be developed and used in the evaluation process. The term "base case components" refers to valid steps for consideration in designing base case options. A downtown parking surcharge, or a precise improvement plan for an existing Intelligent Transportation System would be considered as "base case components."

2.1.2.2 Defining the Base Case

The purpose of this section is to describe the options that will serve as the "base case" in the Cincinnati light rail benefit-cost analysis. Again, the Base Case should be understood as the range of roadway improvements intended to make the most productive use of existing capacity, without the addition of any major new capacity nor transit option. Various alternatives have been defined in the "I-71 Corridor Study Final Report," dated August 1998 (page 2-20). The three alternatives relevant for the Benefit-Cost analysis are summarized in Table 1, below.

For this study, the No-Build alternative has been supplemented with other improvements from the Transportation System Management (TSM) alternatives to serve as a base case option for assessing other investment alternatives.

The No-Build alternative utilizes the existing transportation system and provides for a minimal level of travel expansion. It included all projects currently programmed in the regional Transportation Improvement Program (TIP) for fiscal years 1998 through 2001. The program includes highway improvements and improvements at certain intersections and interchanges.

The TSM alternative, in general, consists of a variety of low-cost capital improvements to the existing transportation system. It focuses on optimizing the existing transportation network, through localized improvements and a variety of techniques to maximize the performance of highways, bus transit, and bicycle/pedestrian facilities. The TSM includes a major expansion of the current bus system, increases in park/ride lots availability, transportation demand management (TDM) programs such as carpooling, telecommuting and parking management strategies in the CBD, Intelligent Transportation Systems[3] (ITS), and traffic engineering improvements.

In summary, the base case will consist of the highway, intersection, and interchange improvements planned as part of the TIP as well as the transit service and TDM improvements listed under the TSM alternative.

[3] TSM includes the expansion of ARTIMIS (Advanced Regional Traffic Interactive Management and Information System), an interactive system providing continuous traffic information to motorists.

Table 1: Summary of Alternatives Considered in the I-71 Corridor Study Final Report

Alternative	Description
No Build	No improvement in the transit system; All roadway projects currently programmed in the T.I.P.
TSM	Enough transit expansion to adequately cover the region; Intelligent Transportation System improvements; Transportation Demand Management programs; All roadway projects currently programmed in the T.I.P.
LRT	43-mile fixed-guideway system New transit-only bridge TSM bus network modified to turn back at stations

The improvements under No-Build and the T.S.M. considered in our base case are described in Table 2 on the next page. The information provided in the table was derived from "Final Definition of Alternatives Report," I-71 Corridor Transportation Study, Ohio-Kentucky-Indiana Regional Council of Governments, May 1998 and from "Final Report," I-71 Corridor Transportation Study, Ohio-Kentucky-Indiana Regional Council of Governments, August 1998, page 2-20 to 2-34.

Table 2: Base Case Components

Option	Components	Sub-Components / Measures To Be Considered
Infrastructure	All projects currently programmed in the regional Transportation Improvement Program for fiscal years 1998 through 2001	• Various roadway projects along the I-71 and I-71/75 freeways: lane addition from Western Row to Pfeiffer Road (Hamilton County); reconstruction/realignment of Fort Washington Way (Hamilton), etc. • Capacity expansion projects (lane additions) along key arterials: Ridge Road (Hamilton County); U.S. 22 (Hamilton), Fields Ertel Road (Warren), etc.
	Minor, if any, modifications to the existing bus network	• None
	Minimal-to-some capital improvements, if any, such as new Park-and-Ride locations	• None
T.S.M.	All projects currently programmed in the regional Transportation Improvement Program for fiscal years 1998 through 2001	• Various roadway projects along the I-71 and I-71/75 freeways: lane addition from Western Row to Pfeiffer Road (Hamilton County); reconstruction/realignment of Fort Washington Way (Hamilton), etc. • Capacity expansion projects (lane additions) along key arterials: Ridge Road (Hamilton County); U.S. 22 (Hamilton), Fields Ertel Road (Warren), etc.
	Expanded Bus Service	• Expand bus service in areas that are currently un-served or under-served. Local and express services. New services would use a variety of bus types, including small buses for neighborhood or circulator services, and large articulated buses for mainline trunk services; • Implementation of timed-transfer Transit Centers (locations where several bus routes converge, with synchronized schedules to permit convenient transferring among routes); • New park-and-ride lots in all sectors of the expanded service area, in addition to lots at the Transit Centers; • Addition of bus loading lanes, new waiting areas and ticket offices; • Most improvements in Ohio (and Cincinnati CBD); relatively few improvements in Kentucky.
	Transportation Demand Management (T.D.M.)	• Alternative work schedules; • Expanded ridesharing programs; • Parking management strategies in the Central Business District; and • Telecommuting.
	Intelligent Transportation System (I.T.S.)	• Completion of ARTIMIS (Advanced Regional Traffic Interactive Management and Information System) implementation. Will provide: pre-trip travel information (via telephone, radio and television), real-time travel information (via highway advisory radio, changeable message signs, etc.) and incident management; • Ramp metering and surveillance at key I-71 interchanges; • Traffic signal coordination, as part of the Integrated Corridor Traffic Management (I.C.T.M.); • Signal preemption for emergency vehicles and signal priority for buses when needed; • Automatic Vehicle Location (A.V.L.) for trucks and buses with transponders; • Real-time information signs and schedule information for transit routes at the transit stations in the corridor; and • Electronic bus fare payment.
	Traffic Engineering Improvements	• None
Pricing	None	• None

2.1.3 Additional Highway Capacity Alternative

2.1.3.1 Interstate 71

The corridor is centered on I-71, which joins with I-75 in downtown Cincinnati. This major interstate route links northeastern Ohio with points south of the regional area (CBD and international airport). The I-71 is a limited access urban interstate facility characterized by grade separations with railroads and local streets and access provided with interchanges at various freeway, expressway, arterial and collector routes. It consists of two main portions within the proposed corridor:

- **The Northeast Expressway (Ohio)**

  Southbound - This portion begins at the northern-most end of the corridor in Ohio. The Northeast Expressway carries two through lanes from Kings Mills Road south to the Cincinnati Circle Freeway (I-275), a distance of approximately 8 miles. From the Cincinnati Circle Freeway to the Norwood Lateral Expressway (SR 562), approximately 10 miles, the I-71 carries three lanes southbound through Cornell Road, Pfeiffer Road, Cross County Highway, Galbraith Road, Montgomery Road (US 22, SR 3), the Red Bank Expressway and Kennedy Avenue. From the Norwood Lateral Expressway south to Reading Road (US 42), approximately 5.6 miles, the I-71 is increased to four lanes. Then the I-71, back to three lanes, traverses downtown Cincinnati as an east/west highway and merges with I-75 immediately north of the Ohio River.

  Northbound - From Lytle Tunnel at the eastern edge of downtown Cincinnati north to Reading Road, the I-71 is three lanes. From Reading Road north to Edwards Avenue/Smith Avenue (SR 561), four lanes are carried northbound. From Edwards Avenue/Smith Avenue to the I-275 interchange, the northbound I-71 carries three lanes. Then, from the I-275 interchange to Kings Mills Road it is reduced to two lanes.

- **I-71/I-75 (Kentucky)**

  Southbound - This portion begins at the Ohio-Kentucky State line, materialized by the Ohio River. The I-71/I-75 carries four lanes to cross the river via the Brent Spence Bridge (southbound traffic uses the top deck of the bridge and northbound traffic uses the lower deck). From the Ohio River to the interchange with I-275, a distance of approximately 7 miles, the southbound interstate route carries four lanes through Kyles Lane interchange (SR 1072) and Dixie Highway interchange (US 25, US 42 and US 127). Then, the I-71 continues towards Florence and finally reaches the southern-most end of the corridor, a distance of approximately 5 miles, while the I-275 goes westward to the Cincinnati/Northern Kentucky International Airport.

  Northbound - The I-71/I-75 is four lanes between the I-275 interchange and the Dixie Highway and only three lanes towards the Ohio River. On the Spence Bridge four lanes enter the state of Ohio and then diverge into separates routes I-71 and I-75.

As of May 1998, a network of 32 park-and-ride lots covered the entire OKI region. Eight lots are located within the I-71 corridor, four in Ohio (Fields Ertel, Loveland, Blue Ash, and Madeira) and four in Kentucky (Fort Mitchell, Fort Wright, Erlanger and Turfway). All park-and-ride lots are served by bus or local transit, except for Fields Ertel, which is used by carpools and vanpools only.

Several segments of the I-71 are already experiencing congestion problems. In 1990, there were seven deficient segments of roadway by level of service (LOS), meaning LOS D or below.[4] In 1997, the Texas Transportation Institute ranked Cincinnati 28th out of 68 urban areas for its congestion problems (as measured by the travel rate index).[5] And according to the most recent OKI's long-range transportation plan,[6] traffic and congestion are expected to increase significantly on all segments of the I-71 and throughout the corridor in the next twenty years. By 2010, the number of deficient segments is projected to jump to 24. Among them, six are on the interstate system itself. Forecasts for 2020 indicate that 40 percent of all regional trips will begin or end in the I-71 Corridor. Travel to the airport is expected to increase by 84 percent and to downtown by 24 percent.

2.1.3.2 Defining the Additional Highway Capacity Option

The additional highway capacity option consists of adding one new driving lane to each direction of the current I-71 throughout the Minimum Operable Segment (MOS). The MOS extends approximately 19 miles from 12th street in Covington, Kentucky, to Grooms Road in Blue Ash, Ohio. For the purpose of the analysis, the addition of one lane in each direction of the current I-71 is assumed to represent a 33 percent increase in capacity (although some portions of the Interstate along the MOS currently have 4 lanes in each direction).

2.1.4 Light Rail Transit Alternative

In November 1998, the Ohio-Kentucky-Indiana Regional Council of Governments adopted the *Managing Mobility: Year 2010 Regional Transportation Plan* and recommended the I-71 Corridor for assessing the feasibility of a Light Rail Transit (LRT) system.

The Light Rail Transit (LRT) alternative provides a 38-mile fixed-guideway system powered by overhead electricity. It will operate in various combinations of street, freeway, and railroad rights-of-way. The current study, however, considers the 19-mile MOS of the Northeast I-71 Corridor between Covington, Kentucky and Blue Ash, Ohio. The main objectives from the LRT system are reducing congestion and benefiting the communities within the corridor. The projected travel time for the LRT system are shown in Table 3, below.

---

[4] Level D borders on unstable flow. Small increases in traffic result in large reductions in speed, and freedom to change lanes is severely limited.
[5] 1*999 Annual Mobility Report*, David Schrank and Tim Lomax, Texas Transportation Institute, The Texas A&M University System, 1999.
[6] *Looking Ahead: 2020 Metropolitan Transportation Plan*, OKI Regional Council of Governments, May 1998.

Table 3: Light Rail Travel Times

All time estimates are in minutes	From Blue Ash (Pfeiffer Rd.)	From Airport (Terminal)	From Mason (Mason)
Distance to Downtown Cincinnati, Government Square Station (miles)	14.5	12.4	21.8
Running Time	32.2	26.3	43.9
Average Station Dwell Time	0.25	0.25	0.25
Number of Stations (excluding end points)	12	8	15
Total Station Dwell Time	3.0	2.0	3.8
Average Access Time	5.0	5.0	5.0
Average Waiting Time			
Peak Period (AM)	10.0	10.0	10.0
Off-Peak Period	20.0	20.0	20.0
Door-to-Door Travel Time			
Peak Period (AM)	50.2	43.3	62.7
Off-Peak Period	60.2	53.3	72.7

Source: "I-71 Corridor Transportation Study, Final Definition of Alternatives Report," page 5-10
Notes: Average waiting times based on L.R.T. schedule

2.2 Baseline Conditions and Issues Under the Base Case Option

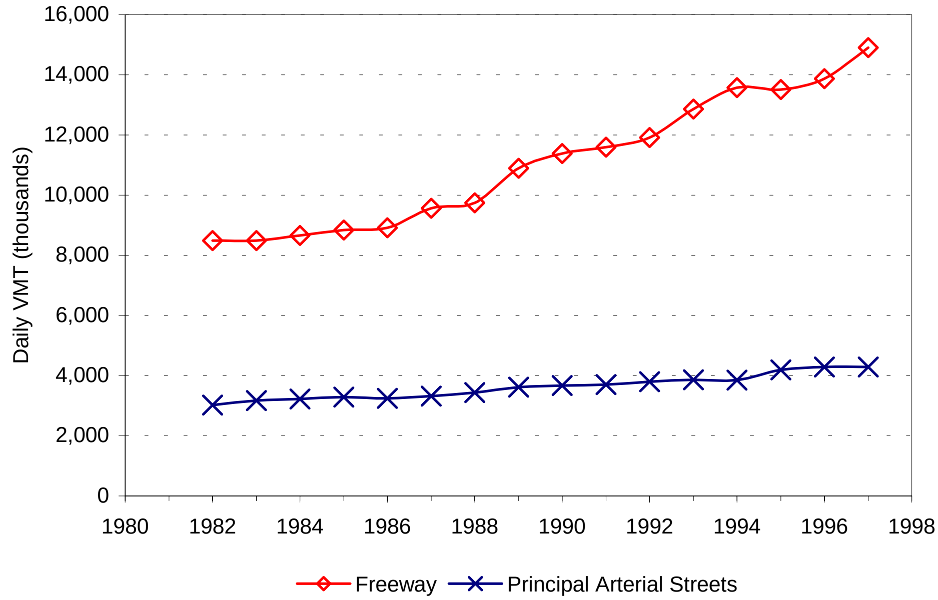
2.2.1 Projected Traffic Conditions Under Base Case Option

The purpose of this section is to present Year 2020 traffic projections under the base case option. Traffic trends in the Greater Cincinnati (as defined in the Texas Transportation Institute annual urban mobility study) are first examined to assess the "likelihood" of current traffic projections.

2.2.1.1 Traffic Trends in the Greater Cincinnati Area

As shown in Figure 1, daily travel volume (as measured by Vehicle Miles of Travel or VMT) has risen steadily along Cincinnati freeways and (to a lesser degree) arterial streets over the past two decades. The average annual freeway VMT growth rate over the period is about 3.5 percent.

Figure 1: Daily Vehicle Miles of Travel in Greater Cincinnati (1982-1997)



As Figure 2 indicates, average vehicle speed along Cincinnati freeways has been steadily decreasing over the period. The figure also shows that the percentage of freeway travel in severe or extreme congestion has increased from less than 2% of total highway travel in 1982 to more than 40% in 1997.

Figure 2: Freeway Congestion in Greater Cincinnati (1982-1997)

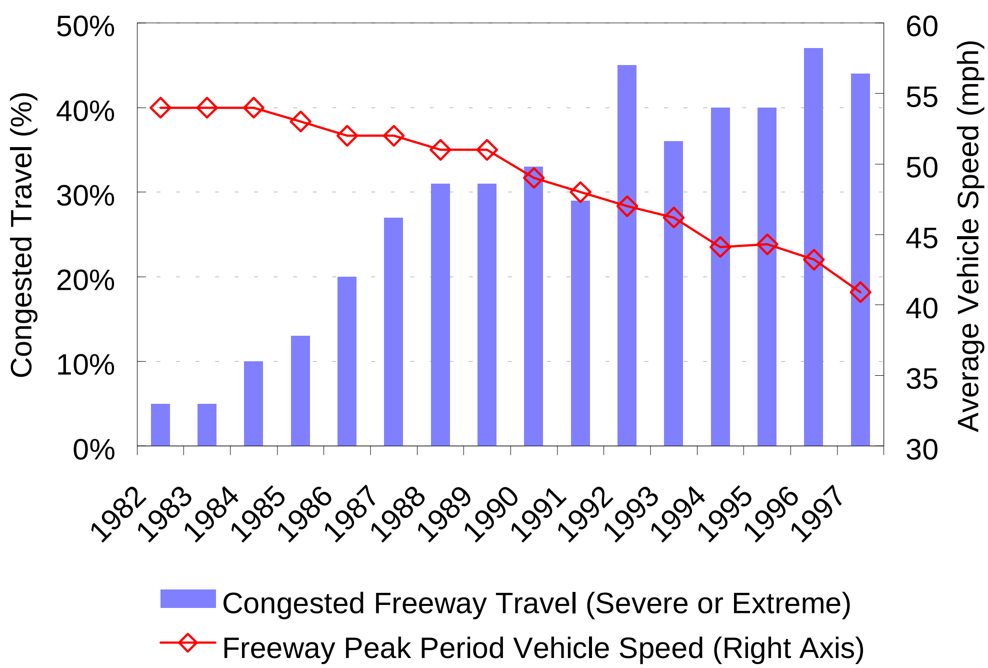


Table 4 below summarizes traffic and congestion trends in the Greater Cincinnati area over the period 1982-1997. Annual congestion costs (including excess fuel consumption costs) have risen sharply over the past 20 years, from an average $80 per driver to $525 in 1997. Cumulative VMT growth (since 1982) exceeded 65% in 1997, while recent developments indicate an acceleration of the growth of travel volume in the area.

Table 4: Traffic Trends in Greater Cincinnati, Summary

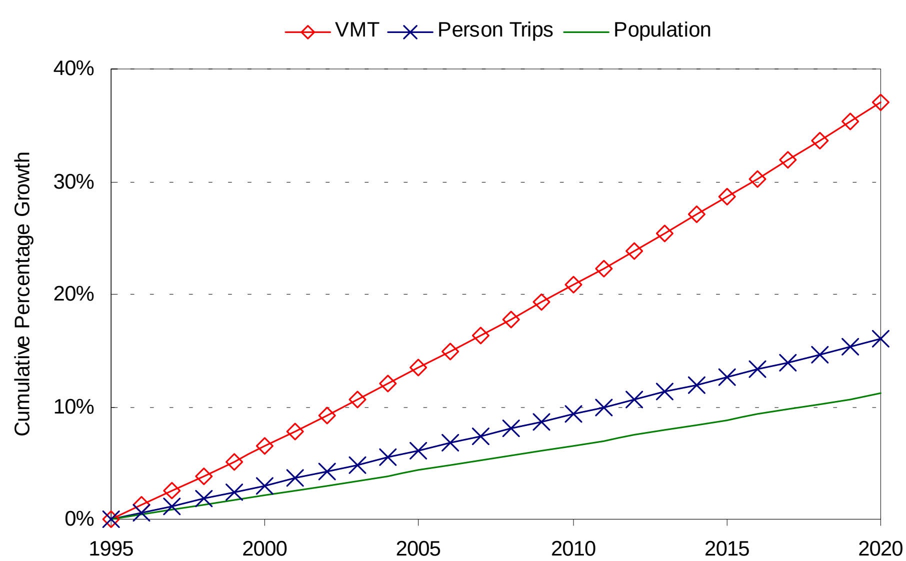
	1985	1990	1995	1997
TTI Travel Rate Index	1.12	1.22	1.26	1.26
Congested Freeway Travel (%)	35	55	60	60
Annual Congestion Cost per Driver ($)	80	255	425	525
Daily VMT along Freeways and Principal Arterial Streets (thousands)	12,135	15,050	17,705	19,190
VMT Growth Since 1982 (%)	5.48%	30.81%	53.89%	66.80%
Average Annual VMT Growth Since 1982 (%)	1.79%	3.41%	3.37%	3.47%

Source: "The 1999 Annual Mobility Report," David Schrank and Tim Lomax, Texas Transportation Institute, The Texas A&M University System, 1999

2.2.1.2 Year 2020 Regional Highway Travel

Figure 3 below shows the assumed growth in population, Vehicle Miles of Travel (VMT) and person trips. Projected annual growth rates in Vehicle Miles of Travel (about 1.3%) and person trips (about 0.6%) appear relatively low compared to traffic developments in recent years.

Figure 3: OKI Region Growth in Population, Person Trips and VMT, 1995-2020



Source: I-71 Corridor Transportation Study, Executive Summary, August 1998

Table 5 below summarizes regional traffic projections for the year 2020, under the base case option. Note that projections for congestion levels and average vehicle speed were not available at the regional level at the time of this report.

Table 5: Year 2020 Regional Highway Travel Summary

	Base Case Option	
Highway Person Trips		
Peak Period		
Drive Alone	2,013,218	28.4%
One Passenger	777,952	11.0%
Two or More Passengers	529,409	7.5%
Total Peak Period	3,320,579	46.9%
Off-Peak Period		
Drive Alone	2,070,737	29.2%
One Passenger	1,018,705	14.4%
Two or More Passengers	669,916	9.5%
Total Off-Peak Period	3,759,358	53.1%
Total Highway Person Trips	**7,079,937**	**100.0%**
Total Highway Vehicle Trips	5,899,432	
Average Highway Vehicle Occupancy	1.20	
Vehicle Miles of Travel		
Peak Period	26,495,411	50.1%
Off-Peak Period	26,439,922	49.9%
Total Vehicle Miles of Travel	**52,935,333**	**100.0%**
Average Trip Length (Miles)	8.97	

In 2020, single occupant vehicle trips will represent about 58% of all highway trips in the OKI region, bringing the average highway vehicle occupancy down to 1.2 persons per vehicle.

2.2.1.3 Year 2020 Corridor Highway Travel

Projections for 2020 indicate that 40% of all regional trips will begin or end in the I-71 corridor. Traffic projections along the I-71 corridor are summarized in Table 6 below. As shown in the table, year 2020 congestion is expected to be moderate for the corridor as a whole. Average vehicle speed along I-71 in the peak period is expected to remain close to 45 mph.

Table 6: Year 2020 Corridor Highway Travel Summary

	Base Case Option	
Vehicle Miles of Travel		
Peak Period	6,291,240	49.4%
Off-Peak Period	6,436,853	50.6%
Total Vehicle Miles of Travel	**12,728,093**	**100.0%**
VMT during Peak Hour	1,319,994	10.4%
Vehicle Hours of Delay		
Peak Period	51,195	83.9%
Off-Peak Period	9,859	16.1%
Total Vehicle Hours of Delay	**61,054**	**100.0%**
Annual Hours of Delay per Driver *		
Peak Period	18.25	
Off-Peak Period	3.44	
Average V/C Ratio (AM Peak Direction)		
Along I-71 **	1.08	
On Key Arterials **	0.63	
Average Vehicle Speed (AM Peak Direction)		
Along I-71 **	44.9	
On Key Arterials ***	55.0	

** Assuming 250 workdays; ** Non-weighted average; *** HLB estimate*

Various segments along the corridor, however, will be severely congested by Year 2020. In fact, most segments of I-71 within the I-275 outer belt will operate at high congestion levels.

2.2.1.4 Projected Travel Times for the Year 2020

Year 2020 vehicle travel time projections between key locations along the I-71 corridor are not available in the MIS reviewed by HLB. The estimates provided in the table below have been derived from average vehicle speeds and the distance between the locations.

Table 7: Vehicular Travel Times, Minutes

	From Blue Ash	From Airport	From Mason
Distance (miles) to Downtown Cincinnati*	14.5	12.4	21.8
Average Vehicle Speed (mph)			
Peak Period (AM)	40	40	40
Off-Peak Period	50	50	50
Door-to-Door Travel Time			
Peak Period (AM)	21.8	18.6	32.7
Off-Peak Period	17.4	14.9	26.2

Sources: "I-71 Corridor Transportation Study, Existing and Future Conditions Report," Figure 3.1.6, page 3-19; " I-71 Corridor Transportation Study, Final Report," pages 2-36, and 3-15.
Note: Highway distances aligned with Station-to-Station distances for comparison.

2.2.2 Ozone Attainment Status of the Cincinnati-Hamilton Area

2.2.2.1 Background and Chronology

Under section 107(d) of the 1977 amended Clean Air Act, the US Environmental protection Agency (USEPA) promulgated the ozone attainment status for each geographic area of the country. All counties in the Cincinnati area were designated as ozone non-attainment area in March 1978 (FR 8962).

The Clean Air Act Amendments of 1990 (CAAA) made it possible however to re-designate an area from non-attainment to attainment provided that certain criteria, including the development of a State Implementation Plan, are met.[7]

In November 1994, the Ohio Environmental Protection Agency (OEPA) requested the re-designation of the Ohio portion of the Cincinnati-Hamilton areas from moderate non-attainment to attainment areas for ozone. USEPA proposed to approve the re-designation request in May 1995. In the opinion of the federal regulator, the area satisfied the requirements of the CAAA. In particular, it had achieved a considerable improvement in air quality and developed a sustainable and enforceable plan of improvements in air quality.

---

[7] Section 107(d)(3)(E) of the 1990 CAAA states that the following criteria must be met in order for an area to be re-designated from non-attainment to attainment:

1. The EPA has determined that the national ambient air quality standard (NAAQS) has been attained. This standard is 0.124 ppm for ozone.
2. The applicable State Implementation Plan (SIP) has been fully approved by the EPA under section 110(k).
3. The EPA has determined that the improvement in air quality is due to permanent and enforceable reductions in emissions.
4. The State has met all applicable requirements for the area under section 110 and part D.
5. The EPA has fully approved a maintenance plan, including a contingency plan, for the area under section 175A.

For ozone, an area may be considered attaining the NAAQS if there are no violations based on three complete consecutive calendar years of quality assured monitoring data. A violation of the NAAQS occurs when the annual average number of expected daily exceedances is equal to or greater than 1.05 at a monitoring site. A daily exceedance occurs the maximum hourly ozone concentration during a given day is 0.125 ppm or higher.

However, in July 1995 an ozone monitor recorded that the area exceeded the ozone standard resulting in a violation of the ozone air quality standard. In February 1997, USEPA proposed to disapprove the re-designation request for the area because it has not met all of the requirements for re-designation specified under Section 107 (d)(3)(E) of the Clean Air Act.

USEPA granted two 1-year extensions of the area's attainment date (62 FR61241, November 17, 1997; and 63 FR 14673, March 26, 1998) making its new attainment date November 15, 1998. The area attained the 1-hour ozone concentration standard by its extended attainment date. As a result, on January 24, 2000, USEPA proposed to determine that the Cincinnati- Hamilton moderate ozone non-attainment area has attained the public health-based 1-hour ozone National Ambient Air Quality Standard (NAAQS).

On June 19, 2000, USEPA issued a final rule stating that the Cincinnati-Hamilton moderate ozone non-attainment area has attained the 1-hour ozone NAAQS by its extended attainment date. This ruling implies that the Cincinnati-Hamilton area has been recognized as the ozone attainment area.

With the June 19, 2000 rule, USEPA also approved OEPA request to re-designate the Cincinnati-Hamilton area to attainment of the 1-hour ozone NAAQS. In addition, USEPA approved (as revisions to the Ohio and Kentucky State Implementation Plans) the States' plans for maintaining the 1-hour ozone standard for the next 10 years.

Re-designation chronology for the Cincinnati-Hamilton area is summarized below in Table 8.

Table 8: Cincinnati-Hamilton Re-designation Chronology

Date	Event
March 1978	USEPA designated all counties in the Cincinnati area as ozone-non-attainment areas
Nov. 15, 1994	Ohio USEPA requested re-designation of the Cincinnati area from moderate non-attainment to attainment for ozone
May 5, 1995	USEPA proposed approval of the re-designation request and maintenance plan
July, 1995	An ozone monitor recorded that the area exceeded the ozone standard resulting in a violation of the standard
February 18, 1997	USEPA proposed to disapprove the re-designation request for the area because it had not met all of the requirements for re-designation specified under Section 107 (d) (3) (E) of the Clean Air Act
January 24, 2000	EPA proposed to determine that the Cincinnati-Hamilton moderate ozone non-attainment area has attained the public health-based 1-hour ozone NAAQS. (Based on ozone data from 1996 to 1998)
June 19, 2000	Federal Register published the final ruling that the Cincinnati-Hamilton moderate ozone non-attainment area has attained the 1-hour ozone NAAQS by its extended date (November 15, 1998). With this ruling, the Cincinnati-Hamilton area has achieved the ozone-attainment status.

On July 17, 1997, the USEPA announced a new national ambient air quality standard for ground-level ozone. Specifically, the USEPA planned to phase out and replace the 1-hour standard with a new 8-hour standard that is more protective of public health. The new standard was to be implemented in the year 2000. The USEPA also revoked the 1-hour standard for six areas, including Ohio and Morgan County, Kentucky, as they did not measure a violation in the preceding three years. The air quality standard in these areas was raised to the 8-hour ozone concentration standard.

At the present time, the Cincinnati area does not attain the 8-hour standard for ozone concentration. Thus, if the new standard were implemented, the Cincinnati area would loose its ozone attainment status and be designated as non-attainment area or “transitional” area (an area that meets the 1-hour standard but not the 8-hour standard).

The 8-hour standard is contested in the Supreme Court as several states have appealed the new proposed standard arguing that it is not based on scientific evidence and it is not enforceable.

2.2.2.2 Air Pollution Trends in the Cincinnati Area

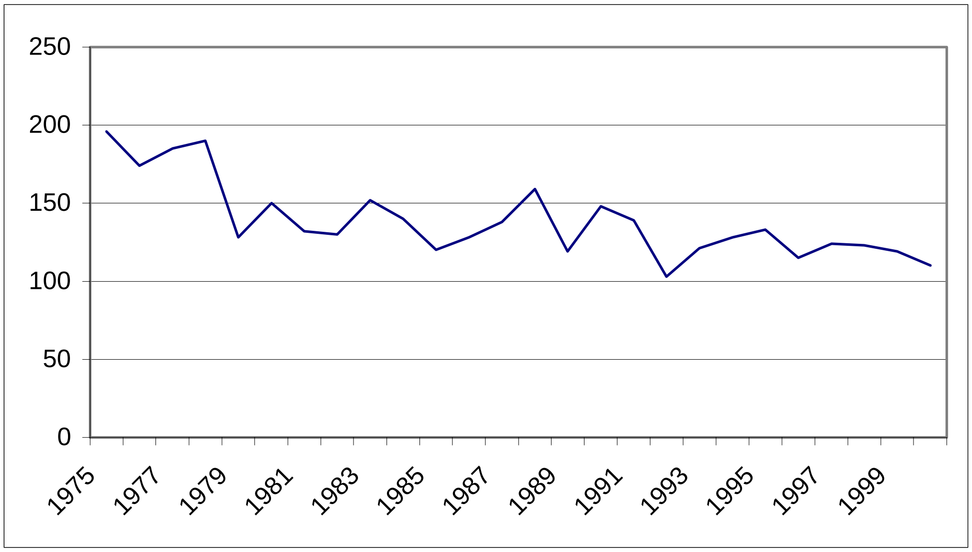
In 1995, the OEPA showed that from the years 1990 to 1993, area total Volatile Organic Compound (VOC) emissions, the main precursor of ground-level ozone,[8] fell from 265.7 tons per day to 227.9, and area VOC emissions from mobile sources (such as cars) fell from 125.8 tons per day to 85.3 tons per day.[9] This improvement in the emission levels was achieved mainly through the implementation of two federal programs, lower fuel volatility and the Federal Motor Vehicle Control Program (FMVCP). The OEPA also projected that for the years 1996, 1999, 2002, and 2005 the total VOC emissions would amount to 212.7, 198.0, 193.1, and 191.3 tons per day, respectively. The VOC emissions from mobile sources for the same years were projected to amount to 67.1, 49.6, 41.6, and 36.8 tons per day.

The actual data on ozone concentration for the years from 1975 to 2000 also show that air quality in the Cincinnati area has improved considerably. Figure 4 below shows the trend in second-highest values of 1-hour ozone concentration in the area.

[8] Chemicals containing carbon, hydrogen and possibly other elements, that evaporate easily, are known (with the exception of Methane (CH_4)) as Volatile Organic Compounds. In the presence of sunlight and nitrogen oxides (NO_x), VOC react to form ground-level ozone. Methane is a non-VOC greenhouse gas resulting, in particular, from incomplete burning of fossil fuels. See chapter on Congestion Management Benefits.

[9] See Federal Register Vol. 60, No. 87.

Figure 4: One-Hour Ozone Concentration in the Cincinnati Area (Second-Highest Value in Parts per Billion)



Source: Ohio Environmental Protection Agency and US EPA.

As can be seen in the figure, ozone concentration fell from the high of 196 ppb in 1975 to a low of 103 ppb in 1992.

However, the concentration levels went up again in 1993. In 1994/ 1995 the ozone concentration exceeded the allowable standard of 124 ppb, and two 1-hour ozone exceedances were recorded in each of these two years. This period corresponds to the proposed rule to disprove OEPA's ozone re-designation request for the Cincinnati area discussed earlier. Ozone levels dropped somewhat in 1996 but increased again to a level close to the allowable limit in 1997 and 1998. Only in year 2000, ozone concentration fell again to a relatively low level of 110 ppb.

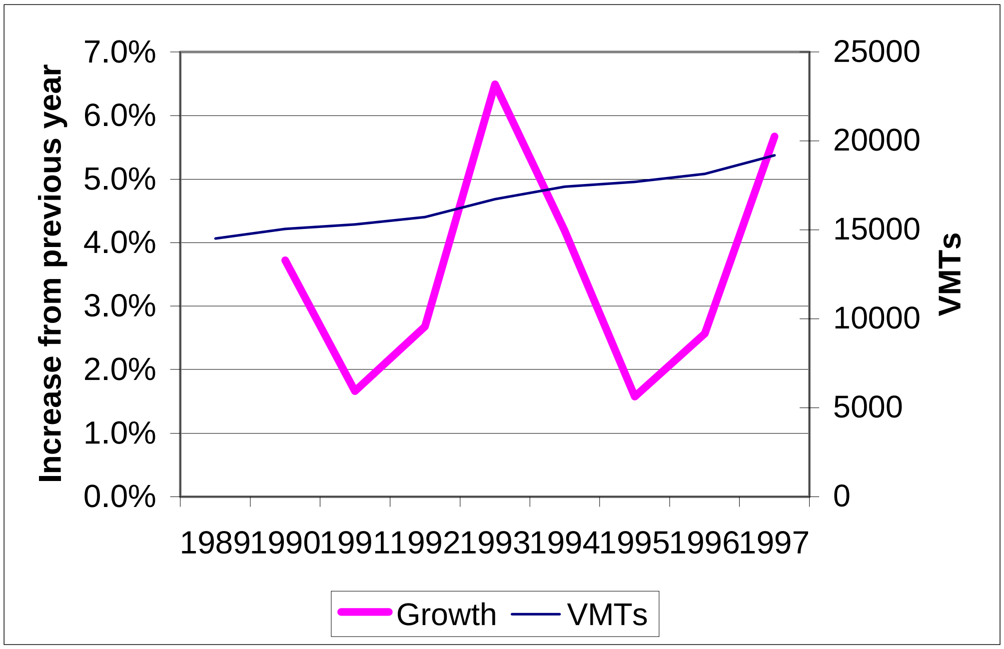
Comparing Figure 4 and Figure 5 we can see that the increase in ozone concentration in 1993 corresponds to an acceleration in the rate of growth of annual VMT. This rate of growth increased from 1.66 percent and 2.68 percent in 1991 and 1992, respectively, to 6.49 percent and 4.18 percent in 1993 and 1994, respectively.

As the ozone concentration levels during the last three years remained at a level fairly close to the allowable limit for NAAQS requirements, the question arises whether air quality can be maintained should traffic growth accelerate again or remain at the current relatively high level.

In fact, projections of mobile source VOC emission inventories were generated by applying the emission factors from USEPA's Mobile5 emission model to the projected VMT in the Cincinnati area counties. Forecasts of VMT to the year 2005 relied on the development of future highway networks, future forecasts of socio-economic data, and travel patterns in the Cincinnati area. VMT were projected to increase by 17 percent by the year 2005 from the 1990 base year.

However, the actual VMT were increasing much faster during the 1990s than projected by the OEPA. Figure 5 below shows the actual VMT on highways and principal roads during the period 1989 – 1997 and the associated annual rate of growth.

Figure 5: Actual VMT (Highways and Principal Roads) and Annual Rate of Growth



Source: http://mobility.tamu.edu/study/cities/cincinati.stm

As can be seen in the figure, VMT increased during the period 1990 to 1997 from approximately 15,000 to about 20,000, or by 27.5 percent. The projected 17 percent increase in VMT materialized by 1995, and the average rate of growth in the 1990s amounted to 4.1 percent.

This trend in VMT again creates serious doubts whether the region can maintain its ozone maintenance status and specifically whether VOC emission targets for 2005 are realistic.

The table below shows actual VMT numbers for 1990, 1993, and the projection for 2005 based on the OEPA's 17 percent estimated increase. VOC emissions broken down by mobile sources emissions, point and area sources emissions and total emissions are also shown. HLB also projected VMT for the years 1998 to 2005 based on the average VMT growth rate during the 1990s of 4.1 percent. These numbers are shown in the second row labeled "VMT – actual numbers and projections based on 1997 growth rate".

Table 9: VMT and Volatile Organic Compound Emissions; Actual and Projected

	1990	1993	1996	1999	2002	2005
VMT - actual numbers and projections based on the average VMT growth rate of 4.1 percent	15,050	16,730	18,160	20,796	23,460	26,466
VMT - actual and projected based on OEAP forecast	15,050	16,730	-	-	-	17,609
Mobile source VOC emissions (tons per day)	125.8	85.3	67.1	49.6	41.6	36.8
Point and Area VOC Emissions (tons per Day)	139.9	142.6	145.6	148.4	151.5	154.3
Total VOC emissions (tons per day)	265.7	227.9	212.7	198	193.1	191.1
HLB revised mobile source emissions for year 2005 (tons per day)						55.3
HLB revised total VOC emissions for year 2005 (tons per day)						209.6

Source: Federal Register Vol. 60, No. 87; http://mobility.tamu.edu/study/cities/cincinati.stm, HLB calculations
Note: VMT for the years 1990 to 1996 are the actual number and those for years 1999 to 2005 are projections. VOC emissions for 1990 and 1993 are the actual numbers and those for the remaining years are projections.

Total projected VOC emissions for 2005 amount to 191.1 tons per day. However, this number is based on VMT in the range of 17,600, whereas on the basis of current trends a more likely estimate for year 2005 is in the area of 26,466, i.e. it is likely to be 50 percent higher than projected by OEPA in the early 1990s. As a result, the mobile source VOC emissions (i.e. emissions generated by cars) are also likely to be much higher than 36.8 tons per day.

Assuming that the emissions are directly proportional to VMT, mobile source VOC emissions will be 50 percent higher than the value projected by OEPA, i.e. mobile source emissions will amount to 55.3 tons a day. As a result, total emissions in year 2005, assuming that other sources of emissions remain unchanged, can be projected to amount to 209.6 tons per day. This number is higher than the 1999 target and is only by about 8 percent lower than the actual emissions in 1993, the emission level on the basis of which the region was re-designated as ozone attainment area.

It should be noted that the HLB emission projection of 209.6 for year 2005 is a conservative estimate as VMT used in the calculations include only highway and principal roads VMT and do not include VMT from the remaining street network. Moreover, these calculations do not take into account the growing and growing popularity of light trucks and sport utility vehicles (SUV). Light trucks and SUV are known to generate a much higher emission levels than cars. Conversations with public officials in Cincinnati confirmed that light trucks and SUV account for a relatively large and growing proportion of all vehicles in Cincinnati making the emission control a challenging task. In addition, if one takes into account the growing number of light trucks and SUV, it turns out that the emission projection models developed 10-15 years ago may likely substantially underestimate the emission levels.

If additional emissions generated from growing numbers of light trucks and SUV as well as mobile VOC emissions from secondary street network are taken into account, the projected emission level for 2005 may be much higher than that reported in Table 9. This in turn would imply that the probability of exceeding the ozone attainment standard in the Cincinnati area in the near future is relatively high.

2.2.2.3 Consequences of Losing the Ozone Attainment Status

Under the Clean Air Act, USEPA is authorized to use two types of sanctions in relation to areas, which do not satisfy air quality standards:

- Withholding of certain federal highway funds, and
- Imposing what are called "2:1 offsets" on new or modified sources of emissions.

Under these sanction provisions, USEPA can prohibit the Secretary of Transportation from awarding any highway grants under Title 23 of the Unites States Code, except for safety-related projects, programs for public transit, roads or lanes for high occupancy vehicles, and programs to limit or restrict vehicle use in downtown areas.

The offset sanction permits USEPA to require that new or modified sources of emissions for which a permit is required offset increased emissions from the permitted facility by emission reductions elsewhere in a ratio of at least 2:1.

In addition, federal departments and agencies may not approve, permit, or provide financial support to transportation improvements unless such improvements conform with the State Implementation Plan for achieving air quality.

2.3 Baseline Conditions and Issues Under the Added Lane Option

Evidence and recent research confirm that building new roads or adding lanes to existing roads does not necessarily reduce congestion. This is due to induced travel.

The purpose of this section is threefold: (i) define induced travel; (ii) provide a short review of recent research on the topic and (iii) evaluate the impact that adding a new lane along a portion of I-71 would have on travel volume and average travel time along the Interstate.

2.3.1 What is Induced Travel?

As a highway becomes more congested, the cost of traveling the facility (travel time costs, fuel consumption costs, etc.) increases. This cost increase tends to constrain the volume of traffic growth. Some travelers may indeed switch to alternative, cheaper, modes of transportation (such as transit) while others may adjust their departure time to avoid congestion. Conversely, when lanes are added, the cost of traveling the highway decreases. This cost reduction will attract travelers who would not have used the facility otherwise: the volume of travel will tend to increase. This increase in the volume of travel is called "induced travel." In other words, induced travel can be defined as the increase in travel attributable to any transportation infrastructure project that increases capacity.[10]

---

[10] From: "Induced Travel: A Review of Recent Literature with a Discussion of Policy Issues," Environmental Protection Agency

Highway upgrades or capacity expansions have been found to generate a series of behavioral changes, not all of which are "induced travel." These effects are summarized below.[11]

- Changes in Route: Travelers may decide to switch routes to take advantage of the new capacity. This can result in either shorter or longer distances being traveled. If the net effect is more travel, this is induced travel.
- Changes in Destinations: If speeds are higher, longer trips (to more distant shopping centers for example) are likely to be taken, increasing the total volume of travel.
- Changes in Transportation Mode: As private vehicle use along the expanded highway becomes cheaper, some public transit riders may switch to driving. Other travelers may stop carpooling. Both changes would increase the total number of vehicles on the facility.
- Changes in Number of Trips Taken: As the cost of traveling the highway goes down, trips that were previously too costly to make are generated.
- Changes in Departure Times: Rescheduling behavior does not necessarily result in increased travel volume. However, as travelers shift back to peak-period travel, congestion at other times of the day may decrease. This decrease in congestion may generate new off-peak trips, increasing total travel volume.

These behavioral changes are generally called "short-term" changes: they occur within one, two or three years. In addition to these short-term effects, various longer run effects may impact travel volume.

Highway expansions, by reducing travel time, make outer suburbs more accessible. This change in the relative accessibility of suburban areas may push residents (and businesses) to relocate over time.

> *"In the longer term… if travel time in an area is reduced substantially for an extended period of time, some people may take different choices about where to purchase a home. If congestion is reduced, purchasing a home far out in the suburbs might become more attractive, since commuters would be able to travel further in a shorter period of time."*
>
> *1999 Status of the Nation's Surface Transportation: Conditions and Performance Report, US DOT (2000)*

These relocations will often result in more trips and longer trips being made, as residents tend to move further away from the city. It is generally assumed that it takes 10 to 20 years for these land use changes to materialize. Recent studies have shown, however, that land use changes can materialize faster if the completion of the facility is fully anticipated by promoters, homebuilders and commuters.

---

[11] From: "Analysis of Metropolitan Highway Capacity and the Growth in Vehicle Miles of Travel," by Robert Noland, University of London Center for Transport Studies and William A. Cowart, ICF Consulting in Fairfax, VA, 2000

To summarize (and clarify), induced travel is not caused by population or employment growth. It is not (solely) caused by traffic diversion from other roadways. Rather, induced travel is the increase in travel volume resulting from increasing highway capacity, beyond that which results from population growth, changes in income and other socio-economic changes.[12]

2.3.2 Review of Recent Research

Most studies on induced travel are confronted with the "chicken-and-egg" question of whether building roads causes traffic, or whether planners build roads in anticipation of new traffic. Different analytical techniques have been used, but none of them can fully account for this simultaneity problem.[13] Besides, study results vary greatly depending upon the choice of location, time period, and the level of aggregation (whether estimates are derived at the project or at the state level, for example). By definition, aggregate studies, at the state or county levels, provide only average results.[14] And what is true for a county as a whole may not be true for a specific facility located within that county. Therefore, one should be extremely cautious when applying "average" findings to evaluate individual projects.

The extent of induced travel is generally measured in terms of "elasticity." The elasticity coefficient indicates the expected percentage change in travel volume brought about by a 1 percent change in highway capacity. If, for example, the short-term elasticity of travel demand with respect to highway capacity is 0.5, total travel volume is expected to increase by 0.5 percent for every 1 percent increase in capacity. The full 0.5 percent increase in travel will materialize over the "short-term," about 2 to 3 years or less. If the long-term elasticity of travel demand is 0.9 and if highway capacity increases by 10 percent today, then travel volume in 10 to 20 years (depending upon how the long-term is defined) will be 9 percent higher than it is today, other things being equal. An elasticity coefficient of 0.9 also implies that after 10 to 20 years, total induced travel will represent 90% of the added capacity.

The table below provides a set of elasticity estimates derived from recent research. In the table, the definition of the short and long terms varies across studies. Short term is generally defined as 2 or 3 years, or less. Long term is generally defined as 10 to 20 years.

---

[12] From: "Misconception about Induced Travel: Recent Research Results and Implications for the Costs of Sprawl," Environmental Protection Agency

[13] Noland and Cowart (2000)

[14] Idem

Table 10: Travel Demand Elasticities Relative to Lane Miles of Capacity

Author(s)	Study Area	Short Term	Long Term
Goodwin (1996)	U.K. Synthesis	N/A	1.0
Hansen & Huang (1997)	California Counties	0.28 - 0.75	0.62
Hansen & Huang (1997)	California Urban Areas	0.43 - 0.91	0.94
Noland (1999)	50 States	0.23 - 0.51	0.71 – 1.22
Noland & Cowart (1999)	70 Metropolitan Areas	0.28	0.81 – 1.02
Fulton et al. (1999)	Mid-Atlantic Counties	0.13 - 0.43	0.47 – 0.81

Derived from "Does Additional Highway Capacity Influence Travel Demand?" A Presentation to Environmental Economics Advisory Committee of the Science Advisory Board, November 12, 1999, USEPA

Studies are relatively consistent in confirming the existence of induced travel: all elasticity estimates are greater than zero. Short-term elasticity estimates range from a low 0.13 to a high 0.91.[15] Overall, the estimates average around 0.2 to 0.6. These estimates imply that over a 1 to 3 year-period, a 10 percent increase in highway capacity results in a 2 to 6 percent increase in travel volume. Long-term elasticity estimates range from a low 0.47 to a high 1.22. From the table it appears safe to conclude that over 10 to 20 years, a 10 percent increase in highway capacity would result in a 5 to 10 percent increase in travel volume. As explained in the previous section, long run elasticities that are significantly greater than short run elasticities suggest that initial congestion reduction benefits stimulate sub-urban development and activities that lead to increased travel volumes.

Induced travel elasticities are also expressed relative to changes in total travel costs or in travel time. In such cases, the elasticity coefficient indicates the extent to which travel volume is expected to change for every 1 percent change in travel costs or travel time. Table 11 below summarizes such estimates. Goodwin (1996), for example, found elasticities with respect to travel time of -0.28 in the short term and -0.57 in the long term. The U.S. Department of Transportation uses an elasticity of travel demand with respect to travel costs of -0.8 for a 5-year period and -1.0 for a 20-year. Other studies provide comparable findings.

[15] Hansen and Huang (1997) found elasticities of 0.91 over a 4 to 5 year period.

Table 11: Travel Demand Elasticities Relative to Travel Time

Author(s)	Study Area	Elasticities
SACTRA (1994)	European Synthesis	-0.5 to -1.0
Dowling (1995)	Synthesis	0.0 to -1.0
NRC/TRB (1995)	Based upon Dowling (1995)	0.0 to -1.0
Goodwin (1996)	U.K. Synthesis	-0.28 to -0.57
U.S. DOT (1998)	United States	-0.8 to -1.0 (Travel Cost)
Lee (1999)	Based on Hansen et al (1993)	-0.375 to -0.675

Source: "Does Additional Highway Capacity Influence Travel Demand?" A Presentation to Environmental Economics Advisory Committee of the Science Advisory Board, November 12, 1999, USEPA

To summarize, recent studies show that building or widening roadways induces more travel. One, two or three years after the lanes are opened, traffic is expected to increase to 20 to 60% of the new roadway capacity. In the longer term (10 years or more), as the new capacity pushes motorists to move farther from work and shopping, total induced travel rises to 50 to 100% of the added capacity.

2.3.3 Induced Travel in Comparable Cities

The purpose of this section is to provide examples that may help evaluate the likely impact of lane additions along I-71. Unfortunately, few studies are available at the city or even facility level. Those identified by HLB are summarized below.

Washington D.C.

"In the mid eighties congestion became close to unbearable on Interstate 270 (a 12-mile stretch outside of Washington, D.C.), which runs northwesterly from the Capital Beltway into suburban Montgomery County. The county applied to the Maryland state government for $200 million to expand the road up to 12 lanes. The state agreed. Now, <u>less than eight years</u> after the expansion was completed, the highway is again reduced to what one official described to the Washington Post as "a rolling parking lot." The daily auto and truck usage is running as high as 210,000 vehicles a day, beyond the official capacity of 190,000, in fact more than state highway officials had projected for 2010."

Source: "Do Widened Roads Create Their Own Gridlock?"
By Neal R. Peirce, Washington, Post Writers Group

Washington - Baltimore Metropolitan Area

"In the Washington-Baltimore metropolitan area, a recent study concluded that about one-third of the added road capacity on main highways--whether new lanes or entirely new roads--was used up by induced travel; every 10 percent expansion in roads led directly to a 3.3

percent rise in the number of vehicles driving on them. (…) The effects identified in the study were immediate, and <u>the full traffic increase occurred in two to four years</u>."

Source: "New Induced Demand Studies"
Peter Morman, Environmental Law & Policy Center, Chicago

Cincinnati, Columbus, Cleveland, Indianapolis, Louisville

The 1999 study by Noland and Cowart[16] (see previous section) provides induced traffic estimates for each of the 70 metropolitan areas in the sample. The study found that over the period 1982-1996, induced traffic in the Cincinnati area (including Northern Kentucky) represented about 14% to 43% of total travel volume growth. Induced travel estimates for nearby metropolitan areas were 12% to 35% in Columbus; 13% to 30% in Cleveland; 20% to 50% in Indianapolis; and 34% to 77% in Louisville. The national average ranged from 15% to 45% of total travel growth. Cincinnati estimates were relatively close to the national average, so it is reasonable to assume that elasticity coefficients for Cincinnati are relatively close to the national estimates as well.

2.3.4 Impact of Highway Capacity Expansion in the I-71 Corridor

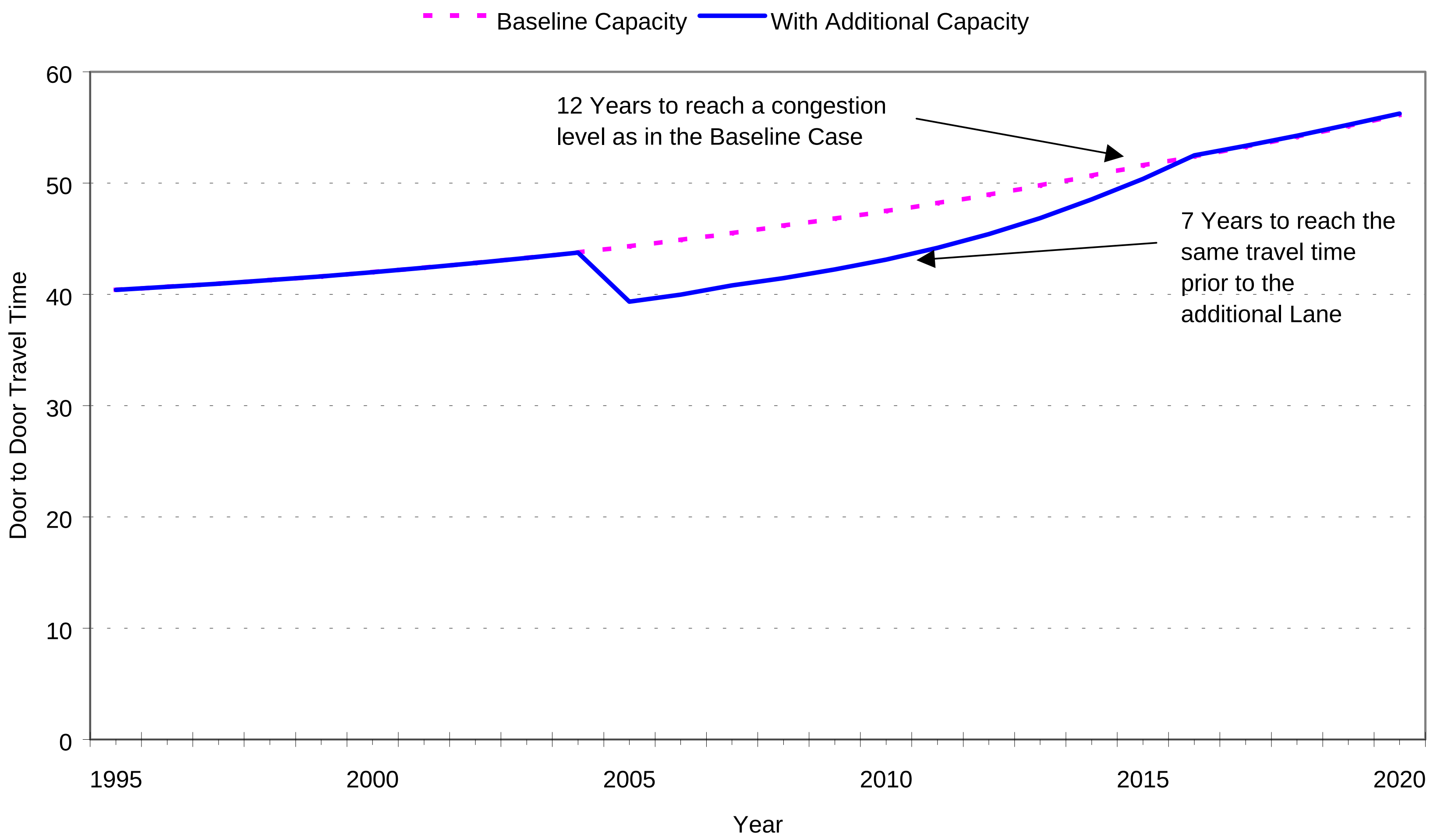
The purpose of this section is to address the specific question raised by the OKI Regional Council of Government: *"If one new driving lane were added to each direction of the current I-71 throughout the Minimum Operable Segment (MOS) and if the light rail and associated bus improvements were not added in the MOS, how many years would elapse before some sections of I-71 would again reach capacity?"*

The Minimum Operable Segment extends approximately 19 miles from 12th street in Covington, Kentucky, to Grooms Road in Blue Ash, Ohio. For the purpose of the analysis, the addition of one lane to each direction of the current I-71 is assumed to represent a 33 percent increase in capacity (although some portions of the Interstate along the MOS currently have 4 lanes in each direction). The average annual daily number of vehicles along the segment is supposed to grow from its 1994 estimates at an average annual 1.5 percent growth rate. The 1994 traffic counts at the intersection of the Interstate with the Norwood Lateral Expressway were used for the analysis. A capacity of 2,300 vehicles per hour per lane was also assumed. As explained in the previous section, an elasticity of 0.2 to 0.6 can be expected in the short term (2 to 3 years). An elasticity of 0.5 to 1.0 can be expected over the long term, 10 to 20 years.

To derive the figure shown on the next page, a short run elasticity of 0.4 and an elasticity of 1.0 over a 20-year period have been assumed. Most of the short run effects (62 percent) are expected to occur in the first year (2006), while the long-run effects are spread over the entire 20-year period. These assumptions imply that it would take about 7 years after opening of the new lane to have a volume to capacity ratio comparable to the Year 2006 ratio. Figure 6 illustrates the impact of induced demand in the case of additional lane option.

[16] Noland and Cowart (2000)

Figure 6: The Impact of Induced Travel



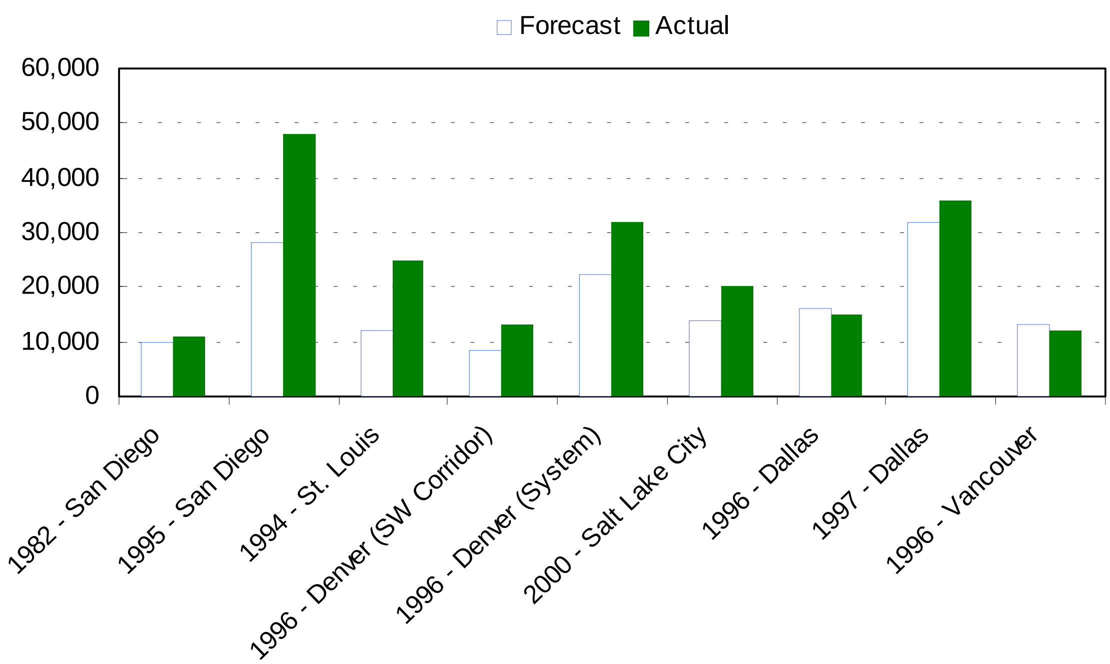
2.4 Baseline Conditions and Issues Under the Light Rail Option

Uncertainty surrounding the level of shifts to the light rail mode from other transportation modes has been an important issue facing local transit agencies when developing the ridership forecast. This chapter first investigates this issue by analyzing historical data from existing systems and then develops probability ranges associated with the forecast uncertainty to be employed in the risk analysis of the light rail ridership forecast for the I-71 Corridor.

2.4.1 Experience from Comparable Cities

HLB has collected and analyzed data on pre-opening ridership forecasts and actual ridership numbers for a number of North American cities of sizes comparable to Cincinnati, which have fairly recent light rail systems. This information is summarized below in Figure 7 and discussed in more detail in the paragraphs following that figure.

Figure 7: Predicted-To-Actual Ridership Experience in Selected Cities



San Diego

The oldest light rail system out of those considered in Figure 7 is San Diego Trolley. The Trolley opened in 1981 with just one line now called the Blue Line. Pre-opening ridership forecast for year 1982 was 9,800 passengers a day whereas the actual ridership number for that year was 10,800. For 1995, the forecast for the same line amounted to 28,000 trips a day whereas the actual number reached 48,000. The high ridership numbers in 1995 are in part due to a second line, the Orange Line, which was in operation in 1995 and the resulting strong "network effects" from that line.

Dallas

A similar trend was observed in Dallas, which opened the first sections of its two light rail lines in 1996. For that year the forecasted ridership was 16,000 rides per day whereas the actual numbers amounted to about 15,000, slightly below expectations. However, when extensions were completed in June 1997, ridership numbers started to exceed the expectations. A pre-opening forecast for late 1997 - when the new stations were opened - was 32,000 rides per day whereas the actual ridership amounted to 35,000 to 40,000 rides a day.

Vancouver

In this context, one could explain the relative under-performance of the Vancouver SkyTrain, which opened in 1986. A 1982 study forecasted 1996 morning peak-hours ridership for 13,000 whereas the actual numbers fell below expectations to about 12,000. However, this forecast assumed that by 1996, there would be a line extension already in operation. This extension did not materialize and, in fact, was undertaken only at the beginning of this year.

In few American cities, from opening day the light rail had actual ridership numbers substantially exceeding the pre-opening forecasts.

Saint Louis

For example, for the St. Louis MetroLink, which opened in July 1993, the pre-opening forecast for 1994 was 12,000 passengers per day. The actual ridership for that year reached 25,000 passengers per day, and the ridership numbers continue to exceed expectations.

Denver

In Denver, the 1996 forecast for the opening day was for 8,400 rides on an average weekday on the South-West Corridor and for 22,400 rides on an average weekday on the entire system. Recent actual ridership counts indicate that weekday ridership on the South-West Corridor is ranging between 12,00 and 13,000, and on the entire system it is ranging between 31,000 and 33,000.

Salt Lake City

Salt Lake City opened its light rail system in December 1999, 13 months before the expected date. The forecasts for the opening months anticipated 14,000 rides a day, whereas the actual ridership amounts to about 20,000 to 30,000, depending on the day. It turned out that the impact of events, such as basketball games, conventions, or Saturday shopping was substantially underestimated. The prevalence of cross-commuting and reverse commuting is also much higher than expected. As a result, the minimum train frequency has been lowered from 20 minutes to 15 minutes, and a second line is already under construction.

2.4.2 Implications for Cincinnati L.R.T. Ridership Forecasts

Based on the review of actual ridership in comparable cities, current ridership forecasts for the city of Cincinnati and Northern Kentucky may under-estimate actual future ridership. The extent of this underestimation can be evaluated from the statistics gathered in the previous section and summarized in the table below.

Table 12: Predicted-To-Actual Ridership Experience in Selected Cities, Summary

Year and City	Forecast	Actual	Difference
1982 - San Diego	9,800	10,800	10.2%
1995 - San Diego	28,000	48,000	71.4%
1994 - St. Louis	12,000	25,000	108.3%
1996 - Denver (SW Corridor)	8,400	13,000	54.8%
1996 - Denver (System)	22,400	32,000	42.9%
2000 - Salt Lake City	14,000	20,000	42.9%
1996 - Dallas	16,000	15,000	-6.3%
1997 - Dallas	32,000	36,000	12.5%
1996 - Vancouver	13,000	12,000	-7.7%

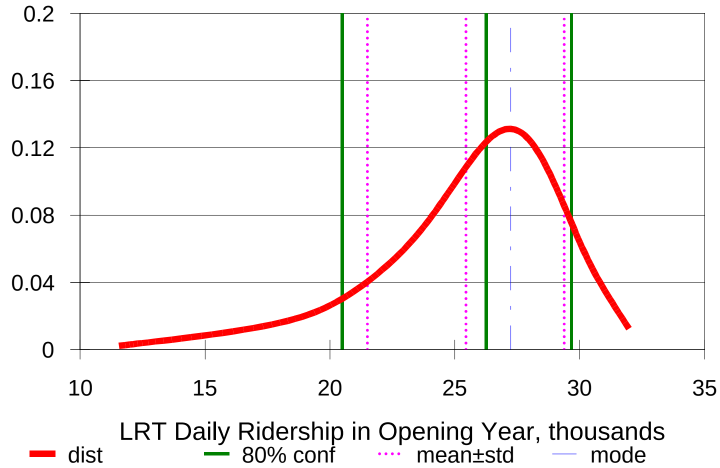
As shown in the table, there is a wide range of possible "differences:" from -7.7% in Vancouver to more than 100% in Saint Louis. As explained in the previous section, projections had overestimated actual ridership in only two cities in the sample: Dallas (1996) and Vancouver (1996). They had underestimated actual ridership in all other cases. Overall the average "difference" is 36.6% meaning that, on average, ridership forecasts were short of actual ridership by more than 35%. This is summarized in the table below. The median value in the table indicates that for more than half of the cases surveyed by HLB, ridership forecasts had underestimated actual ridership by 42.9% or more.

Table 13: Predicted-To-Actual Ridership Experience Summary Statistics

	Minimum	Maximum	Average	Median
Actual vs. Predicted	-7.7% (Vancouver)	108.3% (St. Louis)	36.6%	42.9%

Since the outcome of a light-rail benefit cost analysis depends largely on the projected light rail ridership, HLB has used the predicted-to-actual experience summarized in this section to account for ridership "risk" and adjust all benefit estimates associated with the light rail alternative. Throughout the analysis, ridership forecasts have been treated, not as point estimates, but as probability distributions reflecting an appropriate degree of uncertainty. Current ridership forecasts have been used as central estimates, while the tails of the distribution (the downside and the upside risks) have been derived from the findings presented in the section. This is illustrated in the figure below.

Figure 8: Probability Distribution for Opening Year Daily Ridership



In the figure, the central estimate (or median) is 26,267. The 80% confidence interval (the range within which actual opening year ridership is likely to be found with a 0.8 probability) ranges from 20,500 to 29,667. Overall, the figure shows that a wide range of possible ridership outcomes have been considered in the benefit cost analysis. The overall performance of the light rail alternative has been assessed under all these possible outcomes.

3. REVIEW OF THE MAJOR INVESTMENT STUDY AND NEW STARTS RANKING

This chapter describes the criteria used by the Federal Transit Administration (FTA) to evaluate and rate New Starts projects for discretionary funding under Title 49 United States Code Section 5309 (formerly Section 3 of the Federal Transit Act). It then reviews New Starts submittals for the Ohio-Kentucky-Indiana Regional Council of Governments and provides recommendations to improve the results of the New Starts evaluation for the I-71 Corridor project.

3.1 Background

Section 5309 (e) specifies that discretionary grants or loans used for the construction of a new fixed guideway system or the extension of an existing system may only be approved if the proposed project is:

- Justified by the results of an alternatives analysis and preliminary engineering;
- Justified by a comprehensive review of its mobility improvements, environmental benefits, cost effectiveness and operating efficiencies; and,
- Supported by an acceptable degree of local financial commitment, including evidence of stable and dependable funding sources to construct, maintain, and operate the system or extension.

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 made substantial changes to the legislative basis for assessing candidate projects for Section 5309 (e) New Starts funds. By requiring the FTA to consider land use policies and conditions, it greatly broadened the scope of the criteria used to evaluate candidate projects.

In the December 19, 1996 *Federal Register*[17], the FTA issued a notice redefining the criteria to be used in evaluating New Starts projects. These new criteria replaced those that had been in force since the Statement of Policy on Major Urban Mass Transportation Capital Investments was issued in May 18, 1984, and later incorporated in the Surface Transportation and Uniform Relocation Assistance Act of 1987.

The Transportation Equity Act for the 21st Century (TEA-21) of June 9, 1998, further required the FTA to establish "summary ratings" for each proposed project. Based on the results of the review of all criteria for project justification and local financial commitment, and consistent with Section 5309 (e)(6), summary ratings of either "highly recommended", "recommended" or "not recommended" are assigned to each proposed project. TEA-21 also mandates that proposed New Starts projects must receive FTA approval to advance from alternatives analysis to preliminary engineering, and from preliminary engineering to final design and construction.

[17] "1996 Federal Register" U.S. Government Printing Office, December 1996.
WWW. GPO.GOV

3.2 New Starts Criteria

FTA uses a multiple criteria approach to evaluate and recommend New Starts projects. Ratings of either "high", medium-high", "medium", "low-medium" or "low" are assigned to criteria in two categories, "finance" and "justification." For a proposed project to be rated as "recommended," it must be rated at least "medium" in terms of both "justification" and "finance." FTA makes its rating on the basis of subjective standards rather than pre-defined and quantitative benchmarks. Assessments are based on comparisons among systems and the federal government's own sense of reasonable expectations in relation to national, regional and local policy goals.

3.2.1 Mobility Improvements

To evaluate the mobility improvements that would be realized by a project, the FTA reviews two measures:

- Annual Travel Time Savings: This measure is defined as the value of aggregate travel time savings in the forecast year (year 20 of the analysis period) expected from the New Starts project compared to the No-Build and the Transportation System Management (TSM) alternatives. This is then divided by the annualized capital costs of the project to yield the number of hours saved per dollar of capital cost.

- Absolute Number of Low Income Households: This measure reflects the absolute number of low-income households (households below the poverty level) located within a half-mile radius of the stations of the project. Again, the number of low-income households is divided by the project's annualized capital cost in order to measure the number of low-income residents with access to a station, per dollar of capital cost.

3.2.2 Environmental Benefits

FTA reviews three measures:

- Change in Criteria Pollutant Emissions and in Greenhouse Gas Emissions: This measure is defined as the project-related change in specified pollutant and greenhouse gas emissions in the forecast year compared to the No-Build and TSM alternatives. The measure is expressed as the net change in the number of tons of emissions for carbon monoxide (CO), nitrogen oxide (NOx), volatile organic compounds (VOC) or hydrocarbons (NOC), particular matter (PM10) and carbon dioxide (CO2).

- Change in Regional Energy Consumption: This measure is defined as the project-related change in regional energy consumption compared to the No-Build and the TSM alternatives. The measure is expressed in British Thermal Units (BTUs).

- Current Air Quality Designation by Environmental Protection Agency (EPA): The project is compared with the no build and TSM alternatives in terms of the region's compliance with

EPA National Ambient Air Quality Standards for each transportation-related pollutants (ozone, CO and PM10).

3.2.3 Operating Efficiency

FTA compares the project-related change in operating costs per passenger mile in the forecast year with the No-Build and the TSM alternatives. In the case of Cincinnati, the forecast year is 2008 with a steady state year of 2020.

3.2.4 Cost Effectiveness

To evaluate the cost-effectiveness, FTA assesses the project-related change in annualized capital and operating cost per incremental passenger in the forecast year[18], comparing this with the No-Build and the TSM alternatives.

3.2.5 Transit-Supportive Existing Land Use and Future Patterns

This criterion seeks to account for the degree to which local policies are likely to foster transit-supportive land uses. FTA assesses the kinds of policies in place and the commitment of local authorities to these policies.

The FTA rates six different measurement factors (See Table 14). Three are planning and policy-oriented. The remaining three factors are implementation-oriented and are more relevant in evaluating projects in the early stages of project development (preliminary engineering).

For each measurement factor, the FTA gauges a broad range of sub-factors as proxies for various aspects of existing and future transit-supportive land uses. These sub-factors are summarized in Table 14.

[18] The cost of incremental passenger is calculated on yearly basis. The FTA uses this criteria to compare different system both in the opening year and in steady state years.

Table 14: Transit-Supportive Existing Land Use and Future Patterns

Existing land use: Population and employment density High transit trip generators (university, CBD, etc.) Land use mix and pedestrian-friendly development (parking supply)
Containment of sprawl: Urban containment and growth management policies Planned density and market trends for development
Transit-supportive corridor policies: Public policies and private initiatives to promote transit-friendly development Public policies and private initiatives to enhance station area development Parking management
Supportive zoning regulations near transit operations: Zoning ordinances that support increased development density in station areas Zoning ordinances that enhance transit-oriented character of station area development Zoning allowances for reduced parking and traffic mitigation
Tools to implement land use policies: Endorsement and participation of public agencies, organizations and private companies in the economic development and planning process Involvement of development community in supporting station area plans and joint development efforts Level of jurisdictional endorsement for corridor and station area planning
Performance of land use policies: Demonstrated cases of development affected by transit-oriented policies (transit-supportive housing) Short-term and long-term corridor development targets Station area proposals and joint development proposals received

Source: Assessment of Transit Supportive Land Use for New Starts Projects: FY 1999 New Starts Report, US Department of Transportation, Federal Transit Administration, November 1998.

The ratings for each factor are then combined into a single rating for transit-supportive land use.

3.2.6 Other Factors

FTA examines a range of other factors, including:

- The degree to which the institutions (local transportation planning, programming and parking policies) are in place as assumed in the forecasts;
- The project management capability of the agency submitting the New Starts project;
- Additional factors relevant to local and national priorities and relevant to the success of the project (e.g., Livable Communities initiatives, Empowerment Zone programs, economic impact analysis, etc.).

3.2.7 Local Financial Commitment

In addition to the justification factors described above, the FTA reviews three criteria to evaluate the local financial commitment to a proposed project. These are:

- Proposed Local Share of Project Costs. This measure is defined as the percentage of capital cost to be met using funds from other sources than Section 5309, including both the local match required by Federal law and any additional “overmatch”. Consideration is given to innovative financing techniques and flexible funds;

- Strength of the Capital Financing Plan. The evaluation of the capital financing plan is based on (1) the stability and reliability of each local financial source, with an emphasis on its availability within the project timetable, and (2) whether adequate provisions have been made to cover unanticipated cost overruns; and

- Stability and Reliability of the Operating Financing Plan. The evaluation of the operating financing plan is based on the ability of the local transit agency to fund operation of the system as planned once the project is built. The operation funding should be according to the operating revenue base, and the ability to expand to meet the incremental operating costs associated with a new fixed guideway investment and any other new services or facilities.

The project evaluation is an on-going process. As projects proceed through the stages of the development, the estimates of costs, benefits and impacts are refined. The FTA ratings and recommendations are updated annually to reflect new information, changing conditions and refined financing plans.

3.3 OKI Submittal

The OKI Regional Council of Governments is proposing to develop a 43-mile Light Rail Transit (LRT) system in the Interstate 71 corridor. The Minimum Operable Segment (MOS) is 19-mile long. Since 1998, OKI has been applying for Federal funds under Title 49 Section 5309 of the US Code to finance this project.

For the submittal dated November 1999, the project received an overall rating of "Low-Medium" on March 2000 and was classified as "Not Recommended" for FY 2001 funding. The decision of the FTA was motivated by "the project's poor cost-effectiveness, absence of transit-supportive land use policies and the lack of local financial commitment to build and operate the proposed system".[19] The project remains in the preliminary engineering stage of the development process.

3.3.1 Mobility Improvements

FTA gave a "Medium" rating for this category. The rating is based on the combination of the travel savings and the number of low-income households with a greater emphasis on the latter. The FTA develops the rating after ranking all projects and then assigning a "high", medium-high", "medium", "low medium", or "low" rating based on the project's relative ranking compared to other new starts projects.

3.3.1.1 Travel Time Savings

3.3.1.1.1 OKI New Starts Submittal

Based on the ridership forecast of 23,800 average weekday boarding (including 17,600 new riders) on the MOS, OKI estimates annual travel time savings in 2020 of 1.6 million hours versus No-Build and of 0.8 million hours versus Transportation System Management (TSM). Translated into hours per dollar in annual capital cost, travel time savings range from 54 seconds to 29 seconds per dollar of capital cost.

3.3.1.1.2 FTA Evaluation

For fiscal year 2000 evaluations, the travel time savings index for all proposed New Starts projects[20] versus the No-Build alternative ranges from 5.9 hours per dollar to 7.2 seconds per dollar, with a median of 4.3 minutes. The TSM travel time savings index varies from 1.87 hours per dollar to 3.6 seconds per dollar, with a median of 3.1 minutes per dollar. The FTA believes that the I-71 corridor does not exhibit significant travel time savings compared to other New Starts projects.

3.3.1.2 Number of Low Income Households Served

3.3.1.2.1 OKI New Starts Submittal

[19] *Annual Report on New Starts Proposed Allocation of Funds for FY 2001*, US Department of Transportation, Federal Transit Administration, 2000.

[20] 48 New Starts projects in both the preliminary stage and the final design stage were submitted for the FY 2000 evaluations.

Based on 1990 Census data, there are 13,877 Low-Income Households (LIH), which is about 33% of total households within a half-mile radius of the 18 stations of the MOS.[21] The New Starts shows 126 LIH per million dollars versus No-Build alternative and 145 LIH per million dollars versus TSM.

3.3.1.2.2 FTA Evaluation

For fiscal year 2000, the LIH index for all New Starts projects versus the No-Build alternative ranges from 0.1 LIH per million dollars to 1,453 LIH per million dollars, with a median of 43 LIH per million dollars. Versus the TSM, the index varies from 1,117 LIH per million dollars to 0.1 LIH per million dollars, with a median of 67.5 LIH per million dollars.

3.3.2 Environmental Benefits

3.3.2.1 OKI New Starts Submittal

According to EPA standards, the I-71 corridor is classified as a non-attainment area for ozone and is in attainment for carbon monoxide (CO). OKI estimates that the New Starts project will result in reduced emissions for all pollutants (carbon dioxide in particular) when compared to the TSM alternative. However, in energy consumption, OKI estimated that the British Thermal Units will increase by 61.1 billion BTUs per year versus the No-Build alternative and will decrease by 19.2 billion BTUs per year versus the TSM alternative.

3.3.2.2 FTA Evaluation

The FTA ranked the I-71 Corridor “Medium” in the environmental benefits category mainly due to the expected increase in emissions of nitrogen oxide (NOx) and carbon dioxide (CO2) when compared to the No-Build alternative.

3.3.3 Operating Efficiencies

3.3.3.1 OKI New Starts Submittal

OKI estimates a change in the system-wide operating cost per passenger-mile of $0.001 versus the No-Build and $0.01 versus the TSM. The values are based on the 2020 ridership forecast and 1999 dollars.

3.3.3.2 FTA Evaluation

For fiscal year 2000 evaluations, the operating efficiencies index for all New Starts projects versus No-Build ranges from a low ($0.17)[22] per passenger mile to a high of $0.55 per passenger mile, with a median of $0.00 per passenger mile. The index ranges for the TSM from ($0.16) per passenger mile to $0.63 per passenger mile, with a median of $0.00 per passenger mile.

The FTA gave a rating of “Medium” to this category because the I-71 Corridor’s operating efficiency index is high compared to other corridors and the project does not realize any reduction in operating cost when compared to the other two alternatives.

[21] Based on previous MOS specification; these numbers have been updated since, see Affordable Mobility Chapter
[22] ( ) reflects a negative number.

3.3.4 Cost-Effectiveness

3.3.4.1 OKI New Starts Submittal

OKI estimates that the New Starts project will result in an incremental cost per new passenger of $15.52 and $17.62 when compared to the No-Build and the TSM alternatives in 2020, respectively.

3.3.4.2 FTA Evaluation

The FTA rated this category as "Low-Medium" because I-71 Corridor's cost effectiveness is on the high end of the other proposed projects. Versus the No-Build, the cost-effectiveness index for New Starts projects for fiscal year 2000 ranges from $34.5 per new rider to $3.1 per new rider, with a median of $10.4 per new rider. The cost-effectiveness index with the TSM varies from a high $38.9 per new rider to $0.0 per new rider, with a median of $11.6 per new rider.

The higher cost effectiveness index for the I-71 corridor implies high capital and operating costs and low new rider forecasts in the corridor.

3.3.5 Transit-Supportive Existing Land Use and Future Patterns

3.3.5.1 OKI New Starts Submittal

In 1999, the FTA rating for transit-supportive land use and future patterns was upgraded to "Low-Medium". This improvement shows that OKI has begun to link transportation and land use within its project planning and development process.

OKI shows an estimated total population of 73,700 within a half-mile radius of stations on the 19-mile MOS. The MOS serves the Cincinnati and Covington Central Business Districts (CBD). Total employment in Cincinnati CBD was estimated at 79,700 in 1995. This represents an employment density of 217 jobs per acre. Based on past employment growth of 12 percent, OKI estimates that about 10,000 more jobs will be generated by 2020 (243.14 jobs per acre). The proposed corridor includes a number of high trip generators such as two universities (University of Cincinnati with 33,000 students; and Xavier University with 6,500 students), two new sports facilities (65,000-seat stadium and 45,000-seat baseball park), medical facilities (The Christ Hospital with 3,000 employees) and both urban and suburban retail and office spaces.

3.3.5.2 FTA Evaluation

A review of the ratings of proposed projects for fiscal year 2000 reveals projects ranked high by the FTA perform well in four key categories:

- Existing zoning
- Station area planning
- Economic/market area studies
- Promotion and outreach

Based on OKI projections, the region shows a slower population and employment growth in the corridor than in the region. Employment in the corridor as a percentage of regional employment is expected to decrease from 28% to 25% between 1995 and 2020.

The FTA finds that the OKI submittal shows a lack of growth management policies. The I-71 corridor project involves no less than three states (Ohio, Kentucky and Indiana) and eight counties (Warren, Butler, Hamilton, Boone, Kenton, Campbell, Clermont and Dearborn). FTA states that cooperation between so many jurisdictions is often difficult and makes growth management a complex policy to implement.

According to the FTA, there is a lack of incentives to reduce parking supply, despite a wide range of parking policies including taxes on parking, parking cash-out programs and stated maximum of spaces per a specified square footage. FTA states that there are no zoning ordinances that support increased development density in station areas and no zoning allowances for reduced parking and traffic mitigation have been adopted by any of the jurisdictions in the I-71 corridor although all station locations are already known.

3.3.6 Local Financial Commitment

Under the local financial commitment, the FTA evaluates two main categories:

3.3.6.1 Stability and Reliability of Capital Financing Plan

3.3.6.1.1 OKI New Starts Submittal

OKI proposes to finance the capital cost ($874.7 million) of the LRT project in the following way:

- 431.2 million dollars (49 percent of total capital costs) in Section 5309 New Starts funds;
- 227.9 million dollars (26 percent of total capital costs) in local funds; and
- 215.6 million dollars (25 percent of total capital costs) in State funds.

OKI estimates that the leverage of a half-cent sales tax would be sufficient to finance the project. A local referendum on the implementation a new tax is scheduled for Spring 2001.

3.3.6.1.2 FTA Evaluation

The FTA rated the I-71 Corridor as "Low-Medium" because of the lack of commitment of non-federal funds and the absence of a local entity to build and operate the proposed light rail project. This is partly due to the interstate nature of the project.

Since the submittal, however, OKI has established the Metropolitan Mobility Alliance to study and determine a mechanism for financing the local share of capital costs associated with the region's transit system expansions.

3.3.6.2 Stability and Reliability of Operating Financing Plan

3.3.6.2.1 OKI New Starts Submittal

At the time of the submittal, a local entity to operate the proposed light rail project was not identified. Both Southwest Ohio Regional Transit Authority (SORTA) and Transit Authority of Northern Kentucky (TANK) were considered to be adequate to operate the system.

Since the submittal, the determination of the operating entity has been concluded. The OKI board voted unanimously that SORTA and TANK shall implement and operate the system.

3.3.6.2.2 FTA Evaluation

The absence of a dedicated funding source for the operation and maintenance, at the time of the submittal, led the FTA to give the category a “Low” rating.

Table 15 summarizes I-71 Corridor submittal by criteria as compared to the other New Starts projects evaluated by the FTA.

Table 15: Summary of the I-71 Corridor Submittal Evaluation as Compared to Other New Starts Projects

Project Justification Criteria	I-71 Corridor		Other New Starts Projects						FTA Ratings and Comments
			New Start vs. No-build			New Start vs. TSM			
	New Start vs. No-build	New Start vs. TSM	Median	Maximum	Minimum	Median	Maximum	Minimum	
Mobility Improvements									**Medium -** Annual travel time savings per annualized capital cost are below the median. Low-income households per annualized capital cost are much higher than the median, the FTA however shows lower values on their report.
Annual Travel Time Savings per Annualized Capital Cost (hrs/dollar)	0.015	0.008	0.071	5.908	0.002	0.051	1.875	0.001	
Low-Income Households per Annualized Capital Cost ($ Million)	126.04	144.7	43	1,453	0.1	67.5	1,117	0.1	
Operating Efficiencies									**Medium -** The LRT project realizes a very slight increase in systemwide operating costs per passenger mile as compared to the TSM alternative, and no decrease as compared to the No-Build alternative.
Change in System-wide Operating Cost per Passenger Mile	$0.00	$0.01	$0.00	$0.55	-$0.17	$0.00	$0.63	-$0.16	
Cost-Effectiveness									**Low-Medium -** The estimate of incremental total cost per incremental passenger is higher than the median in both alternatives.
Incremental Total Cost per Incremental Passenger	$15.5	$17.6	$10.4	$34.5	$3.1	$11.6	$38.9	$0.0	
Environmental Benefits									**Medium -** The Cincinnati metropolitan area is classified as a moderate non-attainment area for ozone and is in attainment for carbon monoxide. The LRT project generates an increase in both greenhouse gas emissions and annual energy consumption as compared to the No-Build case.
Change in Greenhouse Gas Emissions (Tons per Year)	4,360	-1,969	-5,705	80,261	-48,564	-4,166	97,356	-32,758	
Change in Annual Energy Consumption (BTU Millions)	61,120	-19,201	-64,640	1,305,826	-488,977	-28,493	1,531,344	-407,589	
Land Use									**Low-Medium**
Project Justification Rating									**Low-Medium**

Local Financial Commitment	I-71 Corridor		Other New Starts Projects			FTA Ratings and Comments
	New Start vs. No-build	New Start vs. TSM	Median	Maximum	Minimum	
Stability and Reliability of Capital Financing Plan	N/A		N/A	N/a	N/A	**Low-Medium -** Lack of commitment of non-Federal funds and the absence of a local entity to build and operate the LRT system.
Stability and Reliability of Operating Finance Plan	N/A		N/A	N/A	N/A	**Low -** Absence of dedicated funding source for the operation and maintenance of the LRT system.
Financial Rating						**Low-Medium**
Overall Project Rating						**Low-Medium (Not Recommended)**

3.4 Strategic Recommendations to Improve the Results of the New Starts Evaluation

3.4.1 Analysis to Improve the New Starts Submittal

HLB believes that OKI can obtain an FTA rating of "Highly Recommended" through a series of steps aimed at achieving specifically targeted ratings. Recommended targets in each FTA evaluation category and a summary of the implementation steps are given in Table 16.

Recommendations are based on seven findings and matters of fact;

1. A recommendation of "Highly Recommended" (as distinct from recommended) is needed to maximize the likelihood of obtaining federal funding. Since FTA ratings are non-binding in relation to actual federal funding decisions, and since the number of projects that obtain funding in a given year is always lower than the number of "recommended" or "highly recommended" projects, OKI should aim to place among the top-ranked projects;

2. An overall FTA rating of "medium-high" is both necessary and sufficient to obtain a standing of "Highly Recommended." Seeking to obtain a rating of "high" is both un-necessary and unrealistic;

3. An overall "medium-high" rating does not require a "high" or "medium-high" rating in every evaluation category. A mix of "medium," "medium-high" and "high" ratings in the justification category is sufficient as long a "high" rating is obtained in the finance category;

4. In light of the above finding, OKI needs to take a highly focused, goal-oriented approach, building on fundamental regional strengths in order to obtain the goal-specific targets given in Table 16. Based on HLB's analysis of FTA ratings and recommendations for other systems, HLB finds that the targets recommended in Table 16 would generate a "Highly Recommended" standing in the FTA process;

5. FTA analysts have seriously misinterpreted OKI findings in the "mobility" category. Low-income household densities exceed the national median more so than most other cities. OKI should build intensively on this strength;

6. Traffic and socioeconomic conditions in the region are such that improved analysis of ridership potential and a value engineering of operating systems and costs would provide the necessary conditions for "Medium-High" ratings for operating efficiencies and cost effectiveness; and

7. Detailed station-by-station design and policy assessments, together with regional letters of commitment to the supporting land-use policies would strengthen the land use and livable community elements of the project by enough to warrant a "Medium-High" rating.

Table 16: Summary of Recommended Analysis Required to Improve Performance Against FTA Criteria

Criteria	FTA Rating	Recommended Target Rating	Analysis Required to Target Rating
Mobility Improvements: Travel Time Savings and Low Income Households Served	Medium	High	• Refine and optimize projected travel time savings based on deeper ridership analysis and FTA-approved convergence analysis • Estimate and stress the low-cost mobility benefits of LRT. In that context, consider possible alignment refinements • Re-estimate mobility indices based on the FTA methodology.
Environmental Benefits	Medium	Medium	• Accuracy check
Operating Efficiencies	Medium	Medium-High	• Review and refine ridership forecast, particularly mode choice and convergence effects • Deconstruct and rebuild the projections of operating cost with value engineering
Cost Effectiveness	Low-Medium	Medium-High	• Review and refine both the ridership and operating cost forecasts, as above
Transit-Supportive Existing Land Use and Future Patterns	Low Medium	Medium-High	• Provide detailed station-specific planning and supportive land use strategies. Include in-depth economic, market area and concept design analysis for each station.
Local Financial Commitment	Low-Medium	High	Measures now underway to improve the rating for this category are sufficient and should continue: • Metropolitan Mobility Alliance coordinated oversight of financing mechanisms • OKI board unanimous support for SORTA and TANK implementing and operating the system.
OVERALL PROJECT RATING	**Low-Medium: Not Recommended**	**Medium-High: Highly Recommended**	**As above; Written submission should provide OKI estimates of FTA index numbers and provide direct assessment relative to other "recommended" systems.**

3.4.2 Concrete Steps that would Likely Improve the Results

HLB recommends that, as soon as possible (and before further work in relation to the New Starts criteria continue) a detailed work breakdown structure be developed in relation to each target score in Table 16. These plans should recognize the quantitative outcomes needed in each category in order to obtain the desired score. This does not mean that the analysis would be manipulated in order to yield those quantitative findings. The purpose of understanding these quantitative outcomes is to provide the context for establishing levels of service, station concepts and other design elements that maximize the likelihood of achieving desired outcomes without either over or under scoping of the system. In short, HLB proposes an Optimal Design Approach targeted on FTA criteria outcomes.

4. CONGESTION MANAGEMENT BENEFITS

Congestion management benefits are presented as the incremental savings associated with automobile riders shifting to light rail services. The savings associated with this switch are defined as the decreased time cost of travel due to lower congestion, lower vehicle operating costs (VOC), increased safety, and decreased environmental cost such as pollution and noise.

4.1 Congestion Costs and Management

The availability of transit provides travelers with significant savings. Because of transit, some travelers can avoid expenses associated with vehicle ownership. In addition, transit is an effective congestion relief mechanism affecting users of the transit system and other travelers as well. Congestion results from vehicle traffic on the highway network in excess of the network's capacity. At low volumes, traffic flows smoothly at the speed limit. But as traffic volume increases during peak hours, additional vehicles eventually slow the traffic flow and increase the travel time of other vehicles. At this point congestion level increases and, as traffic volumes grow, the costs associated with congestion increase.

The social cost of a trip on a congested road includes travel time delay, vehicle operating cost, safety cost, and environmental cost. An increase in transit services results in social costs savings. Moreover, transit services (1) allow for a reduction in travel time for drivers remaining on roadways, (2) lead to elimination of trips being taken by private vehicles, (3) and result in more efficient use of the roadway network. Therefore, transit can be an alternative to congestion management policies such as gasoline taxes, parking taxes, and congestion-zone taxes. The congestion management benefits are expressed as the cost savings associated with transit use versus automobile use.

4.2 Travel Time Convergence Theory[23]

4.2.1 Background

For the past several years, researchers of traffic systems have observed that in congested urban corridors served by a dedicated transit mode, door-to-door journey times tend to be equal. The findings have profound implications for transportation investment strategies in congested urban corridors and favor a transit-led strategy of investment for the improvement of system performance by all modes.

In general, the amount of time it takes to make a trip during peak hours, and the number of users who decide to use roads versus transit, depend on a number of factors: the highway capacity, the costs of using a car versus taking public transit, and individual traveler's tastes. In spite of all of these variables, a travel pattern emerges in congested urban corridors: the time it takes to complete a journey, door-to-door, tends to be the same across different modes of transportation. Furthermore, it is the journey time by the transit mode that seems to determine the journey time for other modes. In fact, this pattern of converging travel times is predicted by economic theory.

[23] Also known as the Mogridge-Lewis Convergence (MLC) theory

Current planning practice usually does not allow for the convergence of travel times and, in fact, proceeds quite differently.

The standard planning practice consists first of predicting the number of trips that will be made between two locations based on the number of inhabitants in both places, the location of jobs, etc. Then, these trips are apportioned among the different modes based on the traveler's income, personal tastes, etc. It is at this point that standard practice departs from the theoretical and empirical results set forth in this chapter: The standard approach does not account for travelers who move back and forth between modes, much as motorists move between lanes on a highway in their search for a faster-moving lane. It is the presence of these "explorers" that allows for the travel times to converge across modes, toward those for transit.

4.2.2 Modal Explorers

What explains the phenomenon of travel time convergence? One claim is that a dynamic relationship exists which parallels that of a multi-lane highway. Speeds across lanes tend to be equal because some drivers are "explorers" who seek out the faster-moving lane thus driving the system to an equilibrium speed shared by all lanes. By the same token, in congested urban corridors some travelers and commuters are explorers who value travel time improvements highly. They are not committed through circumstance or strong preference to either mode and they behave as occasional mode switchers.

If the transit mode has a high-speed, non-stop segment, then the door-to-door journey time by this mode will be relatively stable and small shifts in ridership will not significantly impact the journey time by the transit mode. On the other hand, under congested conditions even a one-half percent increase in highway traffic volume in the peak period can have a major impact on journey times. In two studies[24] sponsored by the Federal Transit Administration (FTA), HLB estimated intermodal door-to-door travel time for 21 corridors. The table below shows travel time convergence evidence from selected corridors.

[24] HLB (1997) "The Benefits of Modern Transit" sponsored by the Office of Budget and Policy" and HLB (1999) "Method for Streamlined Strategic Corridor Travel Time Management", sponsored by the Office of Budget and Policy

Table 17: Door-To-Door Travel Times for Peak Journeys

Corridor	Auto Mode (Minutes)	Transit Mode (Minutes)
New York - Jamaica, Queens- Midtown Manhattan	63.9	64.4
San Francisco Bay Bridge	72.3	73.1
Philadelphia Schuylkill Expressway	48.4	52.5
Chicago – Midway	54.2	60.6
Chicago - O'Hare	53.9	59.3
Pittsburgh Parkway East	38.1	42.5
Princeton - New York	113.4	104.9
Washington - I-270	71.9	67.4

Because the journey time by transit is stable and determined by the speed of the high-capacity mode, transit "paces" the performance of the urban transportation system in the congested corridor. The modal explorers, like exploring drivers on the multi-lane highway, serve to bring about an equilibrium speed across modes as they seek travel time advantages across modes.

4.2.3 Travel Time Equilibrium and Modal Choice

While travel time represents a dominant component in the cost of trips, the generally accepted models of modal choice and the assignment of trips to networks would not predict travel times to be equal. Rather, the theory behind current practice is that individuals choose a mode based on income, car ownership, price differentials and modal preferences which account for non-money factors like convenience, uninterrupted travel, etc. The persistence of equal, or near equal, travel times across modes in congested corridors suggests that current theory fails to correctly capture modal interrelationships in a multi-modal system.

Appendix A presents the economic theory for consumer behavior under congestion and develops the conditions under which door-to-door trip time by highway converges to the trip time by the high-capacity transit mode. It further demonstrates how congestion promotes the modal explorer behavior.

4.3 Methodology for Estimating Delay Savings

This section describes the methodology to estimate delay savings to be brought by the light rail system. The methodology is based on the Mogridge-Lewis Convergence (MLC) theory exposed in the previous section. The methodology consists of four steps:

1. *Estimating the Corridor Performance Baseline;*

2. *Estimating the Corridor Performance in the Presence of transit;*

3. *Extrapolating Delay Savings Due to Transit; and*

4. *Estimating Travel Cost Savings.*

4.3.1 Corridor Performance Baseline

This model represents the baseline that quantifies the role of transit in congestion management. In the absence of transit, the travel time T_1 is estimated as:

$$T_1 = T_{ff} * (1 + A (V)^{\beta}) \qquad \textit{Equation 1}$$

Where T_1 is the door-to-door travel time;

T_{ff} is the trip travel time at free-flow speed;

V is the volume of person trips by auto; and

A is a scalar, and β is a parameter.

Equation 1 implies that the door-to-door travel time in the absence of high-capacity transit depends on the travel time at free-flow speed and the level of congestion on the road.

4.3.2 Corridor Performance in the Presence of Transit

This model establishes a functional relationship between the person highway trip volume and the average door-to-door travel time by auto in the corridor. The door-to-door travel time by auto can be determined using a logistic function that calculates the travel time in terms of travel time at free flow speed, trip time by high capacity rail mode, and the volume of trips in the corridor for all modes. The door-to-door travel time can be estimated as follows:

$$T_2 = (T_c - T_{ff}) / (1 + e^{-(\delta + \varepsilon V)}) + T_{ff} \qquad \textit{Equation 2}$$

Where T_2 is the door-to-door travel time;

T_c is trip time by high-capacity rail mode;

T_{ff} is auto trip time at free-flow speed;

V is person auto trip volume in the corridor; and

δ, ε are model parameters.

Equation 2 implies that the door-to-door auto trip time is equal to the trip time at free-flow speed plus a delay that depends on transit travel time and the person trip volume in the corridor.

In other words, when the highway volume is close to zero, travel time is equal to travel time at free flow speed: $T_2 = T_{ff}$. As the volume increases, the travel time is equal to T_{ff} plus a delay due to the high volume, but adjusted to the travel time by high capacity transit. That is the high capacity transit alleviates some of the highway trip delay as some trips shift to transit.

Equation 2 is transformed into a linear functional form before the parameters δ and ε can be estimated, the transformed equation is:

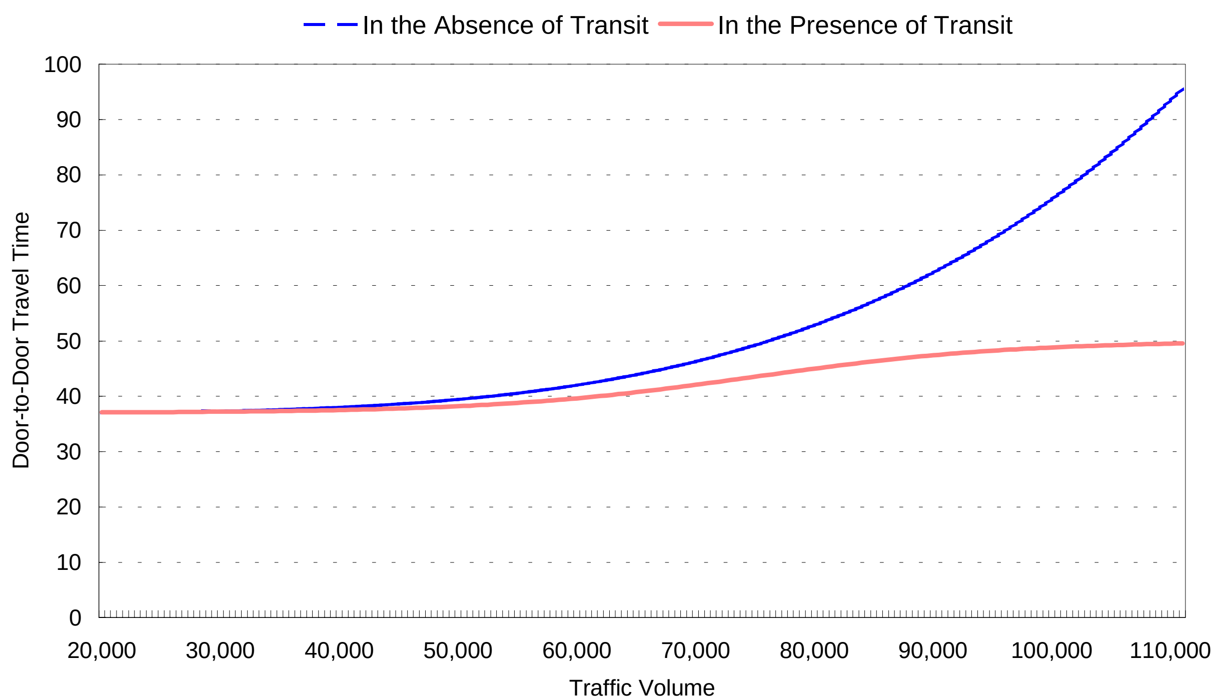
$$U = \delta + \varepsilon V_1 \qquad \textit{Equation 3}$$

Where $U = \ln [(T_c - T_{ff}) / (T - T_{ff}) - 1]$

The parameters δ and ε do not have to be re-estimated each year. They are both specific to the corridor and are relatively stable over the years. Therefore, the person trips volume forecast can be inserted into Equation 2 to estimate the door-to-door travel time by auto.

The model shows that in the absence of transit and high degree of convergence, the person trip volume is very high, which translates into excessive delay. The relationship between trip time and person trip volume can be expressed as a convex curve (as the volume increases, travel time increases at an increasing rate). The figure below illustrates the relationship between volume and travel time, both in the presence and in the absence of transit.

Figure 9: Travel Time in the Presence and in the Absence of Transit



4.3.3 Extrapolating Delay Savings Due to Transit

The estimated hours of delay savings due to transit are an aggregation of three different user savings: savings by light rail commuters (market benefits), savings by users of highway next to the rail line defined as the common segment (club benefits), and savings by users of other highways within the network (spillover benefits).

4.3.4 Network Delay Savings

The methodology employs the MLC hypothesis to measure the savings in network delay brought by transit and its equilibrating effect on the level of service in the corridor. The MLC hypothesis, again, predicts that in congested urban corridors the time it takes to complete a journey door-to-door tends to be the same across different modes of transportation. Furthermore, it is the journey time by the transit mode that seems to determine the journey time for other modes. Therefore, the introduction of light rail services leads to lower congestion and reduced trip time. This relationship implies that in the presence of transit in the corridor, the congestion will improve as trip time and trip volume on the highway decrease.

The methodology uses the functional relationship between travel time and person trip volume. The model is populated by door-to-door auto travel time, door-to-door travel time by rail, and historical travel volume data. The coefficients of the model are estimated using non-linear regression. Delay savings are estimated as the vertical difference between the "In the presence of Light Rail" curve and the "In the absence of Light Rail" curve. That is, at a specific person trip volume, the difference in travel times between the two cases can be defined as "the hours of delay saved due to transit".

Total benefits are calculated as the sum of market benefits (benefits to light rail riders), club benefits (benefits to users of highways next to the light rail alignment), and spillover benefits (benefits to the rest of the network users).

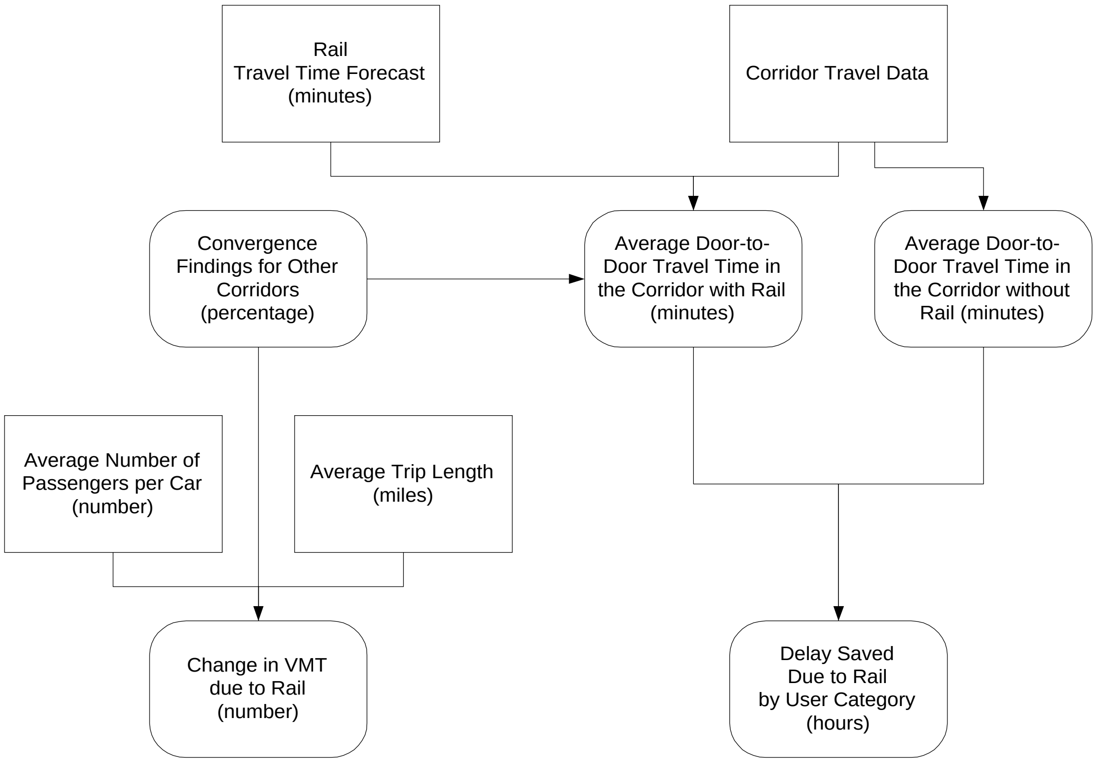
- The market benefits are estimated based on delay saved (which depends on the distance traveled) for each rider within the corridor;

- The club benefits are estimated based on the volume on the common segment (I-71) using an origin-destination table and the daily trip distribution. These savings are the results of faster roadway travel on the corridor due to the shift of motorists to transit; and

- The spillover benefits are estimated based on the savings per mile, traffic volume, and the distance traveled on the overall network including segments parallel to I-71 that will directly benefit from the improvement to the travel speed due to light rail service. The spillover benefits are calculated by multiplying the traffic volume with a percentage of the delay savings. This percentage decreases as the distance between the corridor segment and the parallel highway increases.

Figure 10 shows the structure and logic diagram for estimating delay savings.

Figure 10: Structure and Logic For Estimating Delay Savings



4.4 Methodology for Estimating Travel Cost Savings

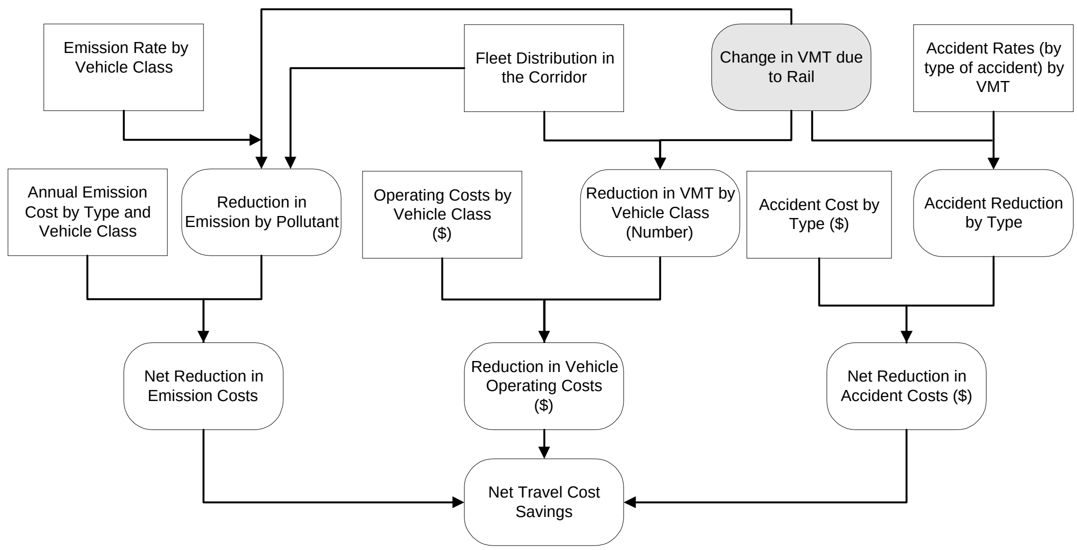
Estimating travel cost savings requires three steps. The first step determines the number of trips diverted from other modes (cars, taxi, and bus) to light rail person trips. The estimate is based on the availability of cars to commuters, the price of alternative modes, and the income level of commuters. The second step consists of translating the number of trips into Vehicle Miles Traveled (VMT), based on average trip length for each mode. The third step computes the cost savings resulting from changes in VMT and speed improvements throughout the network. The cost categories considered in the model are:

1. <u>Vehicle operating costs</u>: fuel consumption, oil consumption, maintenance and repairs, tire wear, insurance, license, registration, taxes, and roadway related vehicle depreciation;

2. <u>Accident costs</u>: monetary cost of fatal accidents, injuries, and Property Damage Only (PDO) accidents; and

3. <u>Environmental costs</u>: social costs associated with vehicular emissions that are leading factors in air pollution: carbon monoxide (CO), nitrogen oxides (NOx), and hydrocarbons (HC). The Greenhouse gases carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) are also estimated.

Figure 11: Structure and Logic for Estimating Travel Cost Savings



4.4.1 VMT Reduction

Based on national experience with similar projects, HLB assumes that, in steady state, 40% of light rail trips will be diverted from the bus system, 6% from taxis, and 54% from non-transit modes.[25] To estimate VMT reduction, total trips diverted to light rail have been converted to VMT reduction based on average trip length and vehicle occupancy by mode. The VMT reduction per day by mode ΔVMT_{Mode} is estimated as follows:

$$\Delta VMT_{Mode} = ((DF * RF) / OR_{Mode}) * ATL_{Mode}$$

Where DF is the diversion factor,

RF is the light rail ridership forecast,

OR is vehicle occupancy rate by mode, and

ATL is the average trip length by mode.

Again, travel cost savings - other than travel time savings - are estimated based on the VMT reduction and the cost factor estimated for each travel cost category: vehicle operating costs, accident costs, and environmental costs.

[25] Median estimates

4.4.2 Vehicle Operating Costs

Vehicle operating costs (VOC) are an integral element of computing highway user costs. They generally are the most recognized of user costs because they typically involve the out-of-pocket expenses associated with owning, operating, and maintaining a vehicle. The cost components associated with operating a vehicle are: fuel consumption, oil consumption, maintenance and repairs, tire wear, insurance, license, registration, taxes, and roadway related vehicle depreciation. Each component is a unique function of vehicle class, vehicle speed, grade level, and surface condition. Thus overall VOC can vary significantly between different facility types, geographic areas, and traffic patterns. In the model, vehicle operating costs in the base and alternate (light rail) cases are estimated based upon relationships developed by the Texas Transportation Institute for the National Cooperative Highway Research Program. These relationships are presented in Appendix C at the end of this report.

4.4.3 Accident Costs

Accident costs are a significant component of highway user costs. Highway safety is a key economic factor in the planning of roads, as well as an important indicator of transportation efficiency. Outside of the economic context, highway safety is often the object of public concern and a leading social issue. However, since improved safety requires the use of real resources, it competes with alternative goals and aspects of transportation efficiency. The accident cost model component is based on incident rate tables developed for the FHWA (See Appendix C). Incident rates, expressed as number of fatalities, injuries and Property Damage Only (PDO) accidents per 100,000,000 VMT are combined with estimated VMT reduction to come up with total accident cost savings.

4.4.4 Environmental Costs

Environmental costs are gaining increasing acceptance as an important component in the economic evaluation of transportation and infrastructure projects. The main environmental impacts of vehicle use, exhaust emissions and vehicle-generated noise, can impose wide-ranging social costs on people, material, and vegetation. Sections of recent federal legislation, such as the Clean Air Act (CAA) amendments of 1990, as well as the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, are designed to directly account for the environmental impacts of proposed transportation investments. The negative effects of pollution depend not only on the quantity of pollution produced, but on the types of pollutants emitted and the conditions into which the pollution is released. As with other travel costs savings, environmental cost savings are calculated based on the vehicle miles traveled reduction and the speed improvement throughout the network. The environmental benefits, however, are also due to speed smoothing (congestion reduction). Therefore, the emission savings are calculated as the difference between emission at lower speed (without light rail) and emission at higher speed (with light rail).

Hydro Carbon, Carbon Monoxide and Nitrogen Oxide Emissions are estimated from the relationships presented in Appendix C at the end of the report. In addition, greenhouse gas emissions (emissions of Carbon Dioxide, Methane and Nitrous Oxide) are estimated from the change in fuel consumption derived in the Vehicle Operating Cost module and an emission factor indicating the average amount of pollutant emitted per gallon of fuel (See Appendices).

The final step of the estimation methodology consists of aggregating all travel costs savings to estimate the congestion management benefits of light rail.

4.5 Assumptions For Estimating Congestion Management Benefits

This section presents the assumptions to be used in estimating the congestion management benefits of light rail in I-71 Corridor. The assumptions are presented in order of their probability of occurrence. Three estimates are presented for each category:

- Median Estimate: represents the central estimate or the "most likely" outcome;

- Lower Estimate: represents the lower 10% probability of occurrence or the conservatively low outcome.

- Upper Estimate: represents the upper 10% probability of occurrence or the optimistically high outcome.

Table 18 lists the key assumptions for estimating the congestion management benefits.

Table 18: Description of Key Assumptions

Variable	Description
Delay Savings	
First Year Annual Average Daily Traffic	Average number of vehicles per day in 2001
AADT Yearly Growth 2000 - 2007	Average annual growth in traffic between 2000 and 2007
AADT Yearly Growth 2008 - 2014	Average annual growth in traffic between 2008 and 2014
AADT Yearly Growth 2015 - 2019	Average annual growth in traffic between 2015 and 2019
AADT Yearly Growth 2020 - 2037	Average annual growth in traffic in 2020 and after
Free Flow Highway Travel Time	Highway travel time at free flow speed
Opening Year Light Rail Travel Time	Light rail travel time forecast for the MOS
Vehicle Occupancy - Auto	Average number of persons in a car
Vehicle Occupancy - Bus	Average number of persons in a bus
Vehicle Occupancy - Taxi	Average number of persons in a taxi
Emission Costs	
Hydro Carbon Emission Cost	Monetary value of a ton of HC emission
Carbon Monoxide Emission Cost	Monetary value of a ton of CO emission
Nitrogen Oxide Emission Cost	Monetary value of a ton of NOx emission
Carbon Dioxide Emission Cost	Monetary value of a ton of CO2 emission
Methane Emission Cost	Monetary value of a ton of CH4 emission
Nitrous Oxide Emission Cost	Monetary value of a ton of N2O emission
Accident Costs	
Fatal Accident Cost	Average cost of a fatal accident
Injury Accident Cost	Average cost of an injury only accident
Property Damage Cost	Average cost of a property damage only accident
Vehicle Operating Costs	

Variable	Description
Fuel Cost	Average cost of a gallon of fuel
Oil Cost	Average cost of a quart of oil
Tire Cost	Average cost of a tire
Maintenance and Repair Cost	Average maintenance and repair cost
Vehicle Depreciable Value	Average depreciable value of a vehicle
Light Rail Ridership	
Ridership in Opening Year	Average daily number of light rail riders in opening year
Annual Ridership Growth 2008 - 2014	Average annual ridership growth between 2008 and 2014
Annual Ridership Growth 2015 - 2019	Average annual ridership growth between 2015 and 2019
Annual Ridership Growth 2020 - 2037	Average annual ridership growth in 2020 and after
Trips Diverted from Auto to Light Rail	Percentage of light rail trips diverted from autos
Trips Diverted from Bus to Light Rail	Percentage of light rail trips diverted from buses
Trips Diverted from Taxi to Light Rail	Percentage of light rail trips diverted from taxis
Ridership in Peak Time	Percentage of total ridership in peak period

The table below presents the ranges (median, lower and upper estimates) assigned to each of the key assumptions.

Table 19: Values Assigned to Key Assumptions

Variable	Unit	Median Estimate	Lower Estimate	Upper Estimate
Delay Savings				
First Year Annual Average Daily Traffic	# of vehicles	63,425	63,425	63,425
AADT Yearly Growth 2000 - 2007	%	1.92	1.41	4.05
AADT Yearly Growth 2008 - 2014	%	1.67	1.03	2.27
AADT Yearly Growth 2015 - 2019	%	1.37	0.93	1.80
AADT Yearly Growth 2020 - 2037	%	1.00	1.00	1.00
Free Flow Highway Travel Time	minutes	37	37	37
Opening Year LRT Travel Time	minutes	50	50	50
Vehicle Occupancy - Auto	# of persons	1.05	1.04	1.09
Vehicle Occupancy - Bus	# of persons	25	25	25
Vehicle Occupancy - Taxi	# of persons	1.05	1.04	1.09
Emission Costs				
Hydro Carbon Emission Cost	$/ton	3,045	1,774	6,258
Carbon Monoxide Emission Cost	$/ton	3,889	3,394	5,939
Nitrogen Oxide Emission Cost	$/ton	6,072	3,731	12,028
Carbon Dioxide Emission Cost	$/ton	25	13	38
Methane Emission Cost	$/ton	147	74	221
Nitrous Oxide Emission Cost	$/ton	3,816	1,908	5,725
Accident Costs				
Fatal Accident Cost	$T/accident	3,384.3	2,621.923	3,984.094

Variable	Unit	Median Estimate	Lower Estimate	Upper Estimate
Injury Accident Cost	$T/accident	94.866	57.43	101.963
Property Damage Cost	$T/accident	3.195	2.603	6.569
Vehicle Operating Costs				
Fuel Cost	$/gallon	1.138	0.955	1.368
Oil Cost	$/quart	3.984	3.373	4.746
Tire Cost	$/tire	84.62	71.078	101.005
Maintenance and Repair Cost	$	97.545	80.939	117.222
Vehicle Depreciable Value	$thousand	13.417	10.734	16.101
Light Rail Ridership				
Ridership in Opening Year	# of riders	26,267	20,500	29,667
Annual Ridership Growth 2008 - 2014	%	1.25	-0.56	5.63
Annual Ridership Growth 2015 - 2019	%	1.03	-0.81	3.88
Annual Ridership Growth 2020 - 2037	%	1.03	-0.81	3.88
Trips Diverted from Auto to LRT	%	54	48	60
Trips Diverted from Bus to LRT	%	40	32	48
Trips Diverted from Taxi to LRT	%	6	2	10
Ridership in Peak Time	%	50	50	50

All values are in Year 2001 dollars.
Value of Travel Time: "Highway Economic Requirements System Technical Report", FHWA, USDOT, Washington DC 1991. Emissions Costs: "Monetary Values of Air Pollution Emissions in Various US Areas," Wang M. and D. Santini, TRB Paper 951046, January 1995. Accident Costs: "The Cost of Highway Crashes," Miller, T., Viner J., Pindus, N, et al., The Urban Institute, FHWA, USDOT, 1991. Vehicle Operating Costs: "Your Driving Costs," American Automobile and Runzheimer International," 1998.

4.6 Estimation of Congestion Management Benefits

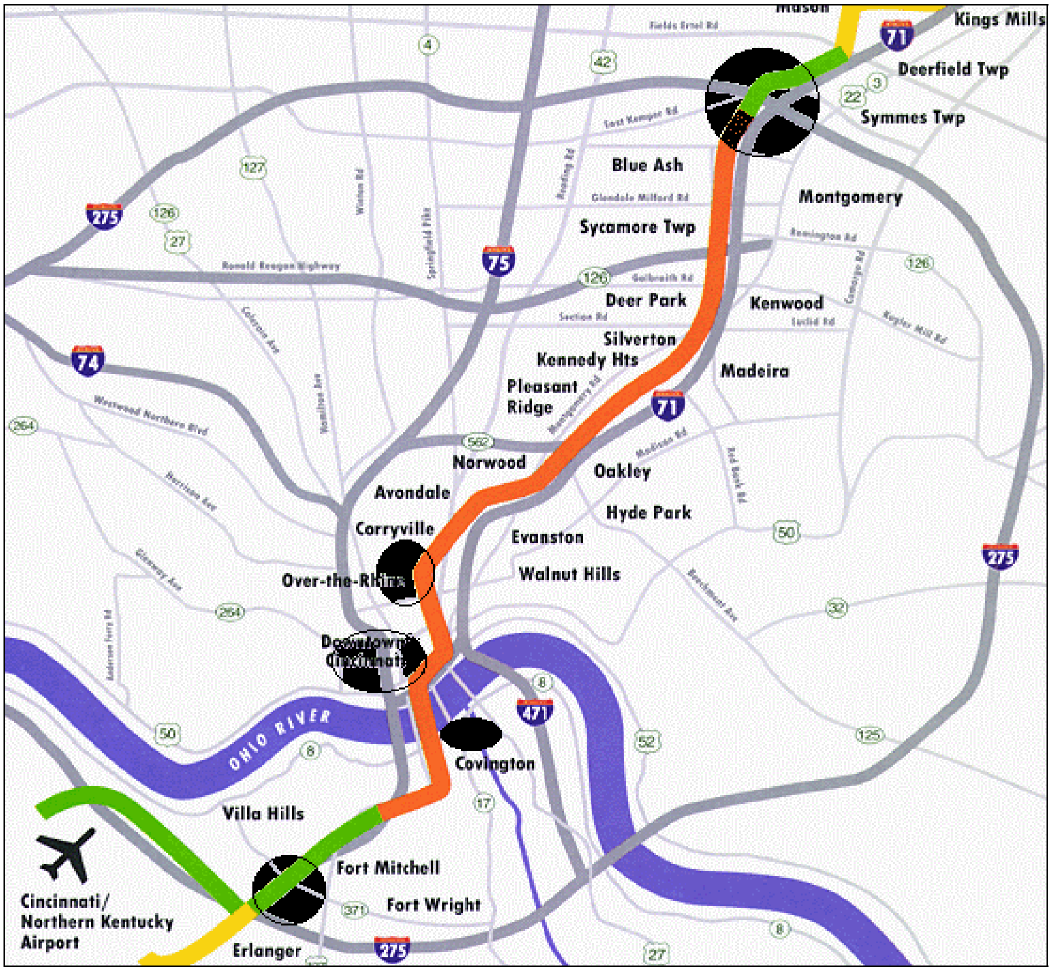
4.6.1 Travel Time in the I-71 Corridor

HLB conducted a three-day door-to-door travel time survey in the I-71 Corridor during the month of November 2000. The survey was based on 50 origins and destinations in five areas of the corridor: Blue Ash, Ohio; Downtown Cincinnati, Ohio; The University of Cincinnati Campus, Ohio; Downtown Covington, Kentucky; and Northern Fort Mitchell, Kentucky. Survey drivers drove four Origin-Destination segments in three distinct sections:

- The route between the original point and the I-71 access ramp (Access1);
- The I-71 Segment (Common Segment); and
- The route from the I-71 exit ramp to the destination point (Access2)

To mimic commuter behavior, survey drivers drove during morning rush hour from neighborhood areas within a 3-mile radius of I-71 to specific destinations in the business district or on the university campus. The evening rush hour trip covered the same routes in the opposite direction. The five origins and destinations used in the survey are shown in the darkened areas of Figure 12, below. The survey results are shown in Table 20.

Figure 12: Map of the I-71 Corridor and the Origin-Destination Segments



Based on thirty trips each way, the travel time survey reveals that the average speed in the corridor (for both the interstate and the access segments) during peak periods varies from 30 miles per hour (mph) on the Blue Ash-Downtown Cincinnati segment, to 16 mph on the Fort Mitchell-Downtown Cincinnati segment. The low speed results from the congestion on the bridges and access segments to the interstate.

To project travel time in the corridor, in the absence of light rail, HLB used the following:

- Survey results described above;
- Traffic growth trends in the corridor[26] during the past decade; and
- Socioeconomic projections developed by OKI.

[26] Traffic volume data were obtained from Ohio Department of Transportation (ODOT). ODOT has 9 data collection points along the I-71 Corridor.

Table 20: Door-to-Door Travel Time Survey Results (in minutes)

		Access Segments			Common Segments			Overall Trip		
Route Segments	Distance (miles)	Median	Lower 10%	Upper 10%	Median	Lower 10%	Upper 10%	Median	Lower 10%	Upper 10%
Blue Ash – Downtown Cincinnati (AM)	20	18	9	39	21	13	28	40	31	55
Downtown Cincinnati - Blue Ash (PM)	20	16	9	41	21	14	27	37	27	66
Blue Ash – Downtown Covington (AM)	22.5	8	5	13	30	26	33	38	37	40
Downtown Covington - Blue Ash (PM)	22.5	12	8	14	21	15	26	33	28	36
Blue Ash – University of Cincinnati (AM)	19	16	12	21	25	22	30	41	35	51
University of Cincinnati - Blue Ash (PM)	19	19	12	36	19	15	23	38	30	58
Fort Mitchell – Downtown Cincinnati (AM)	5.5	10	6	16	13	6	26	21	12	32
Downtown Cincinnati - Fort Mitchell (PM)	5.5	8	6	12	6	6	8	15	12	20

Table 21 presents the assumptions regarding the traffic volume growth through year 2037[27]. The growth rates are presented in ranges per year to account for the uncertainty surrounding the traffic growth in the corridor. Traffic counts by Ohio Department of Transportation indicate that traffic on the I-71 / US-22 interchange grew by about 3% per year between 1991 and 1998. However, given the fluctuations of traffic growth in the corridor and the uncertainty surrounding traffic forecast, HLB used a conservative traffic growth and applied risk analysis to account for uncertainty. Figure 13 shows the door-to-door travel time along the corridor from Blue Ash, OH to Downtown Cincinnati based on the median estimates from the traffic growth assumptions shown in Table 19 and summarized in Table 21 below.

Table 21: Average Annual Traffic Volume Growth Assumptions

	Median Estimate	10% Lower Limit	10% Upper Limit
2000 - 2007	1.92%	1.41%	4.05%
2008 - 2014	1.67%	1.03%	3.27%
2015 – 2019	1.73%	0.93%	3.00%
2020 - 2037	1.00%	1.00%	1.00%

[27] The 30-year period between 2008 and 2037 is used as the asset life for the light rail system.

Figure 13: Door-to-Door Travel Time Projections

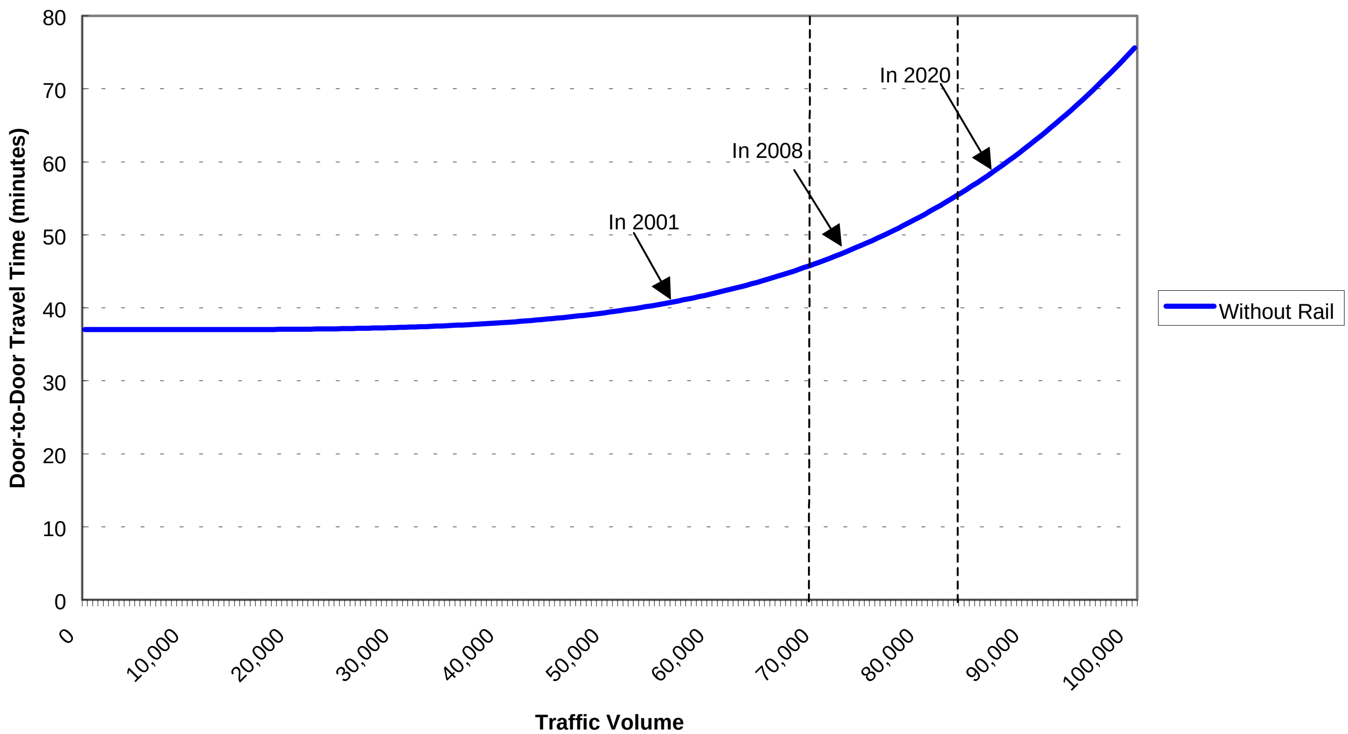


Figure 13 shows that the door-to-door travel time in a 20-mile segment between Blue Ash and Downtown Cincinnati will increase by 20 minutes in the coming 19 years, an increase of about 50% from current commute times. The next section of this chapter assess the effect on travel time when introducing a light rail system in I-71 Corridor.

4.6.2 Model Estimation

Based on the Federal Transit Administration findings, a computer simulation model of delay savings (savings in door-to-to travel times) due to the presence of fixed guideway transit has been developed and applied in forecasting the effects of prospective new fixed guideway and/or dedicated right-of-way transit systems in strategic metropolitan corridors. The model estimates the economic value of projected savings in door-to-door travel times for transit and highway users. For highway users, the model estimates the economic value of vehicle operating cost reductions and accident avoidance. From a regional perspective the model yields estimates of the economic value of air quality improvements associated with reduced highway travel.

To illustrate how the model calculates delay savings, Equations 1 and 2 from Section 4.3 are shown below.

$$T_1 = (50 - 37) / (1 + e^{-(-6.700 + 9.1875E\text{-}05\,(V))}) + 37 \qquad \textit{Equation 1}$$

$$T_2 = 37 * (1 + 1.0432E\text{-}20\,(V)^{4.0}) \qquad \textit{Equation 2}$$

Again, delay savings are estimated as the difference between the average door-to-door travel time with light rail and the average door-to-door travel time in the absence of light rail.

In the opening year, travel time in the absence of transit is $\boldsymbol{T_1 = 47.89}$**,** while travel time in the presence of transit is estimated as $\boldsymbol{T_2 = 43.75}$: a difference of 4 minutes and 8 seconds. This implies that on average, the light rail along the MOS will save about 13 seconds per mile in the opening year.

In 2008: $\Delta T = 47.89 – 43.75 = 4.14$ (4 minutes and 8 seconds or 13 seconds per mile)

The same calculation can be done for year 2020:

In 2020: $\Delta T = 59.13 – 49.75 = 11.38$ (11 minutes and 23 seconds or about 36 seconds per mile)

Figure 14 on the next page shows the risk analysis model simulation results for the average door-to-door travel time based on the traffic growth assumptions listed in Table 21. The figure implies that while in the first 6 years of light rail operation, the average door-to-door travel time by car is faster than the average door-to-door travel time by rail, the generalized price (travel time value plus waiting time, parking, vehicle operating cost, and other car ownership-related costs) is lower for rail trips than for car trips. This generalized price differential provides the incentive for commuters to shift from car to rail. Figure 14 also shows that, given the travel time uncertainty surrounding each mode, travel time by rail and car--in the presence of light rail--will be statistically equal by year 2014. In other words the system will reach the travel time conversion level within 6 years of light rail opening.

Figure 15 shows that in the presence of light rail, the combined average door-to-door travel time in the corridor by car and rail is lower than the average door-to-door travel time in the absence of transit. With light rail, the average door-to-door travel time in the corridor (highway and rail) will increase at a lower rate than in the absence of light rail. The lower rate of travel time growth is mainly due to the light rail commuters' shift across modes, searching for the quickest and least expensive mode.

Figure 14: Travel Time Convergence

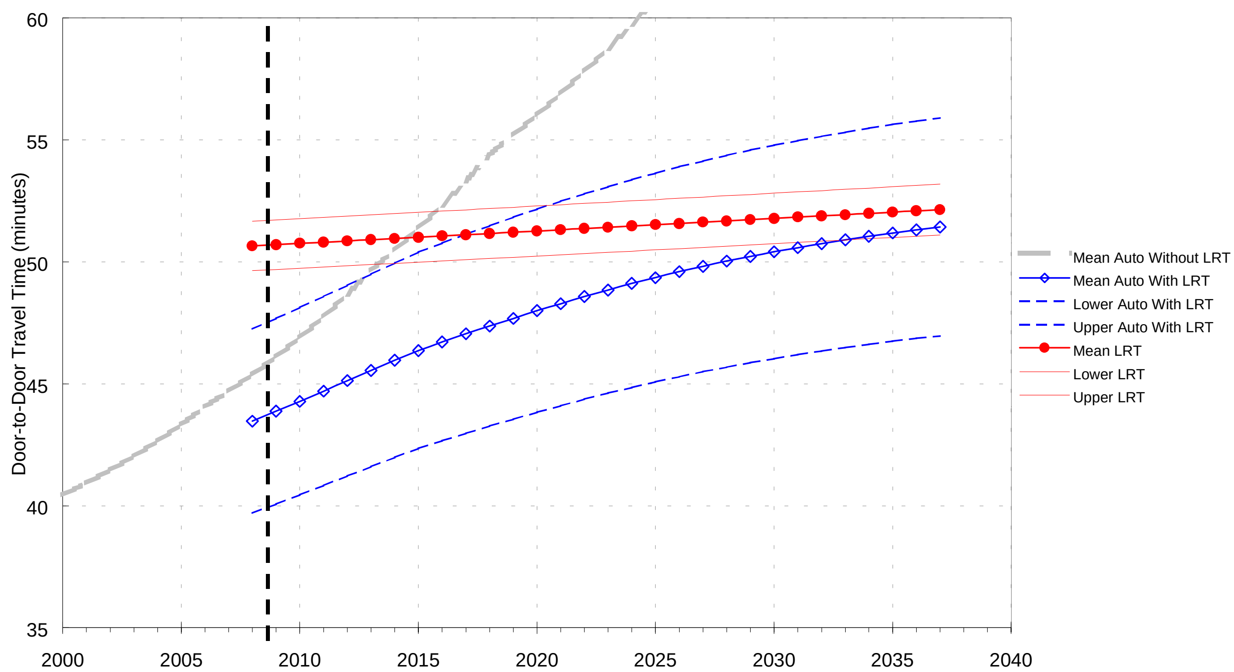
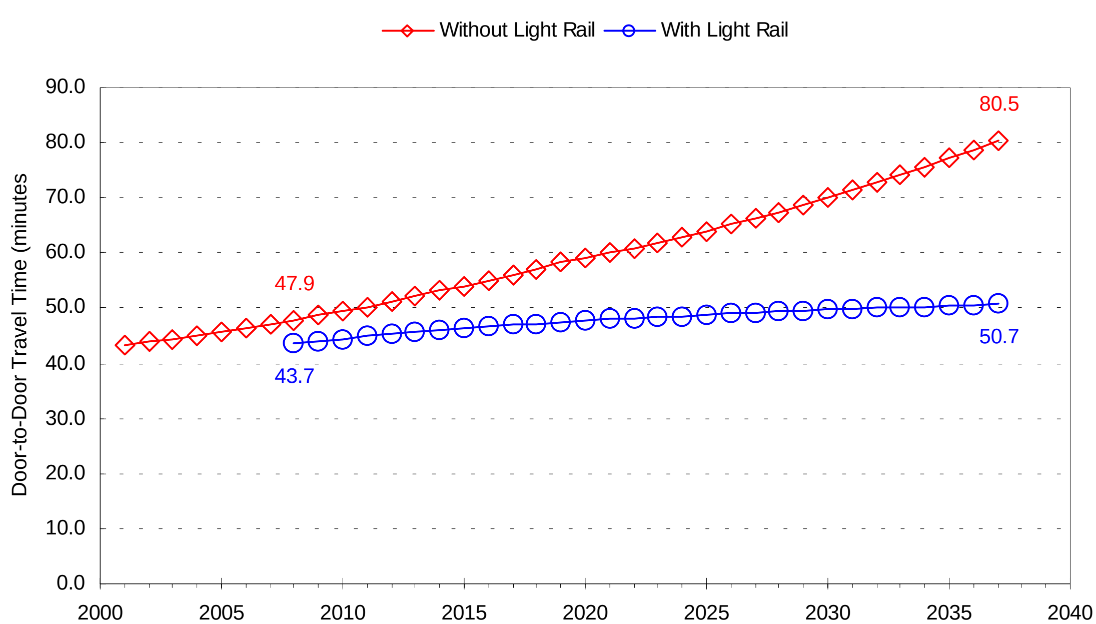


Figure 15: Door-to-Door Travel Time Estimates



The incremental nature of the delay reduction is not estimated as the difference between travel time by rail versus travel time by car, because that method of calculation would underestimate the delay reduction since the presence of the light rail leads to travel time convergence in a congested corridor. Therefore travel time differences between the two modes will not be significant.

4.6.3 Economic Valuation of Travel Savings to Light Rail

Figure 16 below shows that between 2008 and 2037, the projected door-to-door travel time saving due to transit for both highway and transit users is significant. This saving, on an average length journey, ranges from 9% in year 2008 to about 30% in year 2037.

The estimated savings presented in Figure 16 are translated into their equivalent economic value in Table 22. The table reports that the travel time savings per commuter is about $429 in the first year of light rail operation, $1,650 per commuter in 2020, and reaches $3,910 per commuter in 2030. Table 23 presents the value of savings per commuter for four segments along the corridor.

Figure 16: Annual Door-to-Door Travel Time Savings in the Corridor

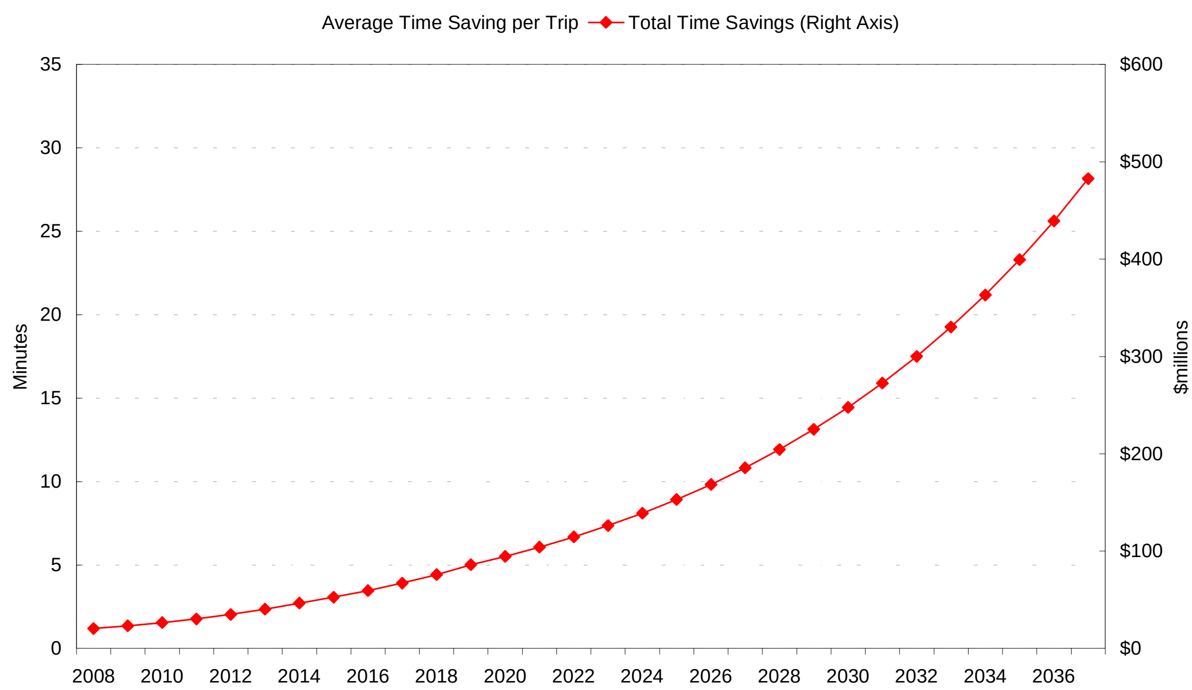


Table 22: Annual Travel Time Savings

	2008	2015	2020	2030
Average Annual Daily Traffic During Peak Period in The Corridor (Without Transit)	72,341	80,815	86,165	95,180
Average Annual Daily Traffic During Peak Period in The Corridor (With Transit)	65,085	72,405	77,132	84,384
Travel Time Without Light Rail (minutes)	47.89	54.09	59.13	69.95
Travel Time With Light Rail (minutes)	43.75	46.31	47.75	49.69
Travel Time Savings				
Per Trip (minutes)	4.14	7.78	11.38	20.25
Per Trip Percentage Time Savings	8.64%	14.38%	19.25%	28.95%
Per Trip (in-year dollars)	$0.86	$1.96	$3.30	$7.82
Per Commuter Annually (in-year dollars)	$429	$981	$1,651	$3,910
Total Annually (millions of in-year dollars)	**$20.4 M**	**$52.6 M**	**$94.5 M**	**$247.8 M**

Table 23: Annual Travel Time Savings Per Major Routes in the Corridor

	2008	2015	2020	2030
Blue Ash to Downtown Cincinnati				
Per Trip (minutes)	4.36	8.19	11.98	21.32
Per Trip (in-year dollars)	$0.90	$2.07	$3.48	$8.23
Per Commuter Annually (in-year dollars)	$452	$1,033	$1,738	$4,115
Blue Ash to Downtown Covington				
Per Trip (minutes)	4.91	9.21	13.48	23.98
Per Trip (in-year dollars)	$1.02	$2.32	$3.91	$9.26
Per Commuter Annually (in-year dollars)	$509	$1,162	$1,955	$4,630
Blue Ash to UC				
Per Trip (minutes)	4.14	7.78	11.38	20.25
Per Trip (in-year dollars)	$0.86	$1.96	$3.30	$7.82
Per Commuter Annually (in-year dollars)	$429	$981	$1,651	$3,910
Fort Mitchell to Downtown Cincinnati				
Per Trip (minutes)	1.20	2.25	3.29	5.86
Per Trip (in-year dollars)	$0.25	$0.57	$0.96	$2.26
Per Commuter Annually (in-year dollars)	$124	$284	$478	$1,132

The estimated hours of delay savings due to transit are an aggregation of three different user savings: savings by light rail riders (market benefits), savings by I-71 highway users (club benefits), and savings by users of the rest of the roadway network within ½ mile of the I-71 highway (spillover benefits).

The market benefits are estimated based on delay saved (which depends on the distance traveled) by each rail rider. The club benefits are estimated based on the volume on the I-71 segment. The spillover benefits are estimated based on the savings per mile and traffic volume on segments parallel to the I-71 common segment. Table 24 shows the summary of benefits by category, demonstrating that 78% of the savings are highway users savings, while transit users enjoy about 10% of the savings.

Table 24: Present Value of Time Savings over 2008-2037, Millions of Year-2001 Dollars

	Mean	90% Probability of Exceeding	10% Probability of Exceeding
Market Benefits	$78.6 M	$29.2 M	$138.8 M
Club Benefits	$661.1 M	$245.6 M	$1,167.4 M
Spillover Benefits	$99.2 M	$36.8 M	$175.1 M
Total Time Savings	**$838.9 M**	**$311.6 M**	**$1,481.3 M**

The next section of this chapter estimates the economic value of associated benefits in relation to vehicle operating costs, safety, and air quality.

4.6.4 Travel Cost Savings Estimation

Figure 17 presents the annual vehicle operating cost savings throughout the life cycle of the investment. Table 25 reports that the average annual vehicle operating costs savings is about $1,634 per light rail rider and $37 per highway commuter during the peak period in 2008. These savings will increase to $3,384 per light rail rider and $308 per highway commuter in 2030. Table 26 shows the risk analysis estimates of the vehicle operating costs savings for the overall light rail life cycle. The table demonstrates a 50% probability that the present value of vehicle operating costs savings in the corridor is $136 million.

Figure 17: Vehicle Operating Cost Savings, Millions of In-Year Dollars

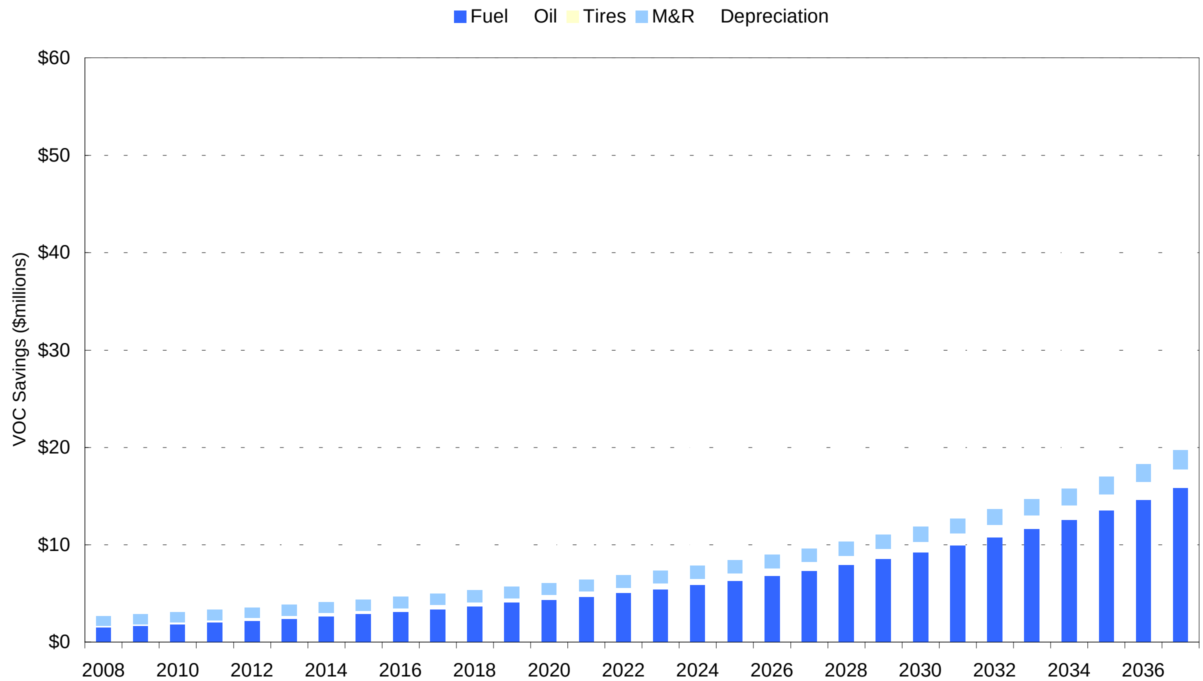


Table 25: Vehicle Operating Cost Estimates, In-Year Dollars

	2008	2015	2020	2030
Average Vehicle Operating Cost Per Trip Without Light Rail (dollars)	$3.27	$4.10	$4.84	$6.77
Average Vehicle Operating Cost Per Trip With Light Rail (dollars)	$3.19	$3.93	$4.57	$6.15
Average Annual Vehicle Operating Cost Savings Per Highway Commuter During Peak Period (dollars)	$37	$85	$136	$308
Average Annual Avoided Vehicle Operating Costs Per Light Rail Rider (dollars)	$1,634	$2,052	$2,421	$3,384

Table 26: Present Value of VOC Savings over 2008-2037, Millions of Year-2001 Dollars

	Mean Expected	90% Probability of Exceeding	10% Probability of Exceeding
From Reduced Traffic	$126.5 M	$72.1 M	$186.5 M
From Improved Speed	$9.5 M	$5.4 M	$14.1 M
Total Vehicle Operating Costs Savings	**$136.0 M**	**$77.5 M**	**$200.6 M**

Figure 18 shows the annual safety cost savings based on vehicle miles traveled reduction and safety cost factors. The results are translated in Table 27 as annual safety savings in year 2008 of $7.5 million, reaching $20 million in total accident cost avoided by year 2030.

Figure 18: Accident Cost Savings, Millions of In-Year Dollars

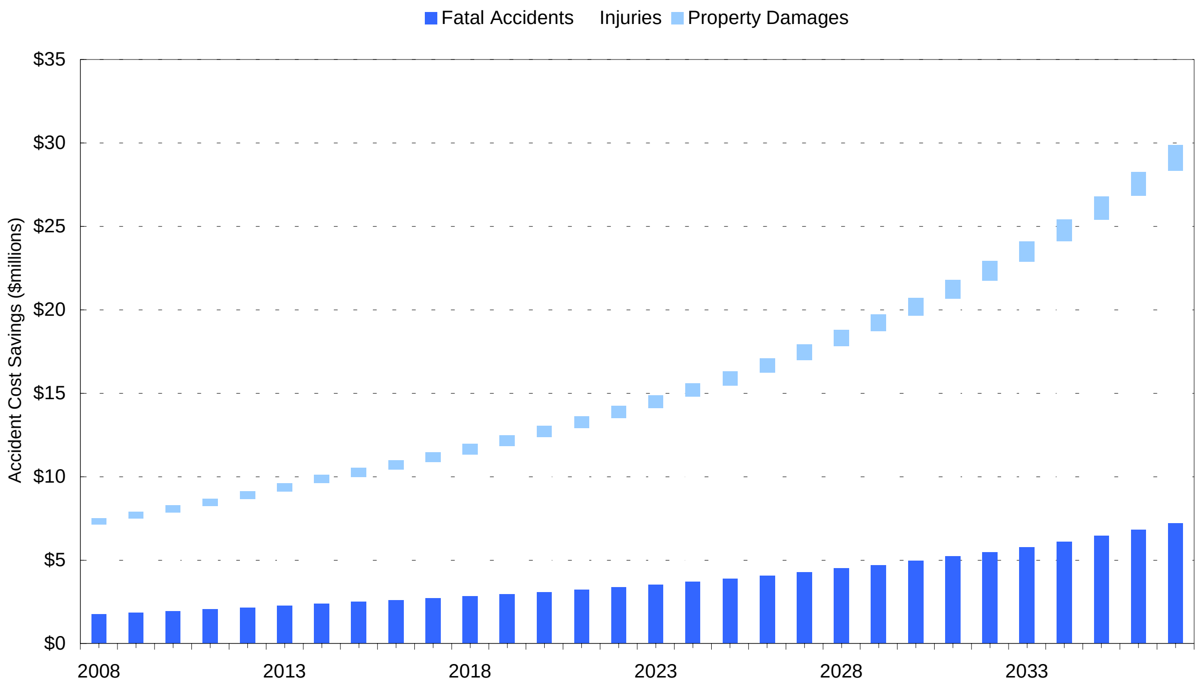


Table 27: Accident Cost Savings, In-Year Dollars

	2008	2015	2020	2030
Number of Fatal Accidents Avoided	0.4	0.5	0.6	0.7
Fatal Accident Cost Savings	$1.8 M	$2.5 M	$3.1 M	$5.0 M
Number of Injury Accidents Avoided	51.7	59.4	63.8	76.2
Injury Accident Cost Savings	$5.4 M	$7.5 M	$9.3 M	$14.7 M
Number of Property Damages Avoided	79.5	92.1	99.0	118.6
Property Damage Cost Savings	$0.4 M	$0.5 M	$0.7 M	$1.1 M
Total Accident Cost Savings	**$7.5 M**	**$10.5 M**	**$13.0 M**	**$20.7 M**

Figure 19 shows the annual emission savings while Table 28 provides the emission savings throughout the light rail life cycle. The table shows that about 10% of the emission savings are due to the reduction in greenhouse gas emissions associated with decreased fuel consumption. The table also shows a 50% probability that total emission savings between 2008 and 2037 will reach $72 million.

Figure 19: Emission Cost Savings, Millions of In-Year Dollars

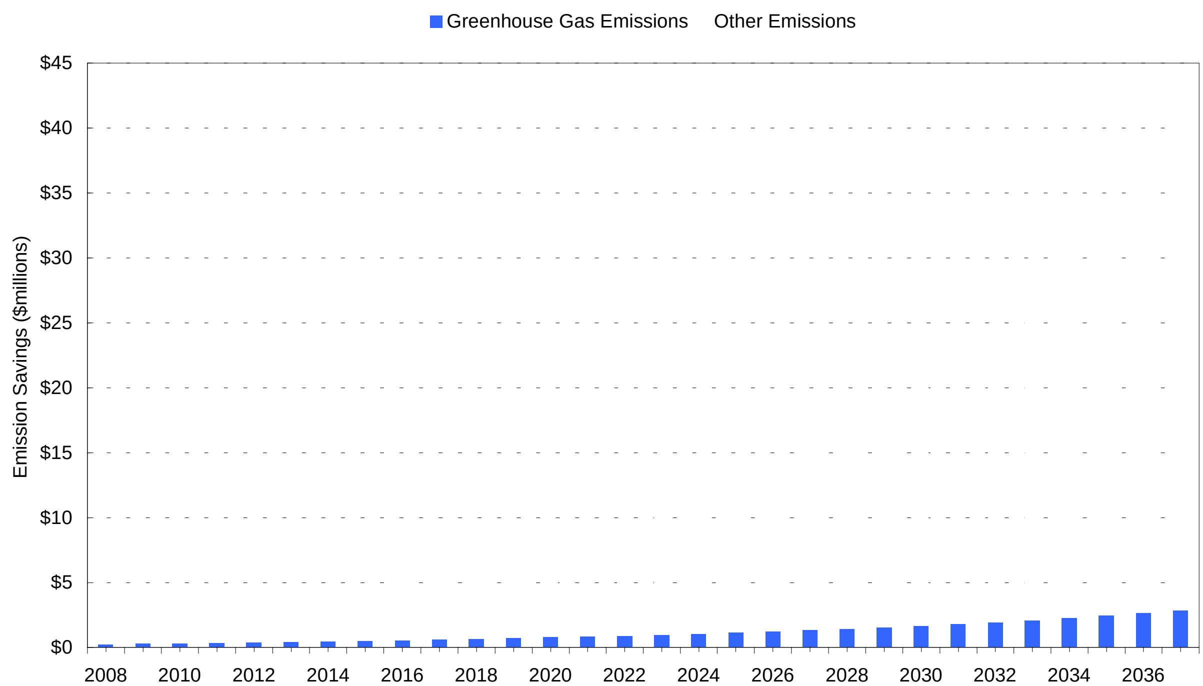


Table 28: Present Value of Emission Cost Savings over 2008-2037, Millions of Year-2001 Dollars

	Mean	90% Probability of Exceeding	10% Probability of Exceeding
Greenhouse Gas Emissions (CO2, CH4, N2O)	$6.6 M	$2.1 M	$11.6 M
Other Emissions (HC, CO, NOX)	$65.2 M	$27.1 M	$114.9 M
Total Emissions	**$71.8 M**	**$29.2 M**	**$126.4 M**

The final step of the estimation methodology consists of aggregating all congestion cost savings to determine the present value of the congestion management benefits resulting from a light rail system in the I-71 Corridor.

4.7 Summary of Findings

The risk analysis results shown in Table 29 indicate an expected $1.15 billion in congestion management benefits between 2008 and 2037 due to the light rail system. The results also indicate a 90% probability that the congestion management benefit alone will exceed $560 million.

Table 29: Present Value of Congestion Management Savings over 2008-2037, Millions of Year-2001 Dollars

	Mean	90% Probability of Exceeding	10% Probability of Exceeding
Total Time Savings	$838.9 M	$311.6 M	$1,481.3 M
Total Accident Cost Savings	$106.3 M	$45.1 M	$184.3 M
Total VOC Savings	$136.0 M	$77.5 M	$200.6 M
Total Emissions	$71.8 M	$29.2 M	$126.4 M
Total Congestion Management Savings	**$1,153.0 M**	**$559.9 M**	**$1,868.1 M**

5. AFFORDABLE MOBILITY BENEFITS

People travel for a variety of purposes such as earning money, visiting friends, going to school and getting to the doctor. An individual's travel objectives are obtained only at a price, which includes the direct money cost people pay plus the cost to them of using up time and of physical effort and inconvenience. The economic value people obtain from mobility is the value they derive from satisfying their journey purposes, not from the journey itself. The net value people obtain from mobility is equivalent to the derived value as defined above minus their cost for the journey.

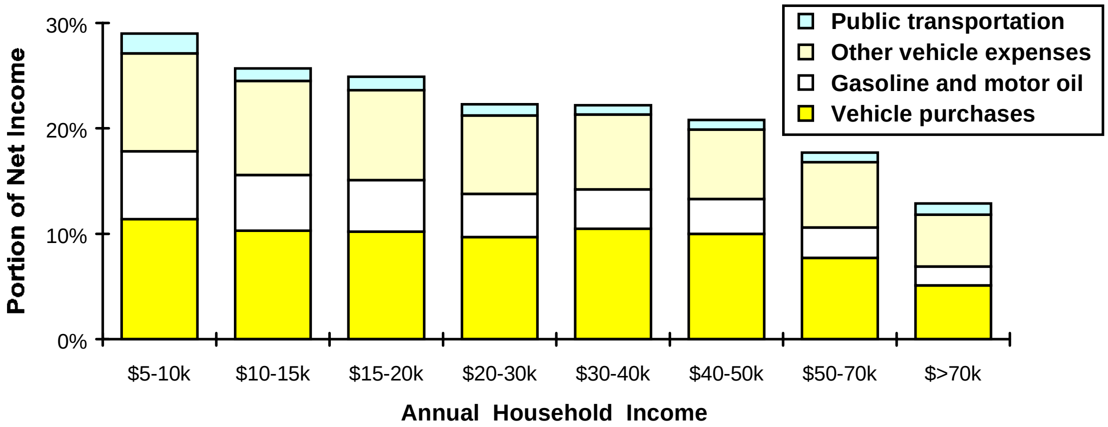
Analysis of household expenditures on transportation adds additional insight into the role of transit in the lives of poor people. First, mobility makes a sharply disproportionate claim on the household budgetary resources of the poor. This is clear from the Consumer Expenditure Survey statistics that show that getting around costs people with low income a larger share of earnings than higher income people. This is true of all modes including autos, transit and even taxis. Even though poor people make fewer daily auto trips than those with high earnings. Figure 20 and Table 30 show that based on the Consumer Expenditure Survey, transportation expenditures are highest as a portion of income for lower-income households. This indicates that automobile dependency is a financial burden to the poor.

The importance of bus transportation to poorer people is strikingly evident in household expenditure data. As household incomes rise from the lowest levels to about $15,000 (in dollars of 1994 purchasing power) spending by household members on bus transportation rises disproportionately. Thereafter expenditure on bus transportation falls and continues on a downward trend as household incomes continue to grow. This pattern of expenditure reflects peoples' propensity to travel by car when they are able to afford to purchase and operate a car. For those in the lowest income bracket however, each one percent increase in income leads them to spend fully 1.7 percent more on bus travel[28].

The cause-and-effect dynamic underlying this pattern is doubtless "two-directional" and mutually reinforcing with (i) rising income creating more opportunities for the poor to participate in life activities and (ii) more income-earning opportunities for the poor, as they arise, creating greater travel requirements. This very high "income elasticity" of demand for transit among low income households indicates that the poor forgo a great many life activities they value highly and that bus transportation facilitates such activity, as it becomes increasingly affordable.

[28] HLB's estimates based on data supplied by Bureau of Labor Statistics, Consumer Expenditure Survey, 1997.

Figure 20: Transportation Expenditures as Percentage of Household Income



Source: 1997 Consumer Expenditure Survey, BLS

Table 30: Distribution of Transportation Use, by Income Category

Income Category	Bus or Trolley (%)	Taxi (%)	Bike (%)	Walk (%)	Auto (%)
<$5,000	19.0	1.6	2.1	16.6	60.6
$5,000-9,999	11.7	1.0	0.8	8.0	78.1
$10,000-12,499	7.2	1.2	1.1	8.5	80.4
$12,500-14,999	7.2	1.2	1.1	8.5	80.4
$15,000-17,499	8.3	1.5	2.5	4.0	83.0
$17,500-19,999	8.3	1.5	2.5	4.0	83.0
$20,000-22,499	5.0	0.8	0.6	5.1	88.3
$22,500-24,999	5.0	0.8	0.6	5.1	88.3
$25,000-27,499	3.8	1.1	0.5	3.0	91.3
$27,500-29,999	3.8	1.1	0.5	3.0	91.3
$30,000-32,499	3.2	1.0	0.8	2.3	92.2
$32,500-34,999	3.2	1.0	0.8	2.3	92.2
$35,000-37,499	3.4	1.2	0.5	1.7	92.8
$37,500-39,999	3.4	1.2	0.5	1.7	92.8
$40,000-42,499	4.7	0.9	0.2	2.8	91.2
$42,500-44,999	4.7	0.9	0.2	2.8	91.2
$45,000-47,499	2.8	0.7	0.4	1.8	93.9
$47,500-49,999	2.8	0.7	0.4	1.8	93.9
$50,000-54,999	1.5	0.5	0.0	2.9	94.6
$55,000-59,999	2.0	1.1	0.3	2.0	94.1
$60,000-74,999	2.0	1.3	0.7	1.2	94.6
$75,000-99,999	3.7	1.7	0.2	1.5	92.5
$100,000-124,999	4.7	2.2	0.2	1.8	90.7
$125,000-149,999	4.7	2.2	0.2	1.8	90.7
>=$150,000	4.7	2.2	0.2	1.8	90.7

Source: Nation-wide Personal Transportation Survey (NPTS), 1997

The value that people realize from mobility is the value they derive from their journey purposes. From this, we need to subtract the journey price they pay in order to measure the net economic benefit transit passengers obtain from mobility. Conceptually, a good measure of net benefit is the difference between the maximum dollar amount individuals are willing to pay for their trips and the fare charged.

5.1 Economic Value of Affordable Mobility

The value of transit trip benefits can be estimated for light rail systems based on national experience. In estimating the affordable mobility benefits of light rail systems, we develop a model incorporating corridor trip characteristics by car, bus, and taxi. The forecast to be developed from these variables permits calculation of the value of consumer surplus for light rail service. For the base case (absence of transit), we derive the number of low-income individuals (poverty line or EIC level) who have no other choice but to drive, car-pool, or take a taxi as a form of daily transportation. Using elasticity (from other similar cities) and trips data, we estimate the number of trips that shift to light rail given the availability of such service.

These diverted trips are calculated by including trip length data, the corresponding taxi fare, bus fare, and vehicle operating costs. The increase in trips diverted to light rail as a result of the new transit service is then derived. Given the change in trips and the associated price of each alternative service, the resulting consumer surplus is measured. If we compare this change in usage over modes of service, low-income individuals now experience a gain in consumer surplus because they pay a lower price (taxi fare/bus fare/VOC > transit fare). In addition, more trips are taken as the overall transportation expenditure decreases for these individuals. The gain in consumer surplus value may be viewed as the benefit of transit.

5.2 Methodological Framework

Three important analytical devices are used to estimate low-cost mobility benefits: the generalized price, the transit demand curve and the consumer surplus.

5.2.1 Generalized Price

The generalized price is composed of cost elements reflecting the major contributors to the full cost of each transportation mode. The cost elements first thought of are the fare paid for public transportation and the average cost per trip based on the annual expenditure on privately owned vehicles (POV) and parking.

The other relevant cost elements that make it a generalized price are the safety value and the time value. The time value is a function of the time spent by an individual who normally uses a certain mode to travel and the unit value of that time spent by that individual. The cost in terms of time of one mode over another will be lower for the faster mode, assuming time has value for that individual. As a consequence, all costs other than travel time being held constant, the choice of one mode over another will be for the faster trip.

This propensity to save time is partly reflected in the expenditure on transportation as an individual's income increases. For example, the use of relatively more expensive rail is exhibited in the increasing household expenditure as household income rises, while expenditure on the relatively less expensive bus decreases. Low-income individuals, who generally do not have access to a POV, typically use taxi. Rail continues to increase even as POV ownership increases because it is timesaving for some trips. Light rail use has an analogous behaviour to rail and shapes are similar though the actual expenditure varies.

5.2.2 Transit Demand Curve

The demand function serves as the basis on which the economic value of low-cost mobility is estimated. From this demand curve, the relationship between the generalized price and the number of passenger-trips can be evaluated. Once this relationship is established, total consumer surplus can be measured.

As transit fares rise and the money cost of travel increases in importance relative to the time and effort components of travel cost, the theory of generalized cost predicts that the market fare elasticity will rise accordingly. Simply stated, when fares are already "high," a one percent increase will precipitate a larger proportional effect on demand than a one percent increase when fares are "low."

$$\eta = \frac{dT}{df}\frac{f}{T} = a + bf \qquad \textit{Equation 1}$$

In words, the elasticity (denoted by the Greek letter *eta*) of trips (T) with respect to fare (f) is a function of fare.

There are strong empirical as well as theoretical foundations for the expectation that the marginal impact of fares on demand increases as fare levels rise. Research indicates that people from low-income households increase their use of transit when their incomes rise by a much larger amount (proportionally) than higher-income people. It is well known that the marginal utility of an extra dollar is much higher for the poor. One can take the evidence regarding income elasticity as empirical confirmation that low-income people are more responsive than high-income people to any transit-related change in their financial circumstances, including change induced by fare increases or reductions. The differential Equation 1 implies the general demand function:

$$\ln T = k + a \ln f - bf \qquad \textit{Equation 2}$$

A special case of which is:

$$lnT = k - bf \qquad \textit{Equation 3}$$

Equation 3 implies that fare elasticity is directly proportional (inversely) to fare level, that is, dT/df (f/T) = bf. Equation 2 is more general than Equation 3, indicating that fare elasticity may in fact be indirectly proportional to fare level and it is in this sense that Equation 3 is a special case of Equation 2. Since the empirical data available are too limited to test the more complex possibilities of Equation 2 the analysis here adopts the assumption of proportionality between fare elasticity and fare level given by Equation 3. Given the current demand for transit, the current fare level and the current fare elasticity, Equation 3 will give the estimated aggregate demand curve for transit.

5.2.3 Consumer Surplus

Economists call the difference between the amount people actually pay for something and the amount they would pay for the next most costly alternative, "consumer surplus." Consumer surplus is a monetary quantity that equates to the economic value (EV) of the mobility afforded to people by the availability of a light rail system. Formally, it can be expressed in the following way:

$$EV = (P^f_1 - P^f_0) * Q^f_1 + \tfrac{1}{2} [(P^f_1 - P^f_0) * (Q^f_0 - Q^f_1)] \qquad \textit{Equation 4}$$

Where: P^f_0 is the expected fare to be paid by passengers;

Q^f_0 is the expected number of passenger-trips;

P^f_1 is the fare that passengers pay to use other travel modes (auto, taxi, etc.); and

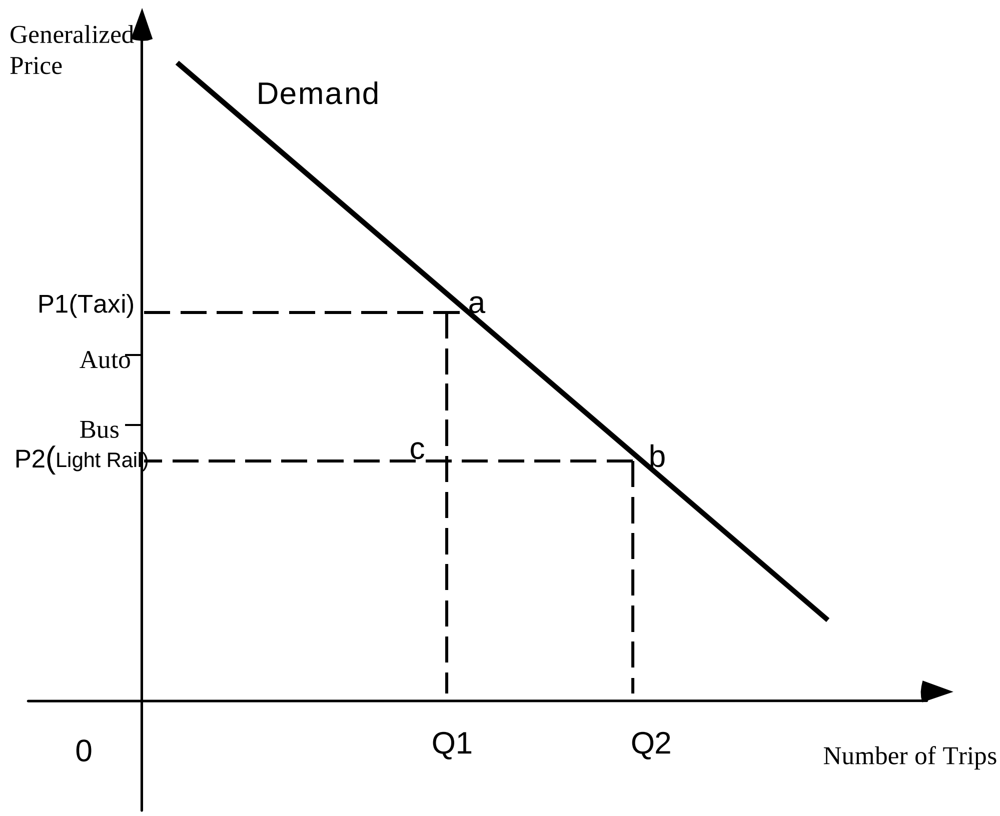
Q^f_1 is the number of passenger-trips using other modes.

The level of demand for light rail and the price difference between light rail and other travel mode measure the consumer surplus, or low-cost mobility benefits of light rail.

This is illustrated in Figure 21 on the next page. Figure 21 implies that, for the taxi example[29], if P1 is the initial price, (aP1) is a perfectly elastic supply of taxi services, and (bP2) is a perfectly elastic supply of transit services. With the opening of transit services, the price falls to P2, and the change in consumer surplus is *P1abP2*. However, the rectangle *P1acP2* is the change in revenue to the taxi industry, and so this component of value is just a transfer from the taxi industry to consumers. Assuming that displaced taxi employees will not be unemployed, but will be employed elsewhere with a value of marginal product as least as great as this rectangle (probably safe in today's labor market), we can focus on area *abQ2Q1*, which is the change in low income mobility benefits from the expansion of the light rail services. Area *cbQ2Q1* is the increased cost to serve this group, and is accounted for elsewhere. Triangle *abc* is the change in consumer surplus to this group.

[29] Thanks due to Dr. Haynes Goddard for this expression of the model.

Figure 21: Consumer Surplus Benefits of Light Rail



5.2.4 Assumptions For Estimating Affordable Mobility Benefits

The table below summarizes the assumptions to be used in estimating the affordable mobility benefits of light rail in I-71 Corridor. The assumptions are presented in relation to their probabilities of occurrence.

Table 31: Description of Key Assumptions

Variable	Description
Average Light Rail Fare	Average fare to be charged per light rail trip in Year 2008
Average Bus Fare	Average fare to be charged per bus trip in Year 2008
Average Taxi Fare	Average fare to be charged per taxi trip in Year 2008
Average Trip Length	Average trip length for all travel modes in the corridor
Average Bus Speed	Average travel speed for buses
Average Light Rail Speed	Average travel speed for light rail
Percentage of Light Rail Trips Taken by Low-Income People	Percentage of light rail trips taken by individuals with an income below the poverty level.
Value of Time of Low-Income People	Average value of time for individuals below the poverty level

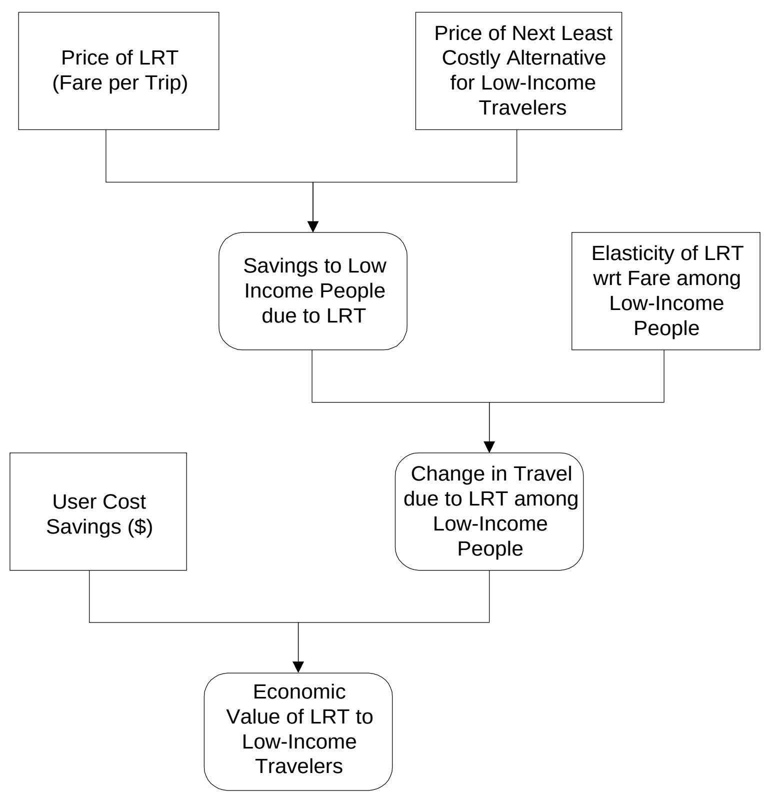
Table 32: Values Assigned to Key Assumptions

Variable	Unit	Median Estimate	Lower Estimate	Upper Estimate
Average Light Rail Fare	$ per trip	1.03	0.84	1.40
Average Bus Fare	$ per trip	0.79	0.65	1.75
Average Taxi Fare	$ per trip	7.80	5.40	11.40
Average Trip Length	Miles	11.80	8.16	14.40
Average Bus Speed	Mph	15	15	15
Average Light Rail Speed	Mph	35	35	35
Percentage of Light Rail Trips Taken by Low-Income People	%	60	60	60
Average Value of Time of Low-Income People	$ per hour	10.25	8.50	15.70

5.3 Estimation of Affordable Mobility Benefits

Figure 22 below presents a structure and logic diagram illustrating the methodology to derive the net economic value from affordable mobility.

Figure 22: Structure and Logic for Estimating the Economic Value of Affordable Mobility



The model in application to the light rail investment option under consideration here yields the results summarized in the table below.

Table 33: Affordable Mobility Benefits, In-Year Dollars

	2008	2015	2020	2030
LRT Generalized Price	$5.7	$7.0	$8.1	$10.7
Bus Generalized Price (Fare and Travel Time)	$11.6	$14.1	$16.3	$21.7
Average Savings per Trip	$5.9	$7.1	$8.2	$11.0
Taxi Generalized Price (Fare Only *)	$9.9	$12.0	$13.9	$18.4
Average Savings per Trip	$4.2	$5.0	$5.8	$7.7
Auto Generalized Price	$8.1	$9.8	$11.3	$15.0
Average Savings per Trip	$2.3	$2.8	$3.2	$4.3
Grand Total Annual Savings	**$16.2 M**	**$22.9 M**	**$28.3 M**	**$44.9 M**
Number of Low-Income Household Served	46,282	53,631	57,584	68,722
Annual LRT Benefits per Household	$349	$428	$492	$653

As indicated in Table 33, the economic value of affordable mobility in 2008 is an estimated $16.2 million, rising in proportion to estimated light rail ridership growth thereafter. The present value of total affordable mobility benefits, over a 30-year period is about $230 million. It should be noted that, as in the case of all benefits reported in this paper, affordable mobility benefits relate only to the incremental effect of introducing the light rail system

5.4 Estimation of Cross-Sector Benefits

Studies[30] have shown that low cost mobility programs alleviate pressure on other, non-transportation safety-net entitlement programs. Cross-sector benefits are defined to be benefits achievable in other sectors of the economy as a result of public transport.[31] The FTA model of cross sector benefits used by HLB accounts for savings in home-based services and social service agency transportation systems associated with the availability of mass transit. Home-based and other social services included in the model are:

- Meals-on-wheels;
- Food stamp expenditures (local agency share);
- Dialysis;
- Home health care visits (Medicare/Medicaid); and
- Unemployment insurance.

Unemployment-related outlays are excluded from the analysis presented below, however. This is because of the risk (in the analytic sense) that reductions in unemployment associated with the light rail system would arise as a result of other forms of economic stimulus even in the absence of light rail investment.

5.4.1 Methodological Framework

The model assesses the impact of a reduction in the level of mobility on the level of social services. In quantifying the resulting increase in costs, such as increased home health care or food stamp compensation costs, the benefits due to transit services can be estimated. These costs would not exist if transit services were provided, and thus are qualified as cross-sector benefits of transit provision in Cincinnati.

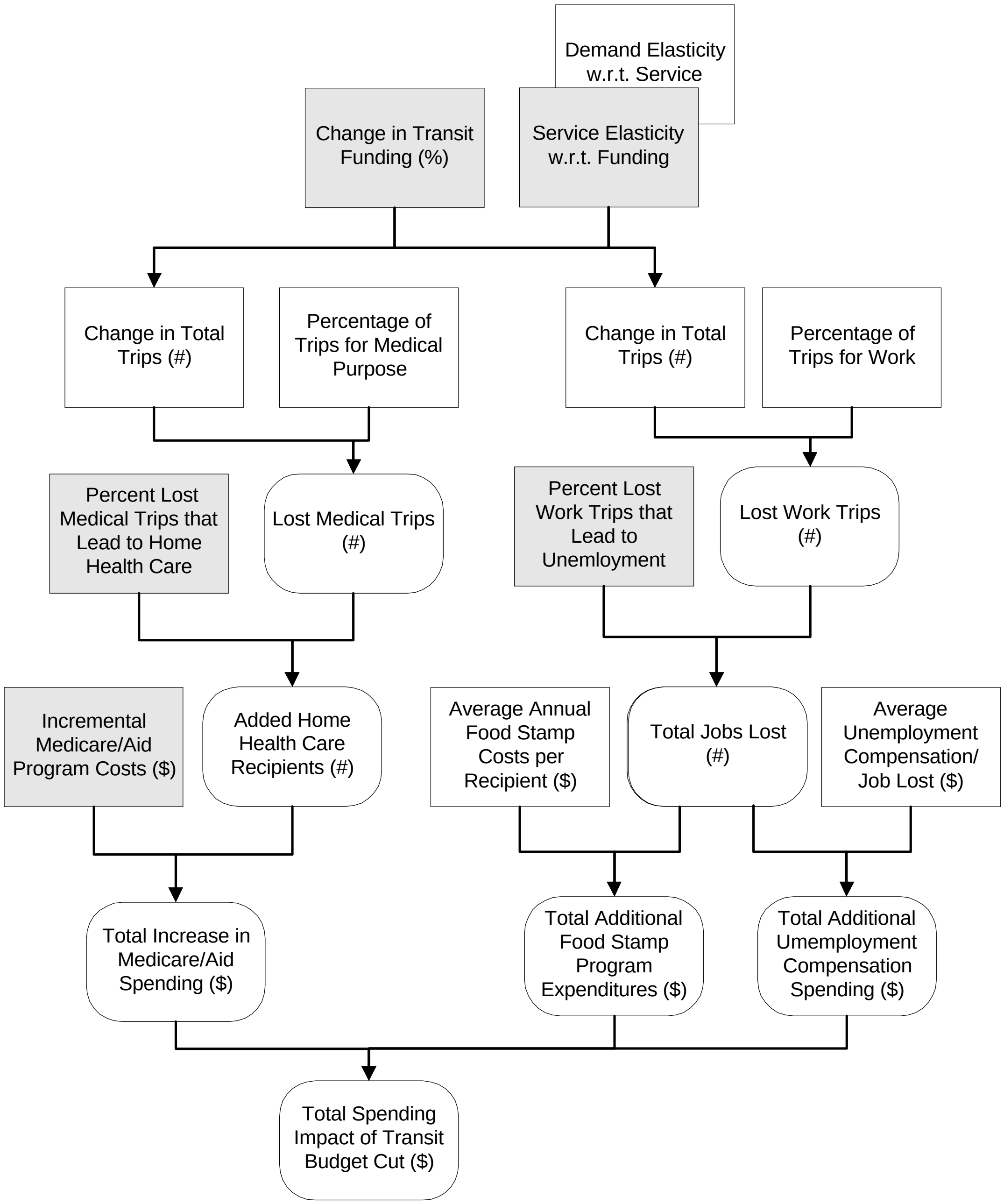
The model presented in Figure 23 provides a graphical illustration of the methodology, identifying all of the model inputs and the relationships between these inputs.

The starting point assumes a level of passenger trips by low-income individuals eliminated due to a lack of transit provision. These trips must be translated into trips by purpose to estimate social spending impacts. The percentage of lost medical trips leading to home health care and lost work trips leading to unemployment generates estimates of the number of added home health care visits and number of lost jobs. The incremental Medicare-Medicaid program costs for each added home health care visit is multiplied by the number of added visits to estimate the monetary value of these trips.[32] Likewise, the added Food Stamp program costs per lost job are multiplied by the number of lost jobs to arrive at estimates of the monetary value of lost employment. To

[30] Hickling Lewis Brod. "*The Benefits of Modern Transit*" Prepared for the Federal Transit Administration. p2-28.
[31] Melanie Carr, Tim Lund, Philip Oxley and Jennifer Alexander. (1993) *Cross-sector Benefits of Accessible Public Transport.* Environment Resource Center, Crowthorne, Berkshire. p1.
[32] In converting passenger trips into the number of medical visits, we account for the fact that ridership data report one-way trips. Dividing the total number of trips made for medical purposes by a factor of 2 gives the number of medical visits.

calculate the cross-sector benefits due to the incremental effect of the light rail system, benefits per trip are estimated by dividing the overall cross-sector benefits due to transit by the total number of trips. Then, the cross-sector benefits due to light rail are calculated by multiplying this benefit-per-trip estimate by the number of new trips generated by the light rail system.

Figure 23: Model of Cross-Sector Benefits



5.4.2 Assumptions For Estimating Cross-Sector Benefits

The assumptions necessary for estimating cross-sector benefits are described in Table 34 below.

Table 34: Description of Key Assumptions

Variable	Description
Medicare / Aid Spending	
Percentage of Light Rail Trips for Medical Purposes	Number of trips for medical purposes as a percentage of all light rail trips taken by low-income people
Percentage of Lost Medical Trips Resulting in Home Health Care	Percentage of lost medical trips (due to lack of access) leading to home health care
Incremental Cost of Home Care	Average cost of a home health care visit *minus* the amount of spending that would occur otherwise
Food Stamp Program	
Percentage of Light Rail Trips for Work Purposes	Number of trips for work purposes as a percentage all light rail trips taken by low-income people
Percentage of Lost Work Trips Leading to Unemployment	Percentage of lost work trips (due to lack of access) leading to unemployment
Average Food Stamp Program Cost	Average food stamp program cost per recipient per year

The inputs used to determine the cross-sector benefits of the Cincinnati light-rail system are summarized in the table below.

Table 35: Values Assigned to Key Assumptions

Variable	Unit	Median Estimate	Lower Estimate	Upper Estimate
Medicare / Aid Spending				
Percentage of Trips for Medical Purposes [a]	%	15	10	20
Percentage of Lost Medical Trips Resulting in Home Health Care [b]	%	10	5	15
Incremental Cost of Home Care [c]	$	50	25	75
Food Stamp Program				
Percentage of Trips for Work Purposes [a]	%	40	25	50
Percentage of Lost Work Trips Leading to Unemployment [a]	%	30	20	45
Average Unemployment Compensation [d]	$	6,180	6,180	6,180
Average Food Stamp Program Cost [e]	$	852	840	864

a. *HLB estimates.*
b. *HLB estimates based on Health Care Financing Administration estimates of medical trips and the National Home and Hospice Care Survey.*
c. *Based on the total cost of a home health care visit of $75 less the amount of spending that would occur otherwise (assumed to be approximately $25). Statistics provided by the Office of the Actuary, Health Care Financing Administration and the National Home and Hospice Care Survey.*
d. *Based on calculations of compensation per hour as 60% of minimum wage and a 40-hour workweek.*
e. *Based on "The Benefits of Modern Transit" prepared by HLB for the FTA.*

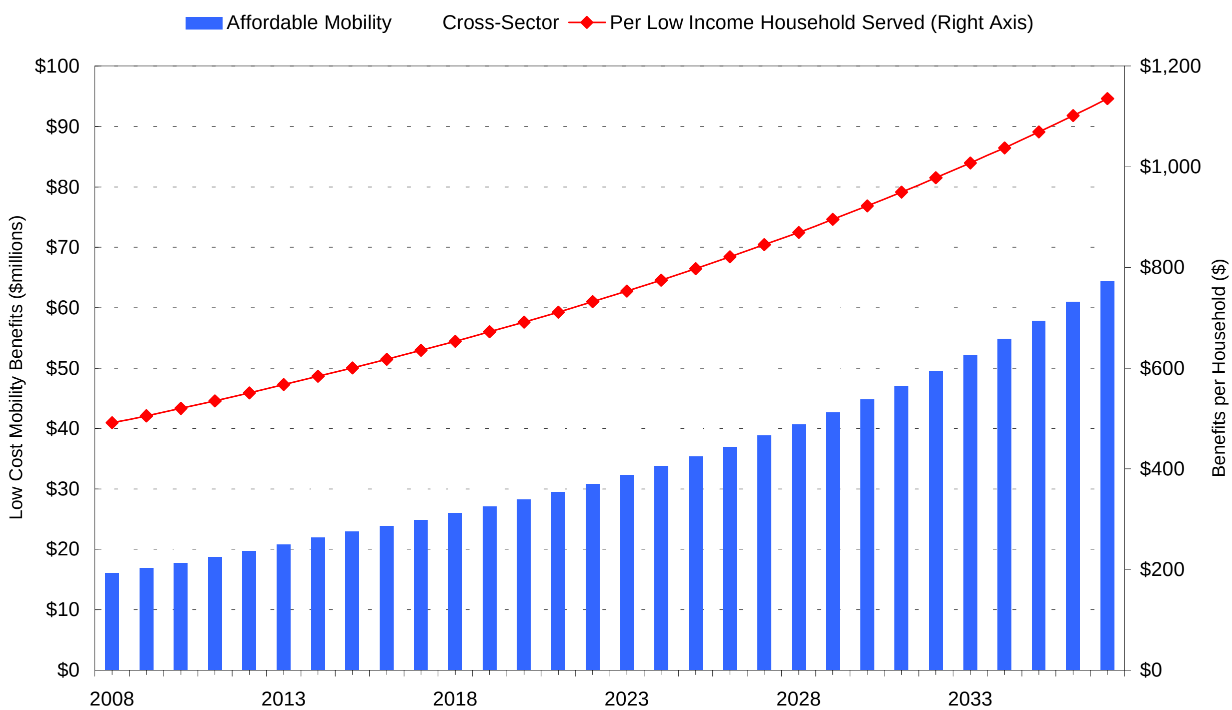
The results of the analysis are summarized in the table below. The light rail system along the minimum operable segment is expected to save more than $6 million of social service spending in the opening year (2008) and up to $18.5 million in year 2030, saving estimates growing with projected ridership and consumer price inflation. As shown in Table 36, about four-fifths of the benefits would stem from reductions in home care costs.

Table 36: Cross-Sector Benefits, Millions of In-Year Dollars

	2008	2015	2020	2030
Homecare Costs	$5.5 M	$7.8 M	$9.7 M	$15.6 M
Food Stamp Program	$1.1 M	$1.5 M	$1.8 M	$2.9 M
Total Savings in Social Service Spending	**$6.6 M**	**$9.3 M**	**$11.5 M**	**$18.5 M**

The chart below shows total annual mobility benefits over the economic life of the project (2008 through 2037). The line in the chart represents total average benefits per low-income household, that is the value of <u>total</u> affordable benefits in a year divided by the projected number of low-income households in that year.

Figure 24: Annual Mobility Benefits, In-Year Dollars



Total mobility benefits over a 30-year period are expected to reach $323.5 million of year 2001 dollars (in present value terms), with a 10 percent probability of exceeding $505.9 million and a 90 percent probability of exceeding $172.3 million. Affordable mobility, with an expected $229.8 millions, accounts for more than 70 percent of these benefits. These results are summarized in the table below. The distributions of the Monte Carlo simulation results for the present value of affordable mobility benefits and cross-sector benefits are shown in Figure 25 and Figure 26 below.

Table 37: Present Value of Mobility Benefits over 2008-2037, Millions of 2001 Dollars

	Mean	90% Probability of Exceeding	10% Probability of Exceeding
Affordable Mobility	$229.8 M	$141.0 M	$338.2 M
Cross-Sector Benefits	$93.7 M	$31.3 M	$167.8 M
Total Mobility Benefits	**$323.5 M**	**$172.3 M**	**$505.9 M**

Figure 25: Risk Analysis of Affordable Mobility Benefits

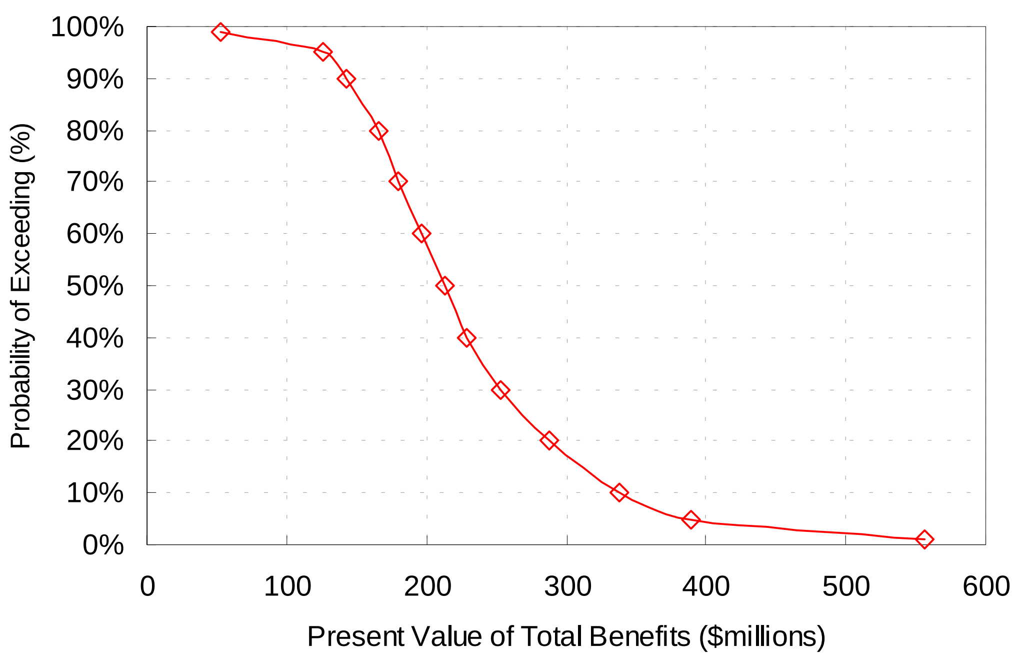
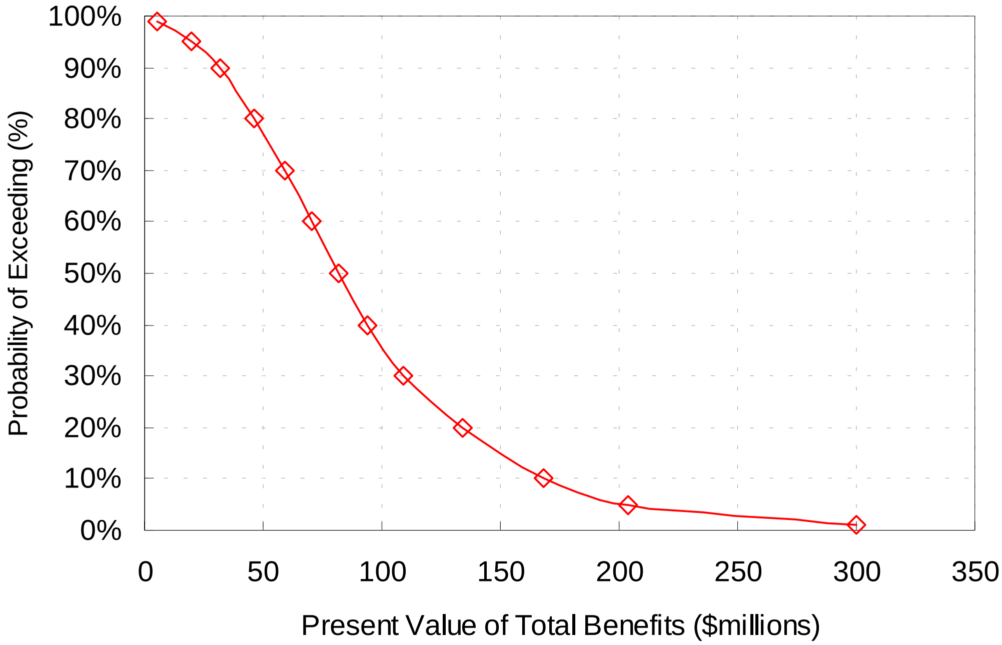


Figure 26: Risk Analysis of Cross-Sector Benefits



5.5 Summary of Findings

Light rail improves mobility in two ways. The first way is the availability of affordable transportation to low-income people. Many of Cincinnati's transit users live in households without an automobile and many more are without access to a car. A disproportionate number of people from low-income households depend upon expensive taxis or circuitous bus routes that put many jobs and other opportunities beyond reasonable cost or access. Compared with the $12 cost (expressed in today's dollars) of an average-length journey by taxi in the minimum operable segment corridor in 2008 (*including the economic value of passengers' time*), the same journey by light rail would cost only $4.70 (of today's dollars). For a low-income elderly person otherwise dependent on taxis for 24 medical and social journeys a month, light rail would offer an economic saving of some $2,080 a year ($12.0 minus $4.70 multiplied by 24 trips a month and 12 months a year). This is enough for substantially greater personal expenditure on food, clothing, housing and access to opportunities away from home. At $4.70 per journey, light rail would also save low income passengers money and time in comparison with bus and car travel whose per journey cost would be $9.60 and $11.20 (*including the economic value of passengers' time, and average downtown parking cost for car travel*).

The second mobility-related effect of light rail is the budgetary saving that arises from reduced social service agency outlays on home-based health and welfare services (such as meals-on-wheels, food stamps and home health care).

In total, light rail is expected to yield mobility benefits of $6.6 million in the minimum operable segment corridor in 2008. The present value of total expected mobility benefits over the economic life of the project reaches $323.5 million.

6. COMMUNITY DEVELOPMENT BENEFITS

This chapter summarizes the methodology used for estimating community development benefits. The chapter starts with a review of the literature focusing on transit-induced community development experiences across the Country. The methodological framework developed by HLB is based on FTA research and integrates the findings of Basile, Baumann, Prost & Associates, a private company specialized in urban planning (see Appendix F at the end of the report).

6.1 Literature Review

6.1.1 The Policy Context

Urban sprawl and growing traffic congestion have pushed local governments to try to reduce dependence on automobile travel, notably through the development of transit-oriented solutions.

6.1.1.1 Sustainable Development and Growing Congestion

The automobile and the extensive network of highways and roads in and between cities loom large in the American physical and cultural landscape. Environmentalists are concerned with the dangerous levels of air pollutants in many cities. The inefficiencies and costs of traffic congestion and the burden it places on the regional economies worry the economists. The reliance on primarily imported oil concerns planners and policy-makers alike. Commuters, who experience the regular extended traffic congestion, complain about the associated stress and unpleasantness. In recent years, residents in hundreds of U.S. suburbs have come to regard traffic congestion as one of their most serious day-to-day problems. The statistics suggest that congestion is rising primarily in metropolitan areas that are either very large - those with a population of two million or more - or fast growing. Most strikingly, for a given area, traffic on highways can grow even faster than population and employment (that was the case, for example, in Montgomery County, Maryland, in the early eighties; see Downs (1992)).

The causes of rising congestion are largely beyond the control of local authorities. They can be divided into two basic categories: immediate causes and long-term causes. At least four immediate causes can be mentioned: rapid population and job growth, more intensive use of automotive vehicles, failure to build new roads, failure to make drivers bear the full costs they generate while driving. Long term, or indirect, causes include: concentration of work trips in time, desire to choose where to live and work, desire for low-density neighborhoods, preference for low-density workplaces, and desire to travel in private vehicles.[33]

6.1.1.2 Assessing Transit-Oriented Solutions

Given the increasing problems associated with automobile dependence, many planners and policymakers are examining potential alternatives to decrease the reliance on automobile travel. Transit-oriented development for residential and mixed-used areas ranks high among these alternatives. Public transit can be expanded through the construction of - or the improvement of existing - bus, light rail and heavy rail systems. It has been shown, however, that aside from a

[33] Anthony Downs, "Stuck in Traffic, Coping with Peak-Hour Traffic Congestion", The Brookings Institution, Washington DC, 1992.

few large cities with extensive mass transit systems, public transit is not widely used for work trips.[34] Among the public policies that can be implemented to increase public transit ridership, are: (i) cutting transit or bus running time, (ii) cutting transit or bus waiting time by increasing service frequency, and (iii) cutting transit or bus fares.

Besides providing relief to congestion problems, transit provides a wide range of benefits to livable communities. This is explained below.

6.1.2 The Neighborhood Benefits of Transit Accessibility

Growing traffic congestion and urban sprawl have led to a realization that communities designed only for automobiles hold disadvantages for residents who may be better served by a regional transit system. For these residents, transit access in neighborhoods may be increasingly valuable in terms of transportation benefits and the positive impact that transit provides to neighborhoods.

Previous research on neighborhood development has found that transit plays a vital role in neighborhoods served by high quality transit system. The impacts of transit include:

- Lower transportation expenses;
- Changes in development patterns; and
- Higher property values.

The nature of the impact that transit might have on transportation costs is straightforward. It is similarly well understood that transportation and land use are intertwined, each influencing the development of the other.[35] Providing high quality transit together with development policies that allow or encourage transit-oriented development, influence land use patterns toward higher densities, better pedestrian environments, and mixed-use developments clustering around transit stations. In this context, how does transit affect property values? The economic literature has early on established that the benefits associated with transit access will be captured or "capitalized" in the price or market value of residential and commercial properties.

Before turning to this issue, it is necessary to introduce two important benefit concepts: the present value of land and the willingness-to-pay for residential and commercial property attributes.

6.1.2.1 Benefit Concepts

The early economic literature focused on the value of land. The concepts introduced for valuing land have been extended to the analysis of commercial and residential properties.

6.1.2.1.1 Market Value of Land

The present value of an asset is the maximum amount that an investor is willing to pay for the asset, given an alternative investment. Investors' willingness-to-pay depend on future anticipated returns. If investors expect a large return from an asset, they will try to invest in the asset, bidding

[34] According to Downs (1992), public transit usage is extremely low among workers living in suburbs.
[35] Downs (1992), for example, reports that Washington D.C.'s Metro rail system has encouraged more downtown development than would otherwise have occurred.

its price up; on the other hand, if the expected return is (comparatively) low, only few investors will be willing to invest and the market value of the asset will fall. Accordingly, the market value of land is the present value of the future annual rental payments from the land. This concept can be extended to commercial (and residential) property value.

6.1.2.1.2 Market Value of Commercial & Residential Properties

The maximum price a commercial enterprise is willing to pay for a site is a function of its anticipated future returns when operating at the site[36]. The annual return can be thought of as the excess of total annual revenue over total annual costs, for all factors of production other than land. A bid-rent function, indicating how much a firm is willing to pay for different office sites, can be defined in this context. Assuming perfectly competitive markets, the equilibrium amount paid by a firm will be exactly equal to the excess of total revenue over non-land costs,[37] i.e. economic profit will be zero in equilibrium. Furthermore, changes in the market value of a commercial property will equal the future discounted changes in income revenue from the property. In the same spirit, assuming perfectly functioning housing markets, the market value of a residential property will depend on the future expected flow of “housing services”[38] that the property is expected to generate over its lifetime.

Because the proximity of transit raises firms' expected revenues, it increases the value of commercial units. Because it reduces automobile-travel dependence and provides households with a wide range of amenities, it increases the value of residential units. These two effects are described below.

6.1.2.1.3 Property Value and Access to Transit

The economic literature has early on validated the existence of a positive relationship between property value on one hand, and access to transportation means and business activity clusters on the other hand.

Differential firm access to business centers elicit significant effects on commercial land markets. Sivitanidou (1996) stresses in particular “the importance of forward (clientele-related) and backward (input-related) linkages between firms providing or using such support services as advertising, accounting, financial, business, and legal.” These linkages “necessitate frequent travel by top-level executives whose time carries significant opportunity costs.” [39] In addressing the role that business centers play within polycentric Los Angeles, Sivitanidou (1996) introduces a model that builds upon previous urban spatial studies postulating joint household and firm equilibria. In this model, property value per unit of land is a function of both property specific traits and location attributes. Property traits include standard building attributes (age, area per floor, elevator, parking, etc.). Location attributes include business centers (main or secondary)

[36] Downing, Paul B, "Factors Affecting Commercial Land Values: An Empirical Study of Milwaukee, Wisconsin", *Journal of Land Economics* 49:1, Feb. 1973

[37] Arthur O’Sullivan, "Urban Economics", Third Edition, Irwin 1996

[38] Including the locational, environmental and diversity attributes of the community where the residential unit is located.

[39] Rena Sivitanidou, "Do Office-Commercial Firms Value Access to Service Employment Centers? A Hedonic Value Analysis within Polycentric Los Angeles", *Journal of Urban Economics* 40:2, pp.125-149, 1996.

accessibility and a set of control locational traits (local service and transportation access, location prestige, worker amenities, and land supply constraints). Center accessibility is measured as the distance to each center, whereas transportation access is measured as the distance to the closest major airport and freeway. The model also allows for different specifications regarding the relative importance and degree of substitutability of secondary business centers. The empirical findings based on this model not only confirm the hypothesis that firms value main center accessibility, but they also show that secondary center accessibility matters too. Both factors generate nontrivial land market effects. The study also shows that distance to air transportation exhibits the expected (negative) sign, and is statistically significant. Downing (1973) estimates commercial land sales prices as a function of distance to the Central Business District, distance to shopping center, traffic level on the main street, area population, median income, amenities, and area dummies. He concludes that these variables explain a substantial portion of the variations in commercial land value for the study area (the city of Milwaukee). A number of theoretical and empirical studies have shown how access to transit and other transportation means enhances the value of residential properties. But what is the exact nature of these benefits?

6.1.2.2 The Property Benefits of Transit

The proximity of transit offers two types of benefits to commercial enterprises; it allows the realization of labor market economies and facilitates the access to customers.[40] For households, public transit makes accessing the workplace, shopping centers, friends and relatives easier. Transit also promotes the emergence of centers of economic activity in the vicinity of the transit stations. Last but not least, transit access reduces auto ownership requirements and the overall dependence on automobiles; it facilitates the development of pedestrian-friendly neighborhoods.

6.1.2.2.1 Transit and Access to Labor Markets

The impact of transportation changes on labor markets can be quite extensive and can occur at a number of different levels. In a study about labor markets and trains, Haynes (1997) divides this impact into supply-side and demand-side effects. On the supply side, transportation affects both the micro-level search behavior of job seekers and the meso-level tradeoffs between commuting and labor migration. Specifically, the latter implies that transportation improvements that lower the cost of migration increase certainty by reducing information decay (i.e. the decline in information about job availability produced by distance) or search costs, lower the cost of labor market adjustments, and increase the efficiency of labor migration. On the demand side, firms that demand labor will have a broader pool to select from at lower prices (as they will have to pay a lower wage premium for extra commuting) with the potential for a more targeted or specialized fit between jobs and employees.

6.1.2.2.2 Transit and Access to Customers

Downing (1973) explains that stores and personal businesses will seek to locate close to where potential customers can access their services. Alternatively, the market value of a store or personal business will be enhanced by easier access to potential customers. First, the accessibility of a site for potential customers will directly affect anticipated future returns. Second, the

---

[40] The benefits to households, with respect to labor markets and customer accessibility obviously mirror the benefits to businesses.

knowledge potential customers can have on the firm's location and existence is also likely to affect expected revenues.

6.1.2.2.3 Other Benefits

For households, the presence of transit facilitates visits by friends and relatives. More generally, it promotes the realization of exchanges with members of different communities. Thereby, it contributes to the social and cultural development of neighborhoods located in the vicinity of the transit system.

Transit, as stated in the introduction of Section 2.2 also promotes commercial and residential expansion around transit stations.[41] Green and James (1993) report, for example, that in Washington DC, "...even in corridors where development was slowing or declining, station areas still seem to be (relative) centers of economic activity and growth."[42]

According to a 1999 study by the Federal Transit Administration,[43] transit-oriented development also promotes the scope for walk and bicycle trips, and reduces the demand for - and dependence on - motorized trips. These features can generate important cost-savings for households. The F.T.A. reports that households living in transit-oriented communities (within a mile of a fixed guideway station) save an average of approximately $250 per month in auto-related costs as compared to households in auto-oriented areas. These savings are associated chiefly with the ability to walk to a wider range of destinations and, to a lesser extent, to transit access itself.

6.1.3 Measuring the Impact of Transit on Commercial and Residential Properties

The dominant approach in studying the impact of transit on commercial and residential properties consists of (i) estimating a hedonic price function, where the distance to transit is one of the property attributes and (ii) discussing the value of the coefficient on this attribute.

6.1.3.1 Hedonic Pricing Methodology

Hedonic methods attempt to estimate a price for a public good by looking for a surrogate market. The surrogate market approach looks for functioning markets for goods and services where specific attributes (public goods) will be capitalized into the value of the observed goods or services. This surrogate market is observed where the attributes are deemed to be present and where they are deemed to be absent. Assuming perfectly functioning markets and market clearing prices, the value of attributes will equal the difference between the observed prices in the two markets. Hedonic price estimation is performed using multiple regression techniques where the change in property values is a function of community amenities and other social and economic variables, as shown in the equation below.

[41] Because it increases commercial and residential densities, transit promotes the development of pedestrian-oriented communities.
[42] Green, R.D. and O.M. James. "Rail Transit Station Area Development: Small Area Modeling in Washington, DC", Armonk, New York, M.E. Sharpe (1993).
[43] Federal Transit Administration, 1996 Report: An Update, U.S. Department of Transportation.

$$P_i = \alpha_0 + \sum_{k=1}^{p} \alpha_k x_{ki} + \eta d_i + \varepsilon_i \qquad \textit{Equation 1}$$

With P_i: assessment value of the i^{th} property;
x_{ki}: k^{th} characteristic of the i^{th} property;
d_i: distance to the closest transit station;
ε_i: error term, what is left unexplained by the model;
α_0, α_k, η: coefficients to be estimated.

The regression coefficients are then used to calculate the implicit *marginal* prices of the amenities (η, in the above example, would measure the implicit price of transit access). The appropriate functional form for the hedonic price equation cannot *in general* be specified on theoretical grounds. Since non-linear forms are more consistent with traditional theory and were found to substantially improve the fit in the residential land value regressions, non-linear form results are generally reported in the literature.

The hedonic approach to benefit evaluation relies on the cross-sectional capitalization hypothesis that assumes mobility of people between different locations (the perfectly functioning market hypothesis). Property prices are higher in an area with better amenities - or better public services - because many individuals want to move into the area, which bids up property prices. Perfect mobility between different areas, therefore, ensures that property prices reflect the benefits associated with neighborhood attributes. With less than perfect mobility, however, property values are likely to underestimate these benefits. This is something to keep in mind when interpreting the results presented in this report.

6.1.3.2 Overview of Previous Empirical Findings

Estimates for the benefits associated with transit presence from previous empirical studies are summarized in this Section. Overall, more effort has been devoted to estimating the impact of transit on residential rather than commercial units. This is reflected in the sample of studies presented here.

6.1.3.2.1 Residential Properties

This overview focuses on studies conducted by HLB Decision Economics Inc., in collaboration with the Federal Transit Administration. Studies from other urban economists are presented as well but will be not be given as much weigh when defining the range of hedonic prices to apply to properties located in Cincinnati.

The same methodology has been applied to three study areas, with markedly different characteristics: San Francisco, Queens in New York City and Portland, Oregon. The results of these three case studies are summarized below.

San Francisco

Area Description: The study area radiates from the Pleasant Hill BART station along the yellow line. This station area is well outside of San Francisco proper, lying east of Berkeley in a low-moderate density suburb within Contra Costa County. The neighborhood is made up of mostly single-family homes with some office, shopping, and multi-family residential development closer to the station. The area hosts middle to high income residents at nearly $60,000 per household. Average home values in the station area are almost $250,000.

Principal Findings: Single-family homeowners are willing to pay, on average, nearly $16 in home price for each foot closer to BART within the study area. The value of an average single family home in the Pleasant Hill Station Area is $22,767 greater due to its proximity to BART. For the 939 single-family homes within a 1-mile radius of this station, the net property value impact is $21.4 million. Alternatively, neighborhood property values are about 10 percent greater due to the existence of the BART station in Pleasant Hill.

New York City, Queens

Area Description: the study focuses on three New York City MTA Subway Stations: Forest Hills, 67 Ave, and Rego Park; all within the neighborhoods of the same names, Forest Hills and Rego Park. These stations fall along the E, F, R lines which travel to uptown Manhattan before spitting off to downtown, Harlem, and the Bronx. Forest Hills is the highest priced neighborhood in the study with average home values around $390,000. The homes nearest 67 Ave are less costly at about $226,000, and Rego Park lowest at just under $200,000. Household income is also highest in Forest Hills at nearly $60,000 followed by 67 Ave at about $50,000 and Rego Park at about $44,000 per household.

Principal Findings: The aggregate data set shows that, on average, home prices decline about $23 for every foot further from the subway stations. Alternatively, the value of an average home within these subway station areas is about $37,000 greater than a home outside the station areas. For the 2,700 single-family residences in the station areas, the net property value impact of proximity to the subway stations is approximately $100 million or about $30 million per station.

Portland Oregon

Area Description: The analysis of Portland's MAX light rail station areas includes three stations along the East Burnside corridor: the 148th Avenue, 162nd Avenue, and 172nd Avenue stations. These three stations are less than a mile apart, creating a heavily transit served neighborhood. Land-use surrounding these stations is dominated by single family detached, moderately priced homes with relatively small amounts of multi-family residential and civic (schools and parks) buildings. The average home value in the station areas within one mile of the three stations is about $95,000.

Principal Findings: No benefits were found for properties located within a 2,500 feet radius of the light rail stations. On the other hand, for properties between 2,500 and 5,280 feet to transit, property values increase by about $0.76 for every foot closer to light rail. Controlling for all other variables, homes 1,000 feet closer to transit are, on average, worth about $760 more than others.

Washington DC

Washington Metro-Rail is comprised of approximately 83 stations, 9 of which are in progress on a 101-mile network. A number of studies have been completed to estimate the effect these station locales have on the surrounding property values. In one such study by Gatzlaff and Smith

(1993), it was found that the average price for a townhouse within 1,000 feet of the station was $12,300 higher than comparable units further away. Lerman et al. (1978) found that for a single-family home, a 10 percent change in distance results in a 1.3 percent change in property value.[44]

Philadelphia

The most examined rail line in Philadelphia is the Lindenwold, a 14.5-mile, 13-station line running to Philadelphia through the New Jersey suburbs.[45] This line has been the subject of intense study over the years, providing a rich repository of data showing the impact of transit stations on property values. In an early study by Rice Center, effects of station location on property value are reported to be about a 7 percent premium, or $4,500 per house.[46] Another study (Voith, 1993) observed that areas with commuter rail service enjoy house value premiums of $5,594... 6.4 percent of the 1980 median house value of $87,455.[47]

Boston

Boston is a city with a well-developed transit system and numerous transit-oriented neighborhoods. Its first light rail transit system began operation in 1897 extending 28.5 miles with a daily ridership of 60,000.[48] A 1994 study undertaken by R.J. Armstrong examines the Fitchburg/Gardner Line in Boston to quantify the neighborhood value created by commuter rail station location, captured in single-family residential property values. He found that property values in proximity of existing rail stations experience a 6.7 percent premium compared to property without rail access.[49] Exploring the micro effects, i.e. the immediate station location area, however, Armstrong discovered inconclusive results regarding property values.

New York City

Anas (1993) examined rail transit in the New York Metropolitan Area to quantify property value effects in regard to station locations. He studied a total of 18,649 parcels by building class and borough.[50] Anas stated that 1/3 of a property parcel's value could be lost if located one quarter mile away from a transit station measured by the shortest path walking distance. Observing the micro effects of station location, i.e. the immediate station area, negative attributes of the station and neighborhood generated lower property values and positive attributes created property premiums.

---

[44] Lerman, Steve R., David Damm, Eva Lerner-Lamm, and Jeffrey Young, "The Effect of the Washington Metro on Urban Property Values." Prepared for Urban Mass Transportation Administration, July 1978.

[45] Gatzlaff, Dean H. and Mark Smith. "The Impact of the Miami Metrorail on the Value of Residences Near Station Locations," *Land Economics*, February 1993 v.69 n.1, pp. 54-66.

[46] Rice Center, Joint Center for Urban Mobility Research, 1987. "Assessment of Changes in Property Values in Transit Areas." Prepared for the Urban Mass Transit Administration.

[47] Voith, Richard. "Transportation, Sorting, and House Values," *AREUEA Journal*, v.19 n.2, 1991, pp. 117-137.

[48] Cervero, Robert. "Light Rail Transit and Urban Development," *APA Journal*, spring 1984, pp. 133-147.

[49] Armstrong, R.J., Jr. "Impacts of Commuter Rail Service as Reflected in Single-Family Residential Property Values." Paper presented at the 73rd Annual Meeting of the Transportation Research Board, Washington DC (1994).

[50] Anas, Alex. "Transit Access and Land Value - Modeling the Relationship in the New York Metropolitan Area." U.S. Department of Transportation, Federal Transit Administration, September 1993.

6.1.3.2.2 Commercial Properties

The hedonic price of the proximity-of-transit attribute has generally been found larger for commercial than for residential properties. Some of these "price" estimates are presented below.

Washington DC Area

Lerman et. al. (1978) observed that retail properties are highly sensitive to transit proximity. A 10 percent change in distance from the station resulted in a 6.8 percent change in retail property values. Another study found that commercial projects next to station areas in Bethesda and Ballston demanded a $2.00 to $4.00 per square foot rent premium than similar projects a few blocks away.[51] In 1999, HLB estimated that, on average, downtown properties located 1,000 feet closer to a Metro Rail station enjoy a $2.3 per square foot - or 2.1 percent - premium.[52]

New York City

Anas (1993) estimated that for every meter closer to a transit station, commercial property values increase by about $2.7 per square foot.

Los Angeles

Fejarang studied the Los Angeles Metro Rail to determine the effects of transit station *announcement* [53] captured in the form of property values. The analysis examined 152 commercial parcels both before and after the announcement. Prior to an *announcement*, property values between expected station areas and expected non-station areas were insignificant. However, the period of realization illustrates a dramatic change. Areas both within and without the proximity of a metro station area realized property value gains of 78.3 percent and 38.2 percent respectively.[54] In hard currency terms, properties near rail have a mean sale price per square foot of $102.1 compared to properties away from rail with a mean sale price per square foot of $71.1, a difference of 30.3 percent.

In summary, the existing economic literature provides a strong support to the hypothesis that transit inflates residential and commercial property values. These property "premiums", again, are thought to reflect the benefits provided by transit to the residents of neighborhoods with transit access.

6.2 Methodological Framework

A model based on the research approach outlined above has been developed and applied to the Cincinnati light rail investment project. The model combines data collected from real estate transactions, socio-economic data, and Geographical Information System (G.I.S.) data for a representative sample of residential and commercial properties located within the area of study.

[51] Parsons Brinckerhoff Quade & Douglas, Inc. "Transit and Urban Form: A Synthesis of Knowledge." Prepared for Transit Cooperative Research Program -Transportation Research Board National Research Council, October 1995

[52] HLB Decision Economics Inc. and KPMG Peat Marwick, LLP, "Commercial Property Benefits of Transit." Prepared for the Federal Transit Administration, February 1999.

[53] 'Characterized by a series of federal, state, and local funding propositions that began in 1983 and was legislated in July 1988 for the purpose of transit investment'

[54] Fejarang, R.A. "Impact on Property Values: A Study of the Los Angeles Metro Rail." Prepared for Transportation Research Board 73rd Annual Meeting, January 1994.

Again, the hypothesis of this research is that transit improves the livability of transit-oriented neighborhoods, producing benefits across the neighborhood, whether or not a particular resident uses transit. Finding a property value benefit with transit access, regardless of use, helps to confirm the notion of a neighborhood benefit apart from transit use.

The property attribute that must be measured in a transit access study is the actual walking distance to the transit station, holding all other property attributes constant. The typical solution to generating data on walking distance to transit is to use point-to-point, straight-line distance from each property parcel to the transit station. This is never an exact estimate of walking distance because streets do not always lead directly from one point to another: some streets curve, meander, or dead-end while other streets are cul-de-sacs. Studies that use geographical distance to approximate walking distance to transit miss some significant variations between properties. The use of a G.I.S. is a major innovation over the typical straight-line methodology applied to transit station areas, both in accuracy and in cost. The G.I.S. contains detailed information regarding the street grid in a given area and specifies each property parcel within the area in question. By calculating the shortest street distance from each parcel to the transit station, detailed data regarding the true variable of interest, walking distance to transit, is accurately specified.

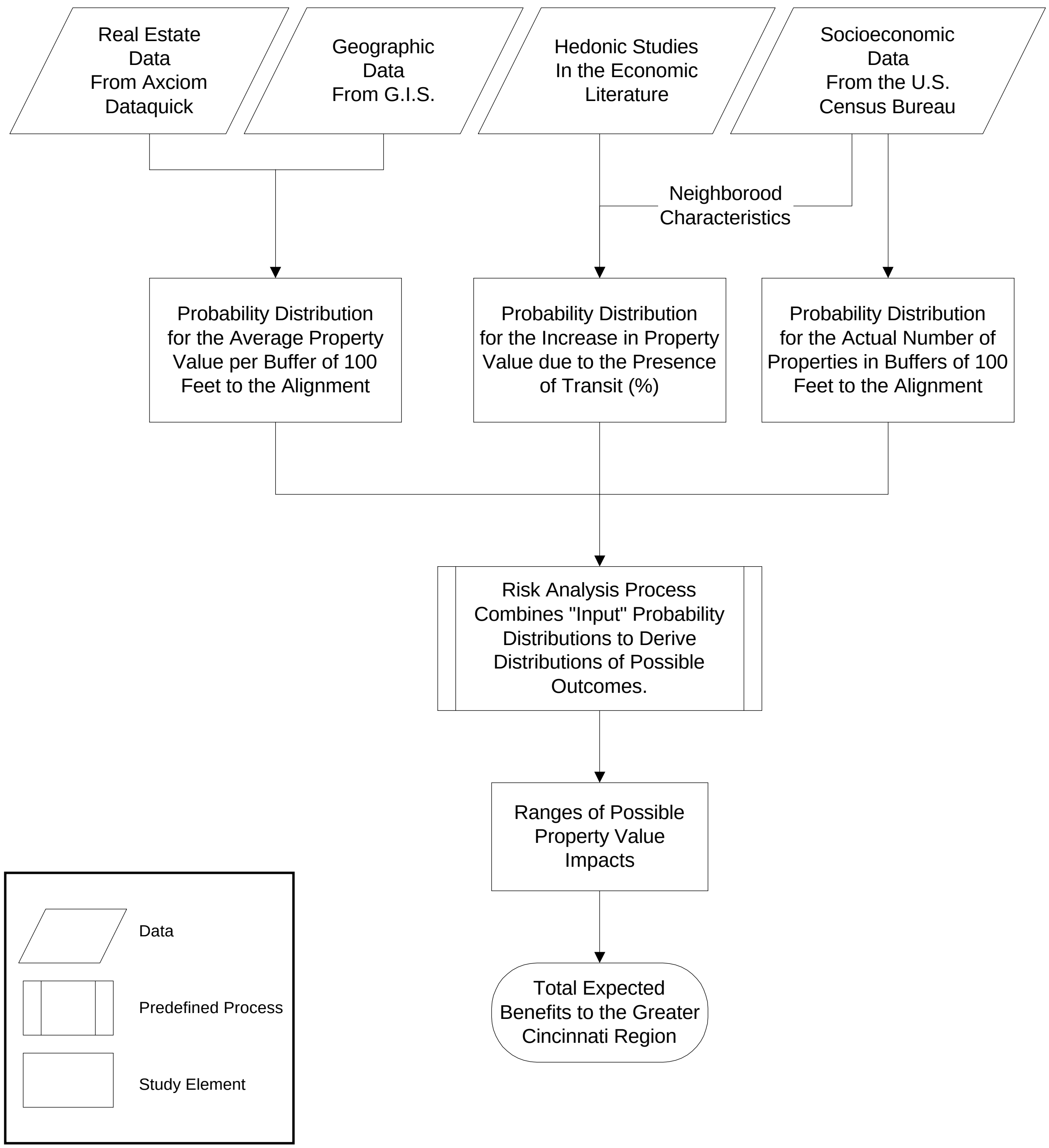
Advanced statistical techniques (see Hedonic Pricing Methodology section) are applied to the real estate, G.I.S. and socio-economic data to estimate the impact of transit access on property values. These techniques allow isolating the effect of transit proximity from other property attributes, on observed differences in property values. The estimated impact is expressed as a dollar value increment in property value per foot of proximity to transit. Alternatively, it is sometimes expressed as a percentage increase in property value per foot of proximity to transit.

For the present study, however, the property value "premium" cannot be estimated by looking at property values along the light rail alignment because the light rail does not exist yet. Instead, HLB used findings from previous studies to derive the likely impact of light rail on residential and commercial development. Findings from national experience, expressed as property value increment per foot of proximity to transit, are combined with estimates of the number of properties along the Minimum Operable Segment (MOS), with the actual walking distance between each property in the study sample and the alignment, and with the current assessed property values to arrive at an estimate of total community development benefits.

Note that the benefit estimates include both transportation benefits and any non-use benefits of transit derived from neighborhood attributes and general livability. Currently, there is no sure way to separate these two effects (see The Risk of Double-Counting Community Economic Development Benefits and Congestion Management Benefits in Chapter 7)

Figure 27 below illustrates the methodology developed by HLB.

Figure 27: Study Methodology Process



6.2.1 Data Collection

Real estate data in the form of detailed assessment records have been purchased from Axciom Dataquick Inc., a private company specialized in collecting nationwide real estate data. The records used in the analysis have been selected within a reduced, homogeneous time period in order to control for business cycles and potential seasonal influences on assessment values. Each observation has been randomly selected from the entire population of commercial and residential properties located in the study area. Socioeconomic Data have been collected from the U.S.

Census Bureau at the zip-code level. Each property in the sample has been given socioeconomic attributes on the basis of the address provided by Axciom Dataquick. Finally, Geographical data have been produced by HLB from Geographic Information System (G.I.S.) software. The software estimates the actual walking distance between each property in the sample and the proposed light rail alignment. The software also allows grouping the sampled properties within buffers (of, say, 300 feet) around the light rail alignment.

6.2.2 Utilization of HLB - FTA Empirical Findings

Table 38 summarizes the findings of HLB - FTA studies, along with other studies, regarding the impact of transit on residential and commercial property values. Whenever possible, the property premium is expressed, in parenthesis, as a percentage increase in property value. This percentage represents the total average estimated impact of transit access.

Table 38: Summary of Research Findings[55]

Study Area	Residential Properties	Commercial Properties
San Francisco	$16 increase in home price for each foot closer to the station (9.1%)	N/A
New-York City	$23 increase in home price for each foot closer to the station (9.5%)	N/A
Portland	$0.76 in home price for every foot closer to light rail (1.0%)	N/A
Washington DC	N/A	$2.1 per square foot for a 1,000 feet (2.1%)
New-York City	$0.09 per square foot for every meter closer to a Metro station	$2.7 per square foot for every meter closer to a Metro station

The value of the premiums shown in Table 38 reflects the full impact of transit on property values, i.e. the benefits to transit users, plus the benefits derived from additional residential and commercial development around the transit stations. Also captured by these estimates, are the potential "nuisances" associated with the development of a transit system: noise, aesthetic considerations, landscaping, etc. This is true because the premiums were estimated in cities where the transit system had been in place for a long time.

As shown in Table 38, there are important variations in the premium estimates. Residential properties enjoy a premium ranging from about 1% for the light rail system in Portland to close to 10% for the heavy rail system in Queens. These discrepancies might be due to differences in the study areas or in the transit system characteristics. HLB - FTA empirical findings have been used to derive a range of possible values for the average property premiums in the Greater Cincinnati region, as summarized in the table below.

[55] The premiums refer to the average increase in property value due to the presence of transit in the study area (one-half to one mile radius), unless otherwise stated.

6.3 Assumptions for Estimating Community Development Benefits

The assumptions necessary for estimating community economic development benefits are described in Table 39 below. Table 40 shows the values for each key assumption.

Table 39: Description of Key Assumptions

Variable	Description
Residential Development	
Residential Property Premium	Average percentage increase in residential property value due to the presence of light rail
Number of Residential Properties within the Community	Actual number of residential properties located within *one mile* of a light rail station
Base Case Residential Property Values	Value of the residential properties located within the community, in the base case
Commercial Development	
Commercial Property Premium	Average percentage increase in commercial property value due to the presence of light rail
Number of Commercial Properties within the Community	Actual number of commercial properties located within *one mile* of a light rail station
Base Case Commercial Property Values	Value of the commercial properties located within the community, in the base case
Common Assumptions	
Size of the Transit-Oriented Community	Size of the area within which residential and commercial property values will be impacted by light rail, that is over which transit-oriented development benefits will be generated (in mile radius from a light rail station)
Measure of Transit Proximity	Actual walking distance between a property and the closest light rail station (in feet)

Table 40: Values Assigned to Key Assumptions

Variable	Unit	Median Estimate	Lower Estimate	Upper Estimate
Residential Development[56]				
Residential property premium				
High	%	3.38	1.25	4.75
Medium	%	3.21	1.19	4.51
Low	%	3.05	1.13	4.29
Number of Residential Properties	#	167,254	167,254	167,254
Commercial Development				
Commercial property premium				
High	%	7.00	3.00	10.00
Medium	%	6.65	2.85	9.50
Low	%	6.32	2.71	9.03
Number of Commercial Properties	#	41,728	41,728	41,728
Common Assumptions				
Size of the Transit-Oriented Community	Mile radius	0.5	0.5	0.5

6.4 Estimation of Community Development Benefits

Data on more than 18,000 residential and 4,800 commercial properties have been purchased from the online database of Axciom Dataquick Inc. All the properties are located within the Cincinnati Metropolitan Area.

6.4.1 Overview of the Real Estate Data

The sample includes 18,941 residential properties and 4,898 commercial properties spread over all regions (zip-code areas) surrounding the 21 light rail stations along the MOS. The original sample has been adjusted to focus on the one-half mile development area. Within this sub-sample, the average assessed value of commercial properties is about $220,000; the average assessed value of residential units is close to $30,000.

The average premiums shown in the assumptions table were distributed over the entire study area by assuming that: (i) the premium is zero for properties located outside the development area (outside the half-mile radius); and (ii) the premium decreases linearly with distance to a light rail station. Properties were grouped within buffers of 300 feet. The average property value within each buffer was estimated from the real estate data. The average residential and commercial development benefits within each buffer were estimated by multiplying average property value by average property premium for that buffer. Total development benefits were obtained by distributing the total number of properties across the buffers, based upon the distribution of properties observed in the sample.

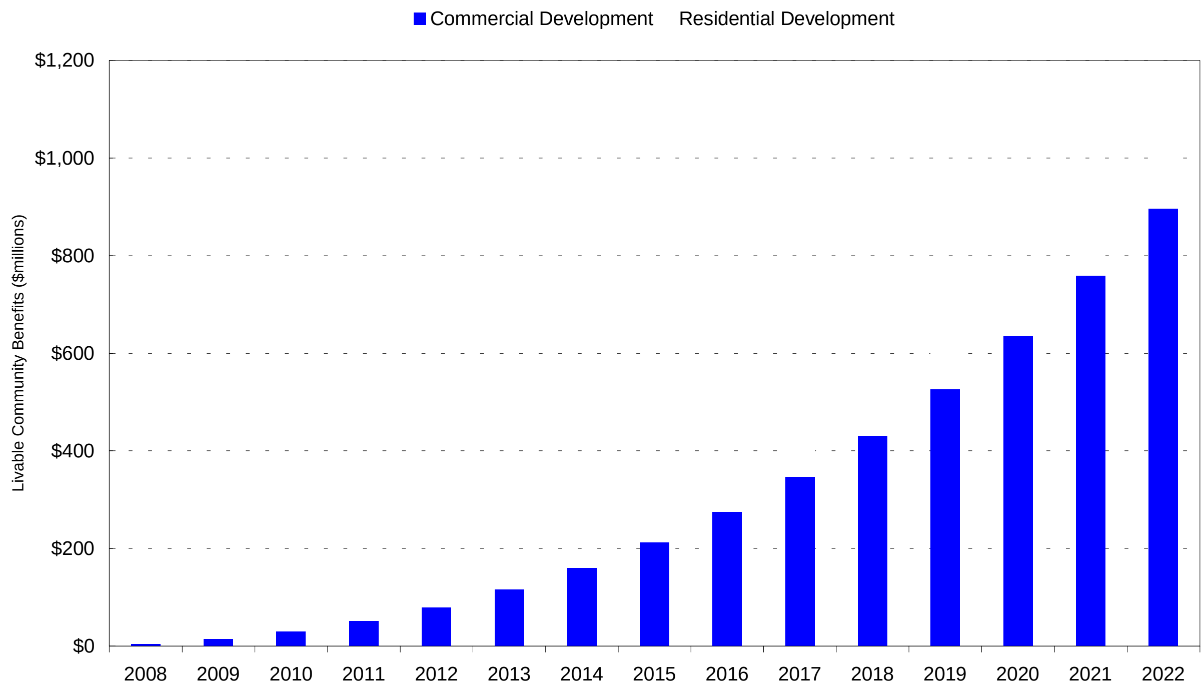
[56] Residential and commercial development were ranked high, medium, and low based on urban planning analysis for proposed station areas along the corridor . The urban planning analysis, which can be found in Appendix F, was conducted by Basile Baumann Prost & Associates, Inc.

6.4.2 Benefit Estimates

Monte Carlo simulation results indicate strong potential benefits for both residential and commercial property owners. Since the benefits presented in this chapter are measured through changes in property values, they will necessarily be shared between property owners (through higher rental incomes) on one hand, and renters (through additional amenities) on the other hand. The distribution of benefits between owners and renters is beyond the scope of this paper. Therefore, the terms "households" or "residential property owners" and " commercial enterprises" or "commercial property owners" have been used throughout the report without any reference to this issue.

The annual cumulative value of total community development benefits is shown in the figure below. Note that development benefits are assumed to grow linearly over a 15-year period (from 2008 through 2022).

Figure 28: Cumulative Community Development Benefits, Millions of In-Year Dollars



6.4.2.1 Residential Development

As Table 41 shows the study estimated the benefits by station for the 21 proposed stations based on existing land use and potential transit oriented development in the station area. The table shows light rail's estimated impact on the economic value of reduced auto ownership, reduced motorized trip making, and the locational, environmental, amenity and diversity attributes of community development. The station analysis indicates that regions around stations between Pfeiffer and Galbraith and stations on both sides of the Ohio River will likely experience a substantial increase in land value.

Table 42 shows the aggregate residential development benefits that total $58 million in present value, or about $1,092 per household living within half a mile of the alignment. While the value was discerned from estimated increases in property value, the results do not imply an increase in residential tax rates. In systems around the nation, increased densities (more taxpayers per square-mile) and larger commercial tax bases have led tax rates to remain steady or decline.

Table 41: Community Development Benefits of Light Rail System in the Residential Sector: 2008-2037

STATION	Present Value of Total Benefits *Millions of Constant 2001 Dollars*	Increase in Land Value Per Square Foot of Developed Residential Property Within One-Half Mile of Station *% Of Assessed Land Value*
Cornell Park	1.8	2.8%
Reed Hartman	2.1	2.8%
Pfeiffer	3.3	3.1%
Cooper	5.0	3.1%
Galbraith	3.2	3.1%
Silverton	2.2	3.0%
Ridge Avenue	2.3	3.0%
Norwood	1.7	3.0%
Xavier U	1.2	3.0%
Reading Road	0.8	2.8%
Medical Center	0.9	2.8%
Zoo	1.5	2.8%
U of Cincinnati	1.7	3.0%
Mount Auburn	0.9	3.0%
Over-the-Rhine	0.9	3.1%
Court Street	5.0	3.1%
Government Square	4.1	2.8%
Riverfront OH	8.4	3.1%
Riverfront KY	7.9	3.1%
Pike Street	2.3	3.1%
12th Street	0.6	3.0%
ALL STATIONS	**57.8**	**3.0%**

Table 42: Residential Development Benefits

	Mean	90% Probability of Exceeding	10% Probability of Exceeding
Number of Households within One Half-Mile of a Light Rail Station	52,956	52,956	52,956
Present Value of Total Residential Development Benefits through 2037	$58 M	$37 M	$75 M
Average Benefits Per Household	$1,092	$700	$1,425

6.4.2.2 Commercial Development

Similar to the residential development, light rail stimulates commercial development because of the increased attractiveness of these locations for commerce, including the amenity benefits to individuals of walk, shopping and other aspects of multi-activity-oriented work places. The station specific analysis shown in Table 43 indicates that areas on the riverfront and in Blue ash area will likely experience an increase in land value for commercial properties.

Table 44 shows that the value of commercial activity in the transit-oriented locations along the light rail alignment would increase by an estimated $296 million. For the commercial properties within a half-mile of a designated station, the estimated commercial development benefit ranges between $14,000 and $29,000 per property.

Here again, higher densities would offset pressure on tax rates associated with higher assessed property value, though not as greatly as in the residential sector.

Table 43: Community Development Benefits of Light Rail System in The Commercial Sector: 2008-2037

STATION	**Present Value of Total Benefits** ***Millions of Constant 2001 Dollars***	**Increase in Land Value Per Square Foot of Developed Commercial Property Within One-Half Mile of Station** ***% Of Assessed Land Value***
Cornell Park	40.8	7.3%
Reed Hartman	40.2	7.3%
Pfeiffer	36.5	6.7%
Cooper	15.7	6.3%
Galbraith	7.3	6.0%
Silverton	2.7	6.3%
Ridge Avenue	4.6	6.3%
Norwood	3.9	6.3%
Xavier U	3.0	6.3%
Reading Road	3.8	6.7%
Medical Center	3.3	6.0%
Zoo	5.5	6.0%
U of Cincinnati	5.3	6.7%
Mount Auburn	3.2	6.3%
Over-the-Rhine	2.4	6.7%
Court Street	7.1	6.0%
Government Square	27.0	6.3%
Riverfront OH	48.2	7.3%
Riverfront KY	26.8	7.3%
Pike Street	6.6	6.0%
12th Street	2.3	6.3%
ALL STATIONS	**296.1**	**6.6%**

Table 44: Commercial Development Benefits

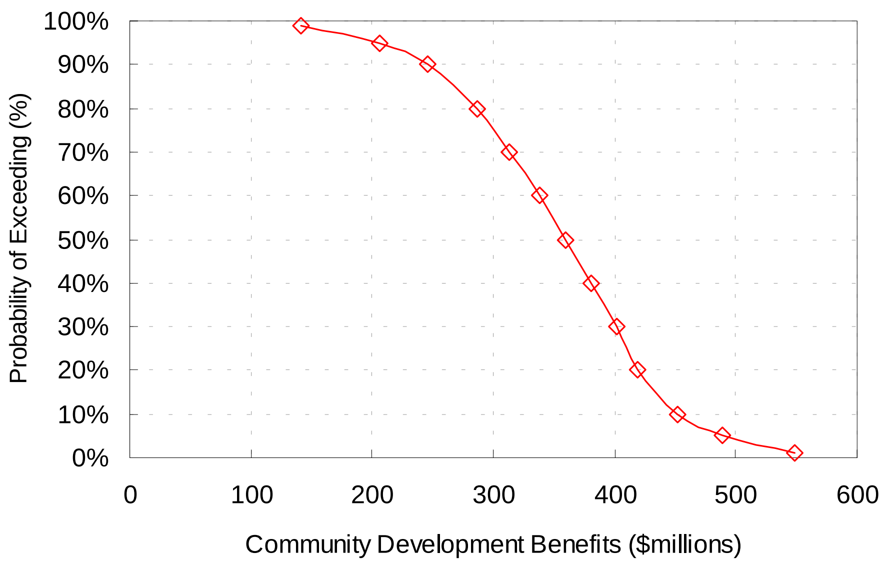
	Mean	**90% Probability of Exceeding**	**10% Probability of Exceeding**
Number of Commercial Enterprises within One Half-Mile of a Light Rail Station	13,212	13,212	13,212
Present Value of Total Commercial Development Benefits through 2037	$296 M	$185 M	$390 M
Average Benefits Per Enterprise	$22,409	$14,002	$29,486

The present value of total community development benefits is shown in Table 45. The light rail system is expected to generate about $350 million worth of community development.

Table 45: Total Community Development Benefits over 2008-2037, Millions of Year-2001 Dollars

	Mean	90% Probability of Exceeding	10% Probability of Exceeding
Present Value of Total Community Development Benefits	$354 M	$244 M	$451 M

Figure 29: Risk Analysis of Total Community Development Benefits



6.5 Summary of Findings

Households located in transit-oriented communities (within a half-mile to a mile of a fixed guideway station) are found to save an average of approximately $250 per month in auto-related costs as compared to households in auto-oriented areas. These savings are associated chiefly with the ability to walk to a wider range of destinations and, to a lesser extent, to transit access itself. The impact of light rail on community development also includes location benefits, benefits that stem from the diversity, urban atmosphere, cultural milieu and architectural amenities characteristic of transit-oriented communities.

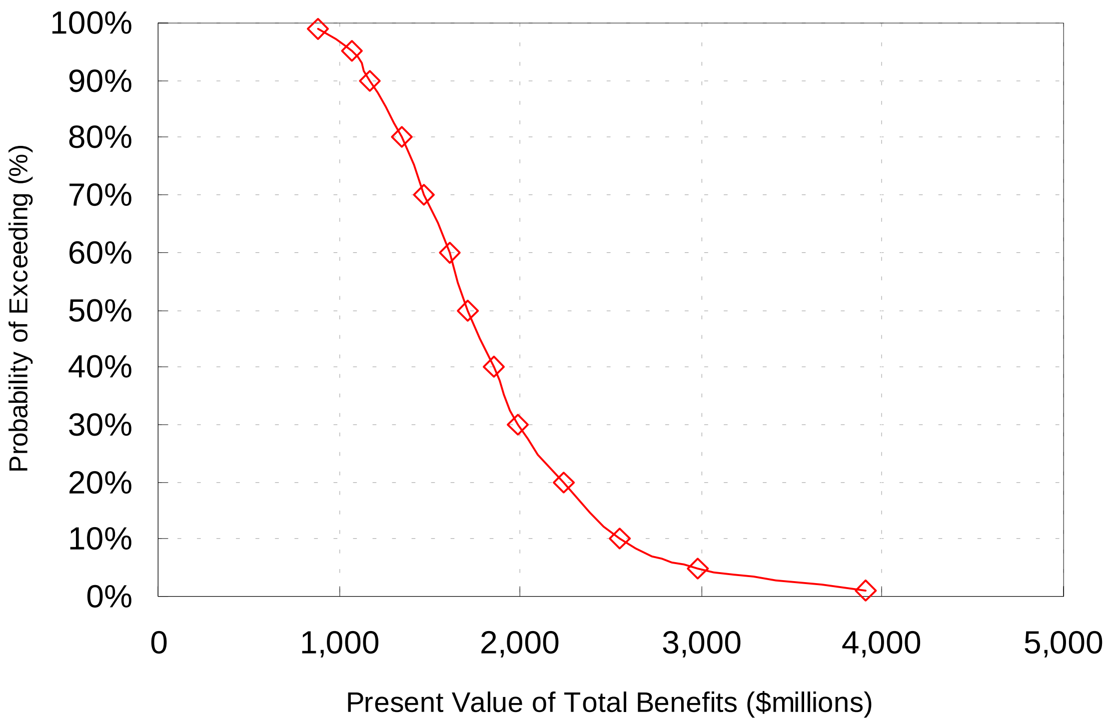
In 1999, a total of 52,956 Cincinnati households lived within a half-mile of a proposed station along the minimum operable segment; about 13,000 commercial enterprises operated in the same area. Total benefits would amount to about $1,092 per household and $22,409 per business over the entire life of the rail project.

7. TOTAL LIGHT RAIL BENEFITS

7.1 Present Value of Total Benefits

As shown in the figure and table below, total light rail benefits are expected to reach $1,830 million of year 2001 dollars. The chart also indicates that there is a non-zero probability that total benefits will be as high as $4 billion, and a small probability (less than 5%) that they will fall below $1 billion.

Figure 30: Risk Analysis of Total Light Rail Benefits, $millions



	Mean	90% Probability of Exceeding	10% Probability of Exceeding
Present Value of Total Benefits	$1,830M	$1,166M	$2,548M

Figure 31 below shows a breakdown of the present value of total light rail benefits by benefit category (mean expected outcome). With $838.9 million, delay savings represent more than 45% of total benefits. Overall, congestion management accounts for 63% of total benefits, affordable mobility 18% and community development about 19%.

Finally, Figure 32 shows how light rail benefits are distributed over the period of analysis. Note that in this graph, benefits are expressed in dollars of the year they occur.

Figure 31: Distribution of Total Light Rail Benefits by Benefit Category, Millions of Year-2001 Dollars, Present Value

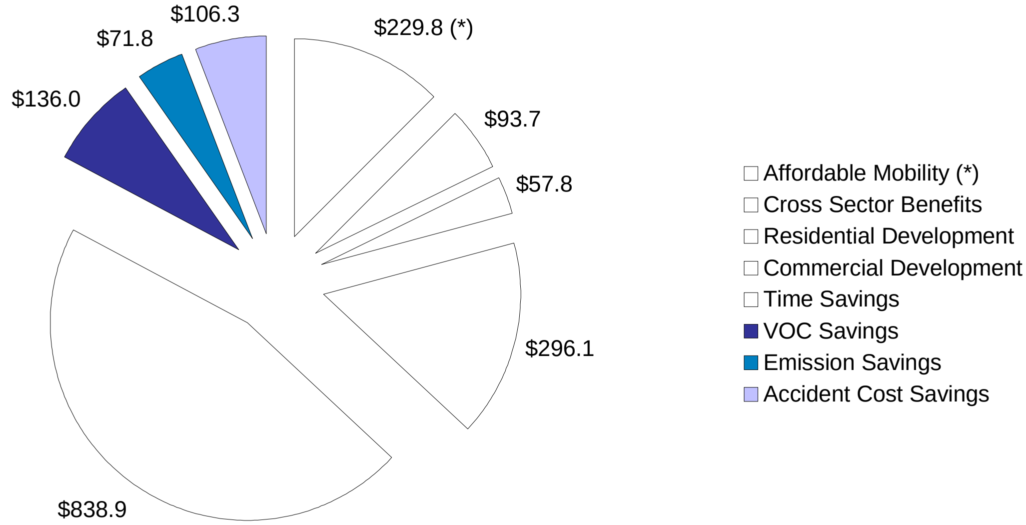
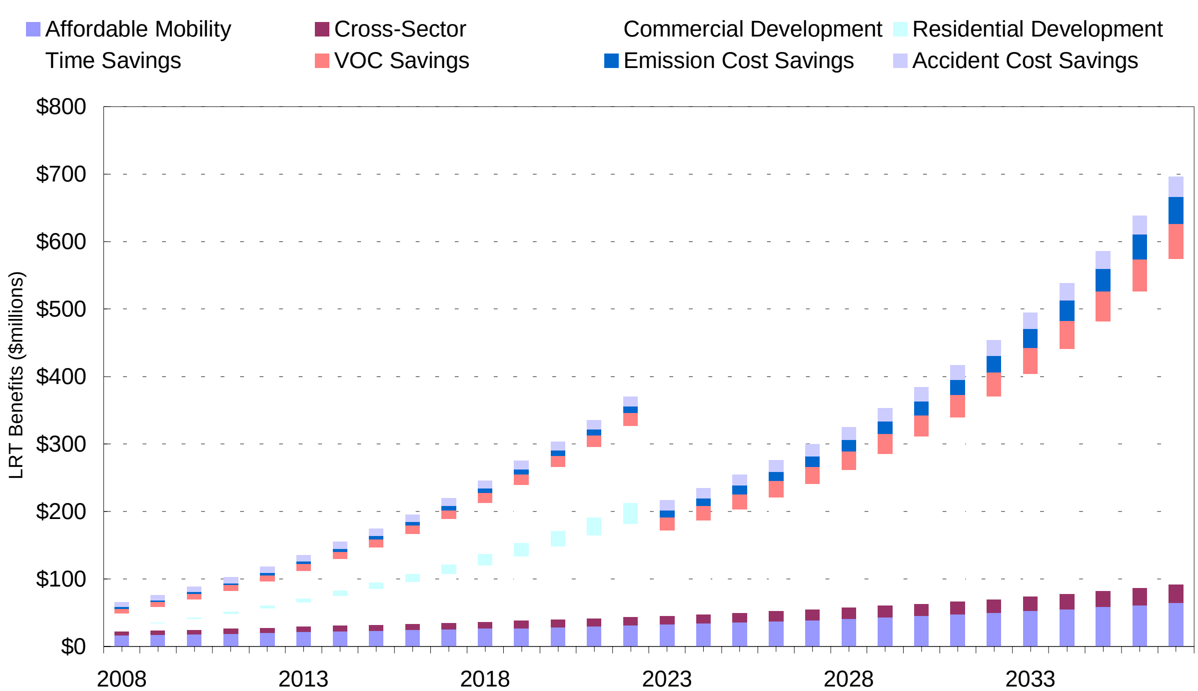


Figure 32: Distribution of Light Rail Benefits over Time, Millions of In-Year Dollars



7.2 The Risk of Double-Counting Community Economic Development Benefits and Congestion Management Benefits

As explained in the introduction to this chapter, the commercial and residential property value impacts reflect a wide array of benefits from transit access. Some of the premium paid for proximity to transit compensates, in particular, for reduced auto-related costs, including travel-time savings. Therefore, there is a risk of double counting these savings when adding up the community benefits derived from the hedonic study of property values with the congestion management time savings derived from implementing the convergence theory. Previous studies (see Section 6.1.3.2) indicate, however, that most of the increase in property value due to transit arises independently of the volume of transit ridership. The economic value of transit in communities appears to be more a reflection of amenity and diversity value than the value of access to one's main mode of travel per se. The risk of double counting in is thus considered small.

8. LIGHT RAIL LIFE CYCLE COSTS

8.1 Cost Component Assumptions

Total capital costs have been broken down into eight components: guideway, stations, systems, special conditions, right-of-way, yards and shops, vehicles and add-ons costs. To account for the uncertainty surrounding the estimation of these costs, a probability distribution has been determined for each of them. These distributions can be thought of as a listing of all possible cost outcomes together with the probability that these outcomes materialize. The distributions are defined with three values or parameters: the median estimate, the 10% upper limit and the 10% lower limit. These parameters have been determined from various sources (as indicated next to the tables below) and confirmed by experts from Parsons Brinckerhoff.

8.1.1 Guideway Costs

The light rail guideway is defined to encompass all of the civil elements directly associated with the construction of the proposed alignment. Examples of light rail guideway elements include retaining walls, tunnels, structures, grading, drainage, sub-grade, ballast, track work, pavement, curb and gutter, traffic barriers, fences, lighting, and landscaping.

Table 46: Estimated Guideway Cost (in millions of 1999 dollars)

	Median Estimate	10% Upper Limit	10% Lower Limit
Guideway	$250.6 M	$310.1 M	$205.4 M

Sources: Median Estimate: BRW for OKI, 2000. Ranges are based on estimates from "Light Rail Transit Capital Cost Study" by Booz-Allen & Hamilton Inc., prepared for Federal Transit Administration, Office of Technical Assistance and Safety, 1991.

8.1.2 Station Costs

Station costs are estimated using typical light rail station designs and unit costs. For each proposed station location, an appropriate typical station design is selected, and the corresponding unit cost is applied. The typical station costs include platforms, shelters, mezzanines, stairways, elevators, and other furnishings. Additional station costs are estimated for each proposed station individually, including site preparation, driveways, bus loading areas, parking lots, and storm-water retention.

Table 47: Estimated Stations Cost (in millions of 1999 dollars)

	Median Estimate	10% Upper Limit	10% Lower Limit
Stations	$77.3 M	$86.6 M	$65.5 M

Sources: Median Estimate: BRW for OKI, 2000. Ranges are based on estimates from "Light Rail Transit Capital Cost Study" by Booz-Allen & Hamilton Inc., prepared for Federal Transit Administration, Office of Technical Assistance and Safety, 1991.

8.1.3 System Costs

System costs include traction electrification, train control signaling, communications, and fare collection.

Table 48: Estimated Systems Cost (in millions of 1999 dollars)

	Median Estimate	10% Upper Limit	10% Lower Limit
Systems	$76.0 M	$96.0 M	$65.2 M

Sources: Median Estimate: BRW for OKI, 2000. Ranges are based on estimates from "Light Rail Transit Capital Cost Study" by Booz-Allen & Hamilton Inc., prepared for Federal Transit Administration, Office of Technical Assistance and Safety, 1991.

8.1.4 Special Conditions Costs

Special conditions costs include construction activity that is not counted for in the light rail guideway component, including roadway restoration, non-guideway structures, traffic signals, grade crossings, and traffic controls.

Table 49: Estimated Special Conditions Cost (in millions of 1999 dollars)

	Median Estimate	10% Upper Limit	10% Lower Limit
Special Conditions	$50.8 M	$90.0 M	$40.0 M

Sources: Median Estimate: BRW for OKI, 2000. Ranges are based on estimates from "Light Rail Transit Capital Cost Study" by Booz-Allen & Hamilton Inc., prepared for Federal Transit Administration, Office of Technical Assistance and Safety, 1991.

8.1.5 Right-of-Way Costs

This component includes all of the costs associated with right-of-way acquisition and relocation of existing land uses.

Table 50: Estimated Right-of-Way Cost (in millions of 1999 dollars)

	Median Estimate	10% Upper Limit	10% Lower Limit
Right-of-Way	$31.4 M	$50.7 M	$22.8 M

Sources: Median Estimate: BRW for OKI, 2000. Ranges are based on estimates from "Light Rail Transit Capital Cost Study" by Booz-Allen & Hamilton Inc., prepared for Federal Transit Administration, Office of Technical Assistance and Safety, 1991.

8.1.6 Yards and Shops Costs

This cost component includes all of the costs associated with any necessary centralized facilities.

Table 51: Estimated Yards and Shops Cost (in millions of 1999 dollars)

	Median Estimate	10% Upper Limit	10% Lower Limit
Yards and Shops	$28.0 M	$51.1 M	$20.0 M

Sources: Median Estimate: BRW for OKI, 2000. Ranges are based on estimates from "Light Rail Transit Capital Cost Study" by Booz-Allen & Hamilton Inc., prepared for Federal Transit Administration, Office of Technical Assistance and Safety, 1991.

8.1.7 Vehicle Costs

Vehicle costs are estimated using light rail and bus fleet sizes indicated in the proposed operating plan, plus a spare ratio. Burgess and Niple's unit costs are based upon recent experience in other systems with similar characteristics.

Table 52: Estimated Vehicles Cost (in millions of 1999 dollars)

	Median Estimate	10% Upper Limit	10% Lower Limit
Vehicles	$120.2 M	$135.9 M	$110.3 M

Sources: Median Estimate: BRW for OKI, 2000. Ranges are based on estimates from "Light Rail Transit Capital Cost Study" by Booz-Allen & Hamilton Inc., prepared for Federal Transit Administration, Office of Technical Assistance and Safety, 1991.

8.1.8 Add-on Costs

Add-on (soft) costs are non-construction costs that can be anticipated during the construction process. These include engineering, construction management, project management, project administration, insurance, and start-up.

Table 53: Estimated Add-ons Cost (in millions of 1999 dollars)

	Median Estimate	10% Upper Limit	10% Lower Limit
Add-ons	$170.8 M	$267.3 M	$158.4 M

Sources: Median Estimate: BRW for OKI, 2000. Ranges are based on estimates from "Light Rail Transit Capital Cost Study" by Booz-Allen & Hamilton Inc., prepared for Federal Transit Administration, Office of Technical Assistance and Safety, 1991.

8.1.9 Operating and Maintenance Costs

Annual operating and maintenance costs include all the costs necessary to operate and maintain the light rail system.

Table 54: Estimated Operating and Maintenance Cost (in millions of 1999 dollars)

	Median Estimate	10% Upper Limit	10% Lower Limit
Annual Operating and Maintenance Costs	$18.0 M	$20.5 M	$16.6 M

Sources: Median Estimate: BRW for OKI, 2000. Ranges are based on estimates from "Light Rail Transit Capital Cost Study" by Booz-Allen & Hamilton Inc., prepared for Federal Transit Administration, Office of Technical Assistance and Safety, 1991.

The results of Monte Carlo simulations combining multiple realizations of the above probability distributions are shown in the next section.

8.2 Simulation Results

As shown in the figure and table below, the present value of total capital costs is expected to reach $779 million (mean expected outcome), with a 10 percent probability of exceeding $879 million. The table also indicates that there is less that one chance out of ten that total costs will fall below $690 million. Finally, as shown in the figure, there is a non-zero probability that the present value of total capital costs will exceed $1 billion.

Figure 33: Risk Analysis of Light Rail Capital Costs

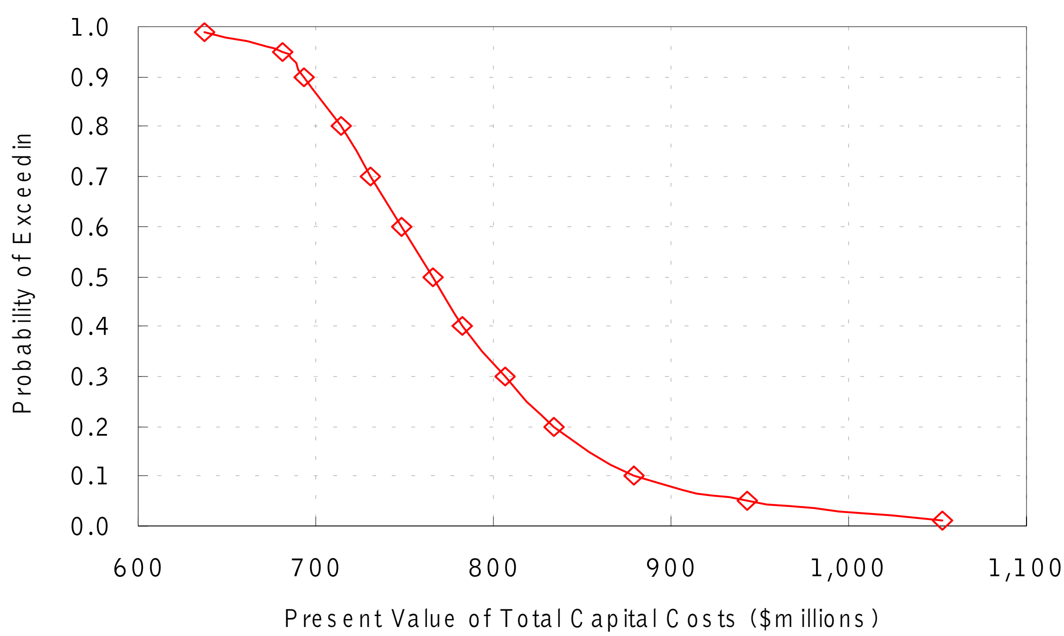


Table 55: Risk Analysis of Total Capital Costs

	Mean	10% Probability of Exceeding	90% Probability of Exceeding
Present Value of Total Capital Costs ($millions)	$779.0M	$879.6M	$693.2M
Total Capital Costs (millions of year-2001 dollars)	$910.0M	$1,027.4M	$809.7M

Over the life of the project, total operating and maintenance costs are expected to reach $264.7 million in present value terms, that is more than $581.1 million of constant non-discounted year 2001 dollars. There is a 10 percent probability that the present value of total operating and maintenance costs will exceed $301.6 million and a 90 percent probability that it will exceed $237.3 million.

Figure 34: Risk Analysis of Light Rail Operating and Maintenance Costs

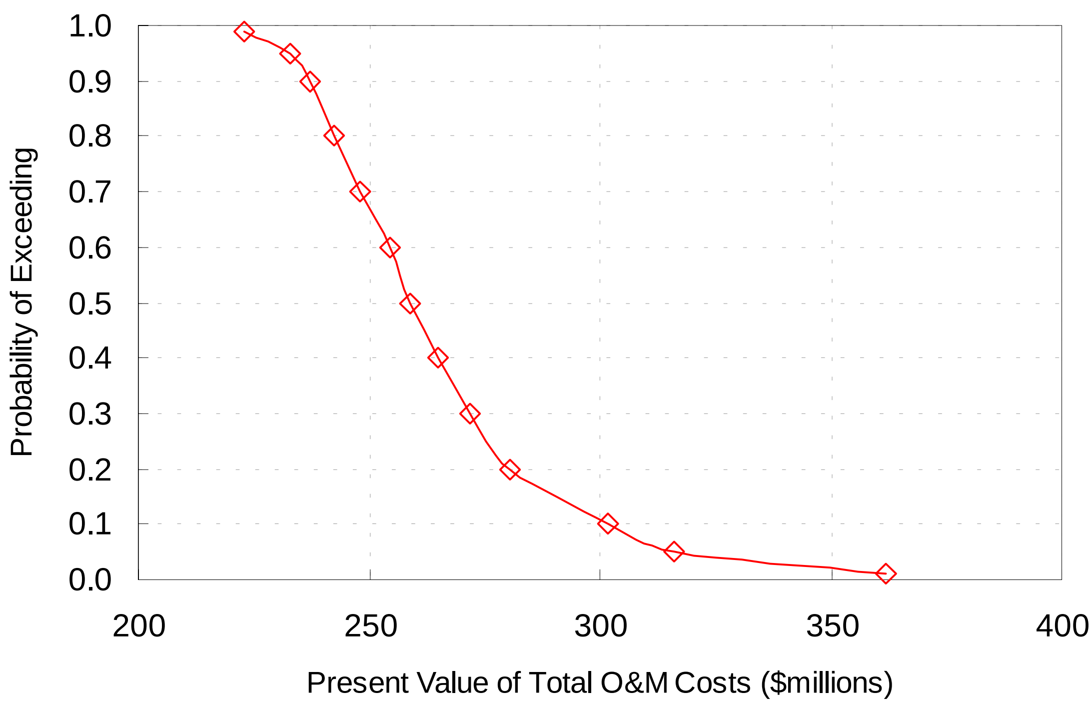


Table 56: Risk Analysis of Operating and Maintenance Costs

	Mean	10% Probability of Exceeding	90% Probability of Exceeding
Present Value of Total Operating & Maintenance Costs ($millions)	$264.7M	$301.6M	$237.3M
Total Operating & Maintenance Costs (millions of year-2001 dollars)	$581.1M	$662.2M	$520.9M

The probability distribution for the present value of total life cycle costs (capital costs plus operating and maintenance costs) is shown in the figure below. Total project costs are expected to reach $1,043.7 million with a 10 percent probability of exceeding $1,162.5 million and a 90 percent probability of exceeding $951.1 million.

Figure 35: Risk Analysis of Total Light Rail Costs

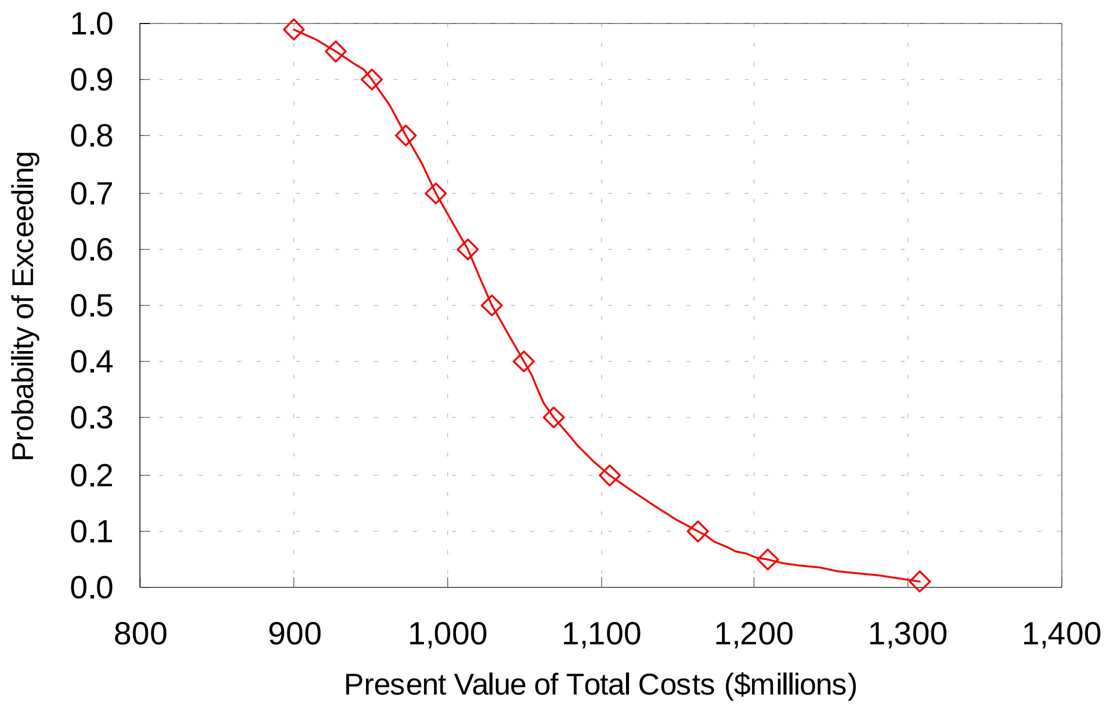


Table 57: Risk Analysis of Total Costs

	Mean	10% Probability of Exceeding	90% Probability of Exceeding
Present Value of Total Costs ($millions)	$1,043.7M	$1,162.5M	$951.1M

9. ECONOMIC IMPACT ANALYSIS

9.1 Introduction

Economic impact analysis is the study of the effect of a change in demand (spending) for goods and services on the level of economic activity in a given area, as measured by business output (sales), employment (jobs), personal income, and tax revenue. This change in demand for goods and services can be the result of decisions made by private enterprise, government, or ordinary households. The construction and ongoing operation of a major facility such as the proposed I-71 corridor light rail system will require inputs (purchases) of labor, materials, equipment, and services which must be supplied by local (and non-local) producers. To the extent that these purchases are result from new investment from outside of the region, or are the result of improved productivity and/or increased levels of labor force utilization (employment), they will cause real growth in the local (regional) economy with attendant benefits of greater employment, personal income, business profits, and local tax revenue.

Economic impact analysis can be undertaken at the national level, but it is most often employed to measure the effects of changes in demand at the <u>local</u> or <u>regional</u> level on <u>regional</u> business activity, as distinct from that business activity generated outside the region. For example, expenditures by the light rail operating agency will generate business output and employment both inside and outside of the greater Cincinnati metropolitan area. However, only the economic impact on businesses and households within that region is relevant for the purposes of this study.

Economic impact analysis involves the estimation of three types of expenditure/production activity within a regional economy, commonly referred to as “direct effects,” “indirect effects,” and “induced effects.”

9.1.1 Direct Effects

Direct effects are the result of direct spending by the sponsor of the project or policy being evaluated. Direct spending results in the employment of workers, sales of locally produced goods and services, and generation of local tax revenue. The distinguishing feature of a direct effect is that it is an immediate consequence of the operating agency activities and expenditures.

9.1.2 Indirect Effects

Indirect effects are the result of purchases by local firms who are the direct suppliers to proposed project. The spending by these supplier firms for labor, goods and services necessary for the production of their product or service creates output from other firms further down the production chain, thus bringing about additional employment, income and tax activity. Output, employment, income, and tax revenue resulting from spending by supplier firms (but not households) are considered to be indirect effects.

9.1.3 Induced Effects

Induced effects are changes in regional business output, employment, income, and tax revenue that are the result of personal (household) spending for goods and services – including employees of the operating agency and agencies directly tied to the operating agency**,** employees of direct supplier firms (direct effect), and employees of all other firms comprising the indirect effect. As with business purchasing, personal consumption creates additional economic output, leading to still more employment, income and tax flows. Indeed, "induced" effects are by far the largest component of the total economic impact.

9.1.4 Total Economic Impact and "Multiplier Effect"

Total impact is the sum of the direct, indirect and induced economic effects of the project or policy change being evaluated. It is the total change in economic output, employment, personal income, and local tax revenue that is generated by successive rounds of spending by businesses and households.

The term "multiplier effect" describes the phenomenon whereby the change in total economic activity resulting from a change in direct spending is greater than the direct spending alone – that is, it is a measure of all indirect and induced effects. The ratio of total effect (e.g., total business output) to the direct effect (direct spending) is termed an "impact multiplier," and is the most direct measure of a regional economy's ability to meet new demand with local (as opposed to imported) resources. The higher the multiplier the greater the total economic response to the new direct spending. Multipliers can also be expressed in terms of employment and income. An employment multiplier is the total overall increase in employment for all industries per new job created by direct expenditures alone.

It should be noted that while indirect and induced effects always occur, the total net change in regional economic activity may or may not be significant. That outcome depends on both the definition of the impact analysis area and the ability of that area to provide additional workers and capital resources within a relatively short period of time. In some case, the effect of new investment can be limited mostly to transfers from one location to another within a region or from one economic sector (industry) thus producing little if any net new output or income.

There are various means by which economic impact can be estimated and each of these deals differently with the types of effects discussed above. The following section summarizes the various methods and describes the chosen approach in more detail. Section 9.1 then presents important input data used in the analysis. The results of the analysis and the implications of those results are discussed in Section 9.2.

9.2 Approach to Economic Impact Analysis

There are four principal methods for measuring economic impact, including (1) input-output analysis, macroeconomic and econometric analysis, activity and site-specific models, and various hybrid approaches. These methods exhibit both similarities and noticeable differences in their approach to estimating economic effects. The measurement of direct effects, which is typically based on a project- or site-specific inventory of employment and spending in various economic sectors, is not a distinguishing feature of the alternative methodologies. Rather, important differences among the four approaches revolve around their treatment of indirect and induced effects, their degree of geographic and economic sectoral detail they allow, and the ease in which they can be understood.

An input-output ("I/O") approach was employed in this study, drawing on an extensive body of research and experience with successful applications to transportation project analysis. I/O models essentially are accounting tables which trace industry to industry and household transactions within a given county, region, state or country. They utilize information on both technology ("What inputs from other industries, in what amounts, are used to produce a dollar of output from each industry?") and local trade ("How much of a given industry's purchases are supplied by other firms located within the study area, and how much are imported?"). An I/O model calculates impact multipliers, which are then used to compute direct, indirect, and induced effects – output, employment, personal income, and local tax revenue generated per dollar of direct spending for labor, goods, and services.

More specifically, the IMPLAN© model – an input-output based economic impact assessment modeling system originally developed by the U.S. Forest Service (and now maintained by the Minnesota IMPLAN Group, Inc.), – was used to evaluate the effects of constructing and operating a light rail system in the Greater Cincinnati area. IMPLAN data files for each of seven counties comprising the defined impact analysis area (see Section 9.3, below, regarding impact area definition) were combined to create a single analysis region. These data files included transaction information (intra-regional and import/export) for 528 different industrial sectors, and data on 21 different economic variables, including employment, output, employee compensation, etc.

In conducting the analysis, two series of adjustments were made to help ensure that all impact estimates would be truly incremental and specific to the O.K.I. region, namely:

1. The model was adjusted to reduce the potential impact of spending in sectors with unemployment rates at or below the Non-Accelerating Inflationary Rate of Unemployment (NAIRU). Research has shown that adding employment or output to sectors of the local economy where the unemployment rate lies below the NAIRU benchmark will more likely to cause inflation than spur economic growth.

2. Multipliers used for estimating indirect and induced effects were adjusted using Regional Purchase Coefficients (RPCs) in order to ensure that imports would not be counted. RPCs are ratios indicating what fraction of total demand for goods and services within a region (both by business and households) is satisfied from within the region; all remaining demand must satisfied from imports, which provide no direct economic benefit to the region. (Of course, an inadequate supply of imports also would have a deleterious effect, in that local production and consumption based on those imports would be constrained to below market equilibrium levels.)

9.3 Analysis Area Definition

The definition of an appropriate analysis area (region) is critical to the effectiveness and utility of an economic impact analysis, given that this definition (i.e., which cities, counties, or other sub-areas are included, and which are not) will greatly influence the characteristics of the "baseline" economy (the economy before the proposed project or policy is introduced) and therefore the nature of the project-driven economic impact. From the viewpoint of those within a defined region, business expansion within the region and relocations from outside to inside the region will be seen as benefits, but imports and shifts within the region will not.

An appropriate impact analysis area should be based on considerations of economic and social integration – that is, the area should operate a social and economic unit, largely free of spatial discontinuities and political separation. The extent to which this applies to a candidate region can be determined through analysis of population and employment patterns, physical development, and political boundaries. For the OKI region, histograms of population and employment by industry were reviewed, with the result that a total of seven counties (Hamilton and six contiguous counties in Ohio and Kentucky) were identified for inclusion in the impact analysis area, falling into three size groups: Group 1–Hamilton (OH); Group 2–Butler (OH) and Kenton (KY); and Group 3–Boone (KY), Campbell (KY), Clermont (OH), and Warren (OH).

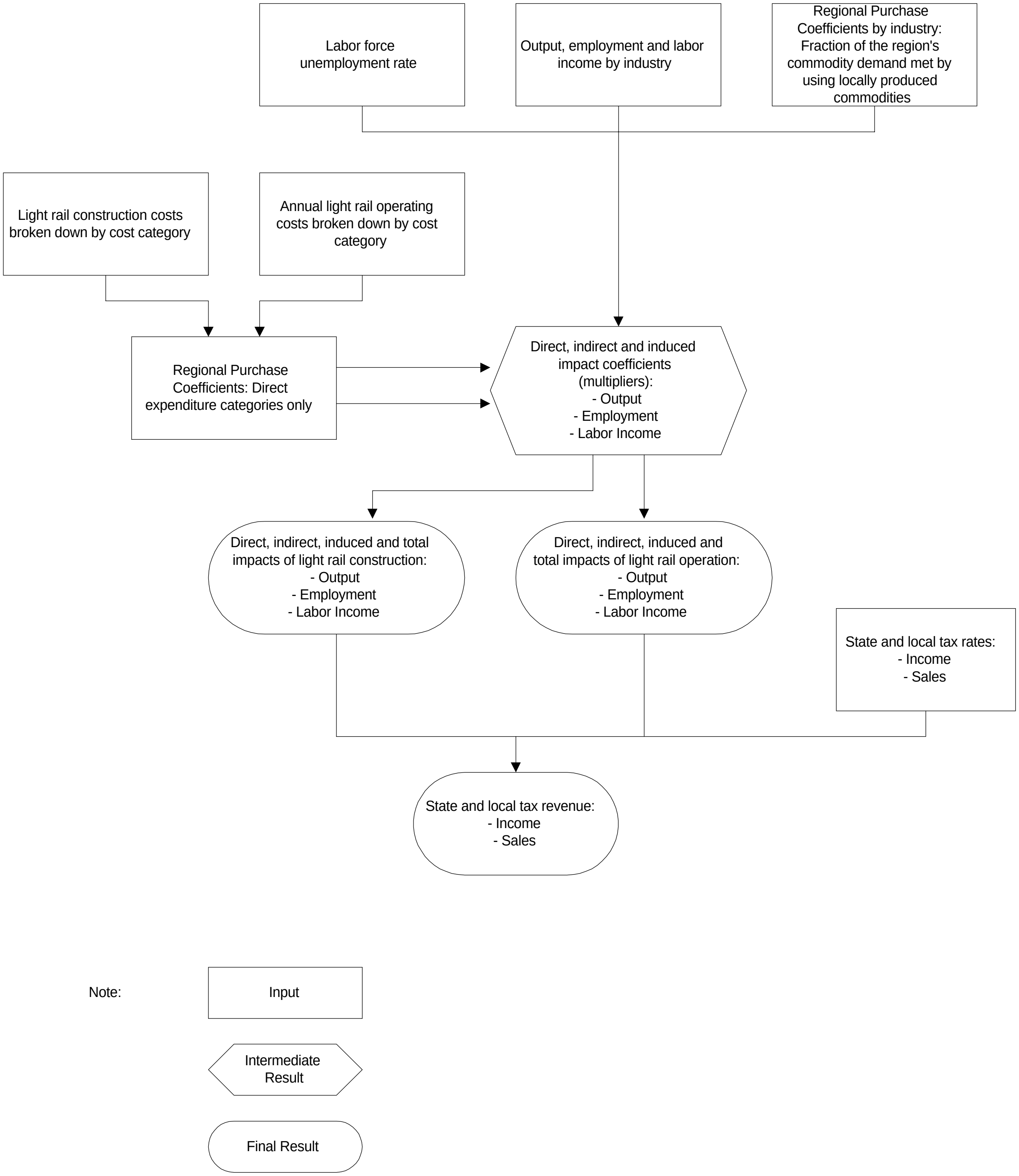
This study area definition was compared with and found consistent with impact analysis areas defined for similar studies performed for transit, highways, and other capital intensive projects in cities such as Baltimore, Dallas, Denver, Miami, Pittsburgh, Portland, Richmond, Sacramento, Salt Lake City and Seattle, as well as in overseas locations.

9.4 Process, Assumptions and Other Inputs

An overview of the economic impact analysis process used in this study is shown in Figure 36, below, while brief descriptions of the data used for the calculations are provided in Table 58, below. Direct and total effects were determine separately for the construction and operation phases of the project in the following manner:

1. Project direct spending was disaggregated into labor, materials and equipment, and service categories, less estimated imports to the region for major cost categories (e.g., transit vehicles, concrete, specialized electrical equipment, etc.).

Figure 36: Economic Impact Analysis Overview



2. All figures were calculated in terms of median (most likely) value, as well as for a 10% lower probability (10% chance of the actual value being less than the estimated value) and 10% upper probability (10% chance of the actual value being greater than the estimated value).

3. Direct purchases met from within the region ("output") were translated into estimates of direct employment and personal income based on prevailing ratios by industry (output/employee, wages/employee).

4. Output, employment and income multipliers reflecting the sum of direct, indirect (business-to-business purchasing), and induced (household consumption) effects were adjusted using regional purchase coefficients to account for "leakage" out of the region (imports).

5. The effect of prevailing tight labor market conditions (low unemployment) was reflected in a further shift from local (regional) sales to imports from outside suppliers.

6. Tax revenue was calculated using prevailing sales tax and effective income tax (total revenue as a share to taxable income) rates by jurisdiction, as well as the distribution of population and employment by jurisdiction.

Estimates, assumptions and other inputs necessary for estimating the economic impact of the proposed I-71 light rail project are summarized in Table 58 below.

Table 58: Economic Impact Analysis, Model Inputs

Variable	Median Estimate	10% Upper Limit	10% Lower Limit
Cost Estimates ($ 000)			
Guideway	$250,595	$205,377	$310,107
Stations	77,316	65,459	86,630
Systems Cost	76,012	65,188	96,023
Special Conditions	50,824	40,028	90,000
Right-of-Way	31,372	22,807	50,719
Yards and Shops	27,984	20,000	51,083
Vehicles	120,233	110,343	135,850
Add-ons ('Soft Costs')	170,847	158,432	267,261
	$805,183	$687,634	$1,087,673
Operating and Maintenance	$18,002	$16,575	$19,500
O&M Direct Employment			
Total	180	165	210
Construction Input Allocation			
Labor Share	36.6%	32.0%	48.0%
Materials/Equipment Share	45.3%	40.0%	51.0%
Services & Other Share	18.2%	16.0%	22.0%
Operations Input Allocation			
Labor Share	60.4%	54.0%	66.0%
Materials/Equipment Share	28.4%	23.0%	31.0%
Services & Other Share	11.2%	8.0%	13.0%

Variable	Median Estimate	10% Upper Limit	10% Lower Limit
Regional Purchase Coefficients (Direct Expenditures)			
Construction			
Labor	75%	60%	85%
Materials	45%	40%	50%
Equipment	25%	22%	28%
Services	80%	75%	85%
Operations			
Labor	95%	93%	97%
Materials and Equipment	60%	55%	65%
Services	90%	85%	93%
Impact Multipliers/Construction			
Output	1.87	1.83	1.95
Employment	2.28	2.22	2.33
Personal Income	1.98	1.92	2.05
Impact Multipliers/Operation			
Output	2.08	1.98	2.15
Employment	2.00	1.95	2.08
Personal Income	1.76	1.70	1.90
Regional Unemployment Rate			
Cincinnati PMSA	3.4%	3.3%	6.6%
State Income Tax Rates			
Kentucky	4.26%	4.00%	4.75%
Ohio	2.76%	2.5%	3.25%
Regional Sales Tax Rates			
Kentucky (No county taxes)	6.00%	6.00%	6.5%
Ohio (Average of 4 Counties)	5.75%	5.75%	7.0%

Sources:

1. *Costs and Direct Employment – BRW for OKI, 2000*
2. *Input Allocations – IMPLAN© model data; HLB Decision Economics*
3. *Regional Purchase Coefficients – IMPLAN© model data; HLB Decision Economics*
4. *Multipliers – IMPLAN© Model data; HLB Decision Economics*
5. *Regional Unemployment Rate – U.S. Bureau of Labor Statistics*
6. *Income and Sales Tax Rates – Kentucky Revenue Cabinet; Ohio Department of Taxation; HLB Decision Economics*

9.5 Results and Discussion

The results of the economic impact analysis conducted for the I-71 light rail MOS project are presented in Table 59, below for both the construction phase and operations phase of the project. In reviewing the figures in Table 59, it is important to keep in mind that construction period figures are total, one-time results, which will be distributed over the entire five-year construction period, while the operations period figures are one-year estimates, which will recur annually while the facility is in operation.

Table 59: Economic Impact Analysis Simulation Results

	Mean	10% Probability of Exceeding	90% Probability of Exceeding
CONSTRUCTION (One-Time Expenditures)			
Total Spending			
Total (thousands)	$805,183	$687,634	$1,087,673
Direct Effects			
Output (thousands)	$434,888	$279,409	$791,060
Employment	3,964	2,547	7,211
Wage and Salary Income (thousands)	$147,862	$94,999	$268,960
Total Effects			
Output (thousands)	$804,848	$487,848	$1,649,756
Employment	9,217	5,387	18,886
Wage and Salary Income (thousands)	$291,525	$170,998	$587,006
Tax Revenue (thousands)	$11,345	$6,350	$30,203
OPERATION (Recurring Annual Expenditures)			
Total Spending			
Total (thousands)	$18,002	$16,575	$20,500
Direct Effects			
Output (thousands)	$16,444	$13,771	$19,034
Employment	181	151	209
Wage and Salary Income (thousands)	$10,968	$9,185	$12,696
Total Effects			
Output (thousands)	$36,527	$28,126	$45,225
Employment	351	281	439
Wage and Salary Income (thousands)	$18,672	$15,008	$23,252
Tax Revenue (thousands)	$727	$557	$1,295

9.5.1 Construction Period

Based on figures provided by BRW, construction spending for the I-71 light rail MOS project will total $805 million over five years, in terms of 2001 prices. Of that total, approximately 31 percent ($251 million) will go for guideway construction, 25 percent ($196 million) for vehicles and systems, 21 percent ($170 million) for design, management and other “soft costs,” and the remaining 23 percent ($188 million) for stations, right-of-way, yard and shops, and “special conditions.”

Of the $805 million project construction outlay, $435 million, or 57 percent, will be constitute direct expenditures within the impact analysis area (Boone, Butler, Campbell, Clermont, Kenton, Hamilton, and Warren Counties). The remaining amounts will fund purchases from outside of the region. The direct expenditures will, in turn, generate a total of approximately 3,960 person-years of employment over the five-year construction period (a person-year is one person employed for one year), producing some $148 million in wage and salary income. (All figures are expressed in terms of constant 2001 prices – that is, without adjustment for inflation.)

Total construction-related regional output, the result of direct, indirect, and induced demand, is estimated at slightly over $805 million. This is the result of a total impact (output) multiplier of 1.85, calculated using regional transactions data, regional purchase coefficients, and an adjustment to reflect relatively low prevailing unemployment.

Total direct, indirect, and induced employment comes to 9,217 person-years over five years, while total wage and salary income is about $292 million over the same period. The employment and personal income multipliers are larger than the output multiplier due to the relatively high wage levels found in the construction trades.

Total sales and personal income tax revenue (to state and local governments) arising from construction-related economic activity in the seven-county impact analysis area is estimated at slightly more than $11 million.

Risk analysis calculations performed on key model variables produce business output (sales) estimates ranging from 50 percent below median (expected value) to 121 percent above median – that is, the distribution is slightly skewed toward the higher end. Similar distributions apply to the employment and income estimates, while the tax revenue estimates are somewhat more skewed toward the upper end.

9.5.2 Operation Period

Operations and maintenance spending for the I-71 light rail MOS project is estimated to total approximately $18 million annually, expressed in terms of 2001 prices. Of this amount, about 61 percent ($11 million) is for labor – 180 full time employees – with the remainder ($7 million) going for purchases of utility services, materials, and equipment.

A much larger share of total operations spending is projected to remain within the Cincinnati region than seen with construction spending (91 percent versus 57 percent), resulting in a proportionately larger impact multiplier and consequently larger total economic effect.

Based on risk analysis calculations, system operations would result in 151 to 209 direct full-time jobs with a payroll ranging from $9.2 million to $12.7 million, and in anywhere from 281 to 439 permanent jobs and $15-23 million in annual payroll when indirect and induced effects are considered. Annual tax revenue yield is relatively modest ($560 thousand to $1.3 million), but does reflect a partial recapture of public funds spent on operating support.

In absolute terms, the total effect of O&M spending is small when compared with that from construction outlay and, more importantly, it is less likely to result in genuine incremental economic growth due to the proportionately larger local funding component for operations. Upwards of 50 percent of construction funding may come from the federal government and much of the local share may be loaned from outside of the region by project bond investors; the federal role in O&M funding, by contrast, will be minimal.

10. POTENTIAL FOR INFRASTRUCTURE COST AVOIDANCE AND OTHER COST SAVINGS

10.1 Potential for Infrastructure Cost Avoidance

Since the presence of light rail may push people to locate in more central areas rather than on the suburban fringe, there is a potential for reduced spending on public infrastructure. The study "Two Roads Diverge: Analyzing Growth Scenario for the Twin Cities Region" prepared by the Minnesota Center for Energy and Environment (MNCEE) provides estimates for local, intermediate and regional infrastructure costs for two alternative growth scenarios: a "Sprawling Scenario" (assuming an average density of 2.1 housing units per acre) and a "Smart Growth Scenario" (5.5 housing units per acre). The difference between the two can be used for estimating light rail-induced infrastructure cost avoidance. The findings of the MNCEE report, expressed as average infrastructure cost savings per unit of housing, are summarized in the table below.

Table 60: Assumed Infrastructure Cost Avoidance per Unit of Housing

	Year-2001 Dollars
New Construction Costs for Local Infrastructure	
Local Roads	$5,057
Other Local Infrastructure	$6,039
Total Local Infrastructure Costs	**$11,096**
Intermediate and Regional Infrastructure Costs	
Intermediate and Regional Roadway	$2,773
Regional Sewer System	$160
Total Intermediate and Regional Infrastructure Costs	**$2,932**
Total Avoided Local, Intermediate and Regional Infrastructure Costs	**$14,028**

Source: "Two Roads Diverge: Analyzing Growth Scenarios for the Twin Cities Region," by the Center for Energy and Environment, June 1999, www.mncee.org

The following assumptions have been made to derive potential cost avoidance in the Greater Cincinnati area due to the presence of light rail (along the MOS) from MNCEE findings:

- *All* new riders to transit (i.e., those not already carried on buses) choose to relocate;
- The opening-year average daily ridership diverted from either auto or taxi is used to estimate the total number of relocations;

- The one-time cost avoidance occurs in either 2020 (for the central estimate), 2030 (pessimistic), or 2010 (optimistic);

- All infrastructure costs are expressed in dollars of year 2001; and

- Total cost avoidance is discounted back to 2001 using a 4.0% real discount rate.

As shown in the table below, the light rail system could save $110 million in infrastructure expenses over the life of the project. The optimistic scenario indicates that total infrastructure cost avoidance could exceed $180 million of present-day dollars.

Table 61: Potential Avoided Public Infrastructure Costs due to Light Rail

	Central	Pessimistic	Optimistic
Number of Riders (Daily, Opening Year)	15,874	12,312	17,889
Year of Full Cost Avoidance	2020	2030	2010
Total Avoided Costs (Dollars of year 2001)	$14,028	$14,028	$14,028
Total Cost Avoidance (Dollars of year 2001)	**$222.7M**	**$172.7M**	**$250.9M**
In Present-Day Value	**$109.9M**	**$57.6M**	**$183.4M**

10.2 Potential for Other Cost Savings

Table 62 below compares the costs of operating and maintaining the region's surface transportation network of streets, highways and buses to the costs of building, operating and maintaining a light rail system along the MOS.

Table 62: Light Rail Cost as Percentage of Operating and Maintaining the Region’s Surface Transportation Network

	Region’s Network O&M Costs	Light Rail Capital Costs	Light Rail O&M Costs	Light Rail Costs as % of Network Costs
Annual Recurring Expenses	$177M	--	$18M	10.2%
Present-day Value of Total Expenses over 2008 –2037	$5,305M	$779M	$265M	19.7%

11. NET BENEFITS AND RATE OF RETURN

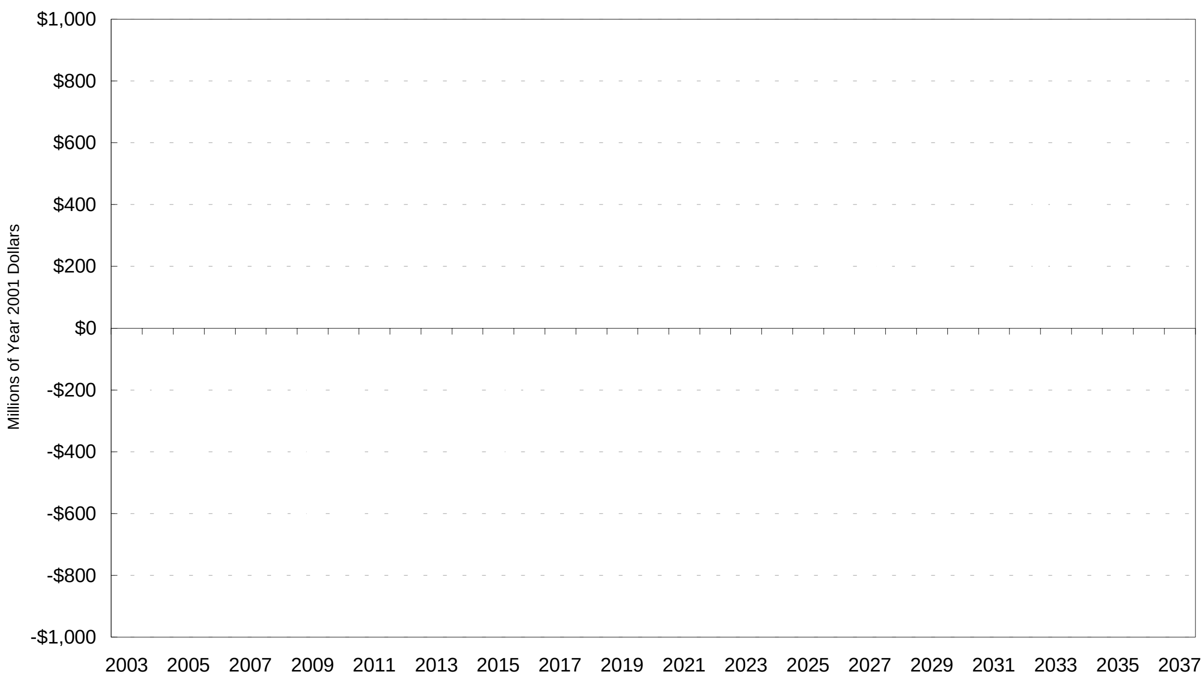
This section combines the elements presented in the report and brings in additional considerations upon which to draw conclusions about the relative economic merits of the strategic options under consideration. The section begins with the light rail option. It then compares the light rail investment with the option of widening I-71 with one additional travel lane.

11.1 Light Rail Investment

11.1.1 Project Worth

The figure below shows the present-day value of cumulative annual net benefits over the life of the project. Annual net benefits are estimated as: total benefits in a year (congestion management benefits, affordable mobility benefits and community development benefits) *minus* total costs in that year. The streams of costs and benefits are discounted with an annual real discount rate of 4 percent. Note that in the graph, the very last column (for the year 2037) shows the Net Present Value of the light rail investment project: $786.6 million.

Figure 37: Cumulative Present Value of Annual Net Benefits



The benefits, costs and rate of return indicators for the light rail option are summarized in Table 63. The table indicates that, relative to the Base Case, the present-day value of the project's benefits are expected to exceed the present-day value of its expected costs by $786.6 million over the 30 years between 2008 and 2037. This represents an average annual rate of return on investment of 8.1 percent, more than double the four percent hurdle rate required to establish the project as economically worthwhile for the Cincinnati region.

11.1.2 Project Timing

A project that shows strong returns over its economic life but fails to begin delivering reasonable annual returns until late in the life-cycle should usually be delayed. A common rule of thumb in the private sector is that a major capital investment may be considered "well timed" (that is, neither premature nor overdue) if it begins to earn at least the hurdle rate of return in its first full year of operation. At 5.1 percent return in the first year (see Table 63), the light rail option earns somewhat more than the hurdle rate of four percent; from this perspective the 2008 opening date can be said to be economically overdue.

11.1.3 Project Risk

The Risk Analysis is given numerically in the final two columns of Table 63 and graphically in Figures 38 and 39. The analysis indicates that the risk of falling beneath the four percent hurdle rate of return is less than ten percent over the life of the project and less than about 12 percent in the first full year of operation. In other words, the taxpayer stands about a 90 percent chance of the light rail option proving economically worthwhile.

Table 63: Benefit-Cost Analysis of the I-71 Light Rail Option, 2008-2037

	Mean	90% Probability of Exceeding	10% Probability of Exceeding
BENEFITS			
CONGESTION MANAGEMENT			
Time Savings	$838.9	$311.6	$1,481.3
Savings in Vehicle Operating Costs	$136.0	$77.5	$200.6
Emission Savings	$71.8	$29.2	$126.4
Accident Cost Savings	$106.3	$45.1	$184.3
Total Congestion Management	$1,153.0	$559.9	$1,868.1
AFFORDABLE MOBILITY			
Value to Low-Income Travelers	$229.8	$141.0	$338.2
Cross Sector Benefits	$93.7	$31.3	$167.8
Total Affordable Mobility	$323.5	$172.3	$505.9
COMMUNITY DEVELOPMENT			
Residential Development	$57.8	$37.1	$75.5
Commercial Development	$296.1	$185.0	$389.6
Total Community Development	$353.9	$244.4	$451.3
ALL BENEFITS	**$1,830.4**	**$1,165.5**	**$2,547.8**
COSTS			
Capital Expenditures	$779.0	$693.2	$879.6
Operating and Maintenance Costs	$264.7	$237.3	$301.6
ALL COSTS	**$1,043.7**	**$950.9**	**$1,162.5**
BENEFIT-COST ANALYSIS			
Net Benefits	**$786.6**	**$111.8**	**$1,516.8**
Rate of Return	**8.12%**	**4.79%**	**11.38%**
First Year Rate of Return (2008)	**5.86%**	**3.88%**	**8.12%**

All figures represent present-day value in millions of 2001 dollars; present-day values are calculated based on a four percent discount rate.

Note that the rate of return reported in this chapter is the internal rate of return, the discount rate corresponding to a zero net present value.

Figure 38: Light Rail Investment, Risk Analysis of Net Present Value, 2008-2037

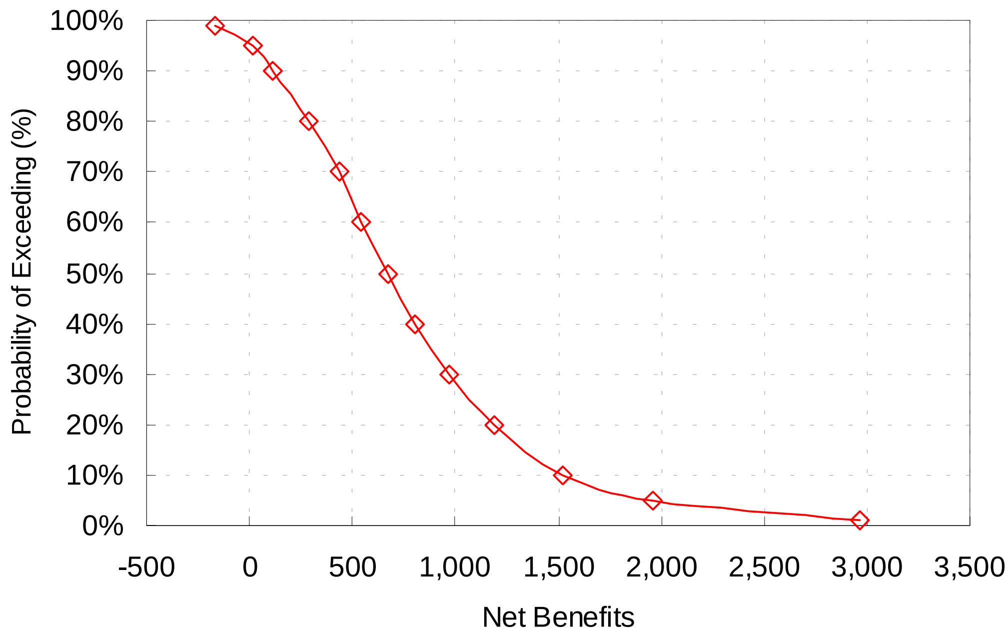
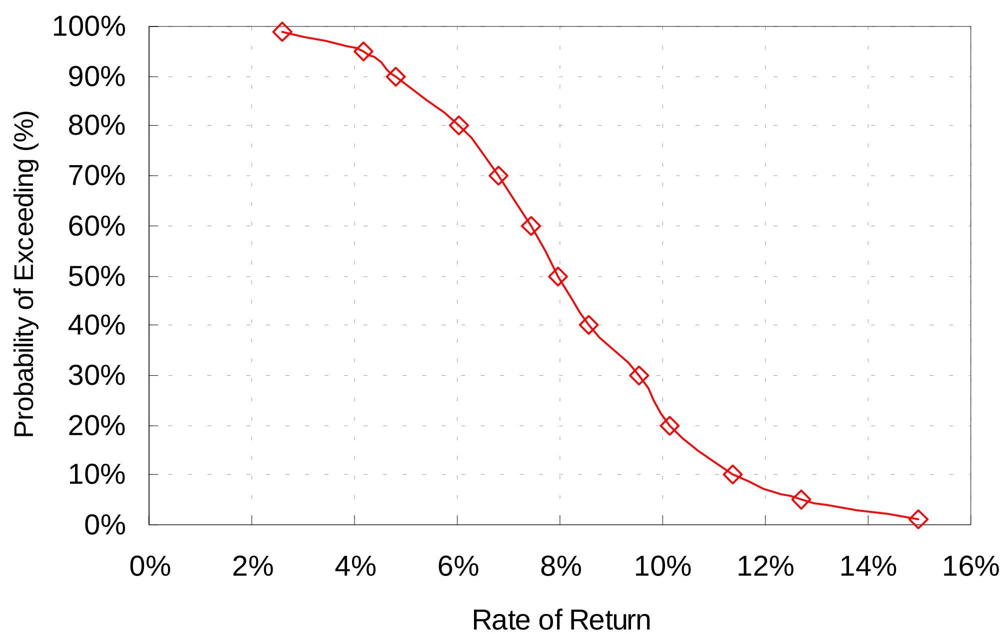


Figure 39: Light Rail Investment, Risk Analysis of Rate of Return, 2008-2037

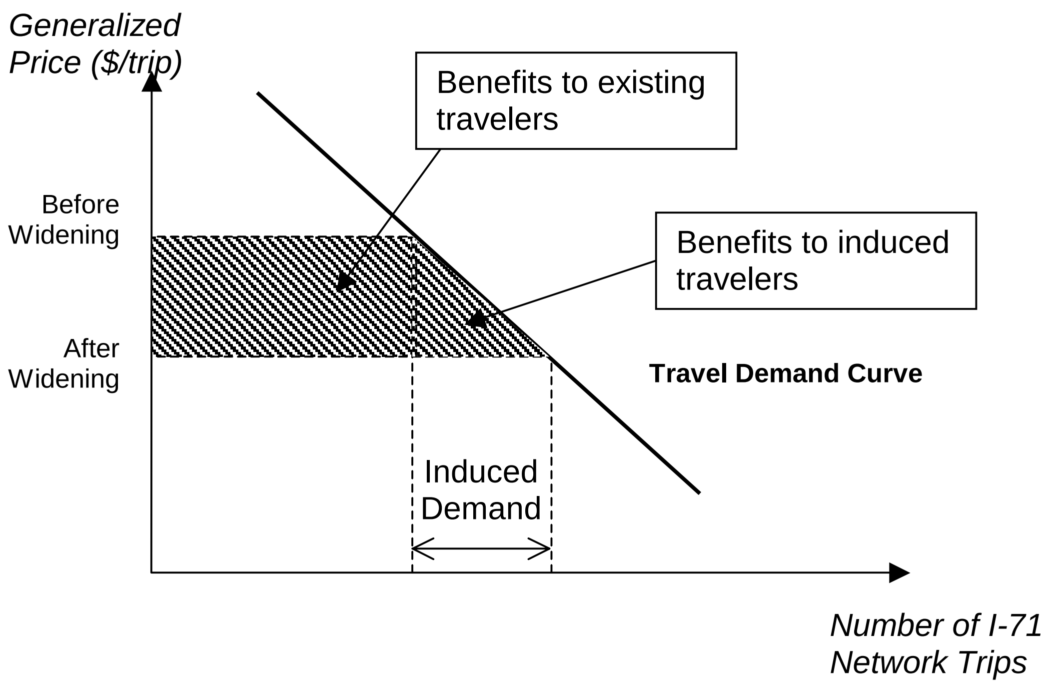


11.2 Highway Capacity Investment

The widening of I-71 over broadly the same 19-mile stretch envisaged under the light rail option would yield economic benefits exclusively in the form of congestion management. Benefits would be manifest in reduced delay and vehicle operating costs, less environmental pollution and reduced accidents (fatal and non-fatal).

The framework of measuring the economic benefits of widening I-71 is illustrated in Figure 40. The figure shows that when the highway is widened the generalized price of using the highway decreases because of speed improvements. The figure shows that as a result of the decrease in generalized price, the number of trips increase mainly due to the induced demand (see Chapter 2 of this report).

Figure 40: Framework for Measuring the Economic Benefits of I-71 Widening



Based on the Transportation Research Board's "StratBencost" model for applying Benefit-Cost Analysis to strategic highway investments, Table 64 reports the estimated benefits, costs and net benefits of the I-71 widening option. The table gives two scenarios, one assuming zero induced demand and one based on the consensus estimates of induced demand rates outlined above. Although a zero rate of induced demand is outside the present consensus range of scientific evidence, the question is a matter of considerable debate among researchers. The zero case is thus presented in Table 64 in order to give an upper bound, though relatively low probability bound on the prospective rate of return on this option. The Risk Analysis given next provides the estimated rate of return on the I-71 widening when the whole range of evidence regarding induced demand is combined.

Table 64: Benefit-Cost Analysis of Added I-71 Lane Capacity, 2008-2037

	2008	2015	2020	2030
Base Case				
Highway Volume	72,357	81,251	86,971	96,071
Average Travel Time (minutes per trip)	47.78	54.13	59.49	70.49
Additional Capacity With Induced Demand				
Highway Volume	73,965	95,696	112,097	128,094
Average Travel Time (minutes per trip)	40.72	47.43	56.64	70.49
Travel Time Savings				
Per Trip (minutes)	7.05	6.70	2.85	0.00
Per Trip (dollars)	$1.20	$1.14	$0.49	$0.00
Additional Capacity Without Induced Demand				
Highway Volume	72,356	81,251	86,971	96,070
Average Travel Time (minutes per trip)	40.41	42.42	44.12	47.60
Travel Time Savings				
Per Trip (minutes)	7.37	11.71	15.38	22.89
Per Trip (dollars)	$1.26	$2.00	$2.63	$3.91

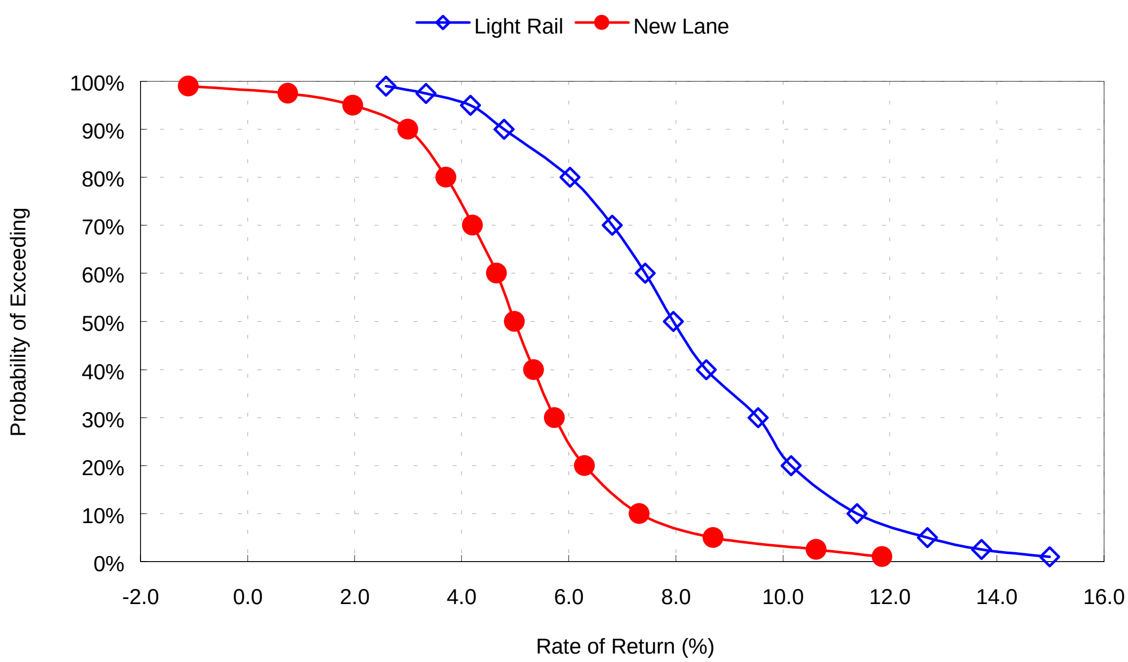
	With Induced Demand	Without Induced Demand
Present Value of Total Benefits	$1,365.2	$1,916
Present Value of Total Costs	$1,209.1	$1,209.1
Net Present Value	$156.1	$707.20
Rate of Return	4.91%	7.10%

Notes: Present-day values are calculated based on a four percent discount rate. Widening costs are estimated at $70 million to $90 million per mile (based on data from Ohio-Kentucky-Indiana Regional Council of Governments and Expert Panel review).

11.2.1 Risk Analysis, Other Effects and Comparative Performance with Light Rail Investment

Figure 41 provides the basis for comparing the economic merit of the I-71 light rail option with that of the I-71 widening alternative. The comparison indicates that the light rail option offers a higher expected rate of return, a lower downside risk of poor economic performance and a higher upside potential to yield better than expected economic results. These conclusions are reinforced when other effects of the widening option (effects not considered in the Benefit-Cost Analysis above) are taken into account. One such effect is the impact of urban sprawl that new highway capacity can bring about. Another is the effect of additional traffic noise associated with induced traffic. Although the potential noise effects of the light rail option have not been counted either, roadway noise is known to be far greater on a per traveler basis than that associated with light rail vehicles (one of quieter transportation technologies in use today).

Figure 41: I-71 Widening Option and I-71 Light Rail Option: Comparative Risk Analysis of Rate of Return, 2008-2037



12. CONCLUSIONS

Economic growth in greater Cincinnati has attendant problems of congestion, mobility and urban sprawl that erode the potential of economic growth to improve peoples' standard of living. Focusing principally on the I-71 travel corridor, this study finds that investing in light rail transportation is economically worthwhile, with minimal risk of economic failure. It also finds that a light rail investment is an economically stronger choice than either the current regional plan of more moderate transportation improvements alone, or the alternative of widening I-71.

Economic Performance of Other Light Rail Alignments

The I-71 corridor alignment considered in this report represents the first stage of the complete I-71 line and one of five proposed light rail lines that would eventually serve Greater Cincinnati region. As shown in Figure 40, the lines would connect Cincinnati's central business district with seven counties and serve more than 90 percent of the region's population. An overview of each alignment is given in Table 64.

Figure 42: Regional Rail Transit System

Table 65: Summary Characteristics of the overall regional transit system, by Alignment

Alignment	Description	Mileage	Estimated Cost (millions)	Average Commute Time in the Corridor (minutes per one way trip)	Average Daily Traffic Volume in the Corridor (vehicles per day)	Percentage of the Area's Population within one mile of the Alignment (percent)
Alignment 1: I-71	Extends from southwestern Warren County and the Cincinnati/Northern Kentucky International Airport in Boone County	43	1,311	24	76,975	34
Alignment 2: I-75	Parallels I-75 from Cincinnati to I-275; splits into two legs, one serving the City of Hamilton and the other extending to Middletown	44	1,311	23	132,405	15
Alignment 3: Southeastern	Connects Cincinnati downtown with Northern Kentucky University crossing the Ohio River via the L&N Bridge	7	213	21	34,220	19
Alignment 4: Western	Connects Cheviot and downtown Cincinnati	7	252	25	22,466	14
Alignment 5: Eastern	Commuter rail would connect downtown Cincinnati with I-275 in Clermont County	18	94	25	14,800	14

Source: Ohio-Kentucky-Indiana Regional Council of Governments

Note: This study examined only the first 19-mile segment of Alignment 1.

Although the analysis presented in this report applies to the first stage of the I-71 alignment, it is possible to use these results to develop preliminary indications of how other alignments might perform from an economic point of view. Such indications are derived by extrapolating the I-71 results to other corridors in proportion to relative traffic volumes and populations.

Table 66: Benefit-Cost Analysis of Light Rail Investment, by Alignment

Alignment	Benefit-Cost Measure	Mean	90% Probability of Exceeding	10% Probability of Exceeding
I-71 Stage A (19 miles)	Net Benefit	$786.6 M	$214.6 M	$1,385.3 M
	Rate of Return	8.12%	4.79%	11.38%
I-71 Stage B	Net Benefit	$778 M	$180 M	$1,442 M
	Rate of Return	7.98%	5.29%	9.67%
I-71 Total	Net Benefit	$1,564 M	$402 M	$2,854 M
	Rate of Return	8.21%	5.52%	9.90%
I-75	Net Benefit	$2,758 M	$1,119 M	$4,588 M
	Rate of Return	10.29%	7.58%	12.04%
Eastern	Net Benefit	$232 M	-$61 M	$555 M
	Rate of Return	5.98%	3.27%	7.64%
Western	Net Benefit	-$29 M	-$137 M	$89 M
	Rate of Return	3.51%	0.68%	5.17%
South-Eastern	Net Benefit	$47 M	-$71 M	$176 M
	Rate of Return	4.88%	2.13%	6.54%
ALL	Net Benefit	$4,566 M	$1,248 M	$8,253 M
	Rate of Return	8.36%	5.67%	10.06%

Note: Results shown above represent an extrapolation from detailed findings for the I-71 stage minimum operable segment alignment.

The results indicate that traffic volumes and population levels are sufficiently large in the I-75 corridor to justify light rail investment. In fact, the preliminary analysis indicates that the I-75 line could outperform the I-71 option from an economic perspective. Economic merit is questionable in relation to the Eastern, Western and Southeastern corridors where light rail rates of return are marginal, particularly at the 90 percent level of probability. Taking all line segments together, however, the system presents an estimated net benefit to the region of $4.6 billion (a rate of return of 8.4 percent). This ignores added ridership and economic benefits likely to be forthcoming from the “network effects” of an interconnected system, namely the effects of enabling people to change trains in order move between suburban centers.

REFERENCES

Arnott, Richard and Kenneth Small, "The Economics of Traffic Congestion," American Scientist, Vol. 82, Sept./ Oct. 1994, pp. 446-455

Cohen, Harry, "Review of Empirical Studies of Induced Traffic," Expanding Metropolitan Highways: Implications for Air Quality and Energy Use, Transportation Research Board, Special Report #345, National Academy Press (Washington DC), 1995, Appendix B, pp. 295-309

Federal Highway Administration, "Estimating the Impacts of Urban Transportation Alternatives, Participant's Notebook, National Highway Institute, NHI Course #15257, Washington DC, Dec. 1995

Fulton, Lewis, Daniel Meszler, Robert Noland and John Thomas. "A Statistical Analysis of Induced Travel Effects in the U.S. Mid-Atlantic Region," forthcoming in the Journal of Transportation and Statistics

Goodwin, Phil, "Empirical Evidence on Induced Traffic," Transportation, Vol. 23, No. 1, Feb. 1996, pp. 35-54

Hansen, Mark and Yranling Huang. "Road Supply and Traffic in California Urban Areas," Transportation Research A, 31. 205-218, 1997

Johnston, Robert and Raju Ceerla. "The Effects of New High-Occupancy Vehicle Lanes on Travel and Emissions," Transportation Research, Vol. 30A, No. 1, 35-50, 1996

Marshall, Norman. "Evidence of Induced Demand in the Texas Transportation Institute¹s Urban Roadway Congestion Study Data Set," presented at Transportation Research Board, Washington, D.C., Jan. 2000

National Cooperative Highway Research Program Report 342, "Primer on Transportation, Productivity and Economic Development," Transportation Research Board, National Research Council, Washington D.C., September 1991

Noland, Robert. "Relationships Between Highway Capacity and Induced Vehicle Travel," Transportation Research Board Annual Meeting Paper 991069, Jan. 1999. Available at http://www.epa.gov/tp/trb-rn.pdf

Noland, Robert, and William Cowart. "Analysis of Metropolitan Highway Capacity and the Growth in Vehicle Miles of Travel," presented to the annual Meeting of the Transportation Research Board, 2000.

Schrank, David, and Tim Lomax, "The 1999 Annual Mobility Report," Texas Transportation Institute, The Texas A&M University System, 1999

Standing Advisory Committee on Trunk Road Assessment (SACTRA), "Trunk Roads and the Generation of Traffic," UK DOT, HMSO (London), 1994

APPENDIX A: FTA RATING BENCHMARKS FOR THE PRELIMINARY ENGINEERING PHASE

Financial Ratings

CAPITAL FINANCING COMMITMENTS	
High	FTA considers the applicant to be in sound financial condition based upon the reviews outlined in FTA's Financial Capacity Circular. The applicant has committed or dedicated sufficient funds to cover all or nearly all of the non-Federal share of the overall undertaking, including provision for contingent cost overruns
Medium	FTA considers the applicant to be in reasonably sound financial condition based upon the reviews outlined in FTA's Financial Capacity Circular. The applicant has adopted a realistic capital finance plan that adequately covers projected non-Federal capital costs. The plan may be vulnerable to economic downturns and other funding uncertainties, but these vulnerabilities can probably be managed without significant disruptions to capital programs and/or operations.
Low	FTA does not consider the applicant to be in reasonably sound financial condition based upon the reviews outlined in FTA's Financial Capacity Circular. The applicant has not adopted a capital finance plan, or FTA considers the adopted finance plan to be inadequate or infeasible. The plan may be so vulnerable to economic downturns and other funding uncertainties that implementation of the project would put capital programs and operations at significant risk.
STABLE AND RELIABLE OPERATING REVENUE	
High	Ample dedicated funding sources are in place, or there has been a clear pattern of general appropriations from State or local governments, which regularly provide a balanced budget for the existing system. Existing transit facilities have been well maintained and improved through continuing reinvestment in the system. Financial projections show that the applicant currently has ample financial capacity to operate and maintain the locally preferred alternative, supporting feeder systems, other programmed projects, and other elements of its transit system under reasonably conservative assumptions.
Medium	Dedicated transit funding sources are in place, or there has been a clear pattern of general appropriations from State or local governments, which regularly provide a balanced budget for the existing system. Existing transit facilities have been adequately maintained and replaced through continuing reinvestment in the system. The applicant's funding plan demonstrates an ability to continue with an adequate maintenance and replacement program The applicant has adopted a realistic financial plan which, once implemented, would provide adequate financial capacity to operate and maintain the locally preferred alternative, supporting feeder systems, other programmed projects and other elements of its transit system under reasonably conservative assumptions.

Low	Sources of local transit funding have not kept pace with costs. Financial conditions have led to a pattern of service level cuts to reduce operating costs. The applicant has a history of deferring capital replacement and/or routine maintenance. Or, implementation of the project would create deficiencies in the applicant's ability to provide timely maintenance and capital replacement. The applicant has not yet adopted a finance plan, or has adopted a plan that is unrealistic or inadequate. For example, a "low" rating would be given where the region has demonstrated an unwillingness to adopt new funding sources with the required level of financial capacity, or where the operating plan is dependent upon unreasonable passenger revenue projections. A "low" rating would also be appropriate where financial projections show that, even if the adopted plan is fully implemented, the applicant would still not have the financial capacity to operate the proposed project, other programmed projects, and other elements of its transit system under reasonably conservative assumptions.

Land Use Assessment Ratings

EXISTING LAND USE	
High	Current levels of population in the corridor are sufficient to support a major transit investment.
Medium	Current levels of population and employment in the corridor are only marginally supportive of a major transit investment. Projected levels of growth must be realized.
Low	Current and projected levels of population and employment are not sufficient to support a major transit investment
CONTAINMENT OF SPRAWL	
High	Adopted and enforceable urban containment and growth management policies are in place.
Medium	Significant progress has been made toward implementing urban containment and growth management policies.
Low	Limited consideration has been given to implementing urban containment and growth management policies.
TRANSIT SUPPORTIVE CORRIDOR POLICIES	
High	A detailed corridor plan and related policies which encourage and facilitate transit supportive development have been adapted in the proposed major transit investment corridor.
Medium	Significant progress has been made toward completing a corridor plan and implementing related policies which encourage and facilitate transit supportive development in the proposed major transit investment corridor.
Low	Limited progress, to date, toward preparing and adopting a corridor plan and implementing related policies which encourage and facilitate transit supportive development in the proposed major transit investment corridor.

SUPPORTIVE ZONING REGULATIONS NEAR TRANSIT STATIONS	
High	Significant progress is being made toward preparing and adopting station area plans and related zoning.
Medium	Initial efforts have begun to prepare station area plans and related zoning.
Low	Limited consideration has been given to preparing station area plans and related zoning.
TOOLS TO IMPLEMENT LAND USE POLICIES	
High	Local capital improvement programs and development initiatives have been adopted to implement local land use policies and which leverage the Federal investment in the proposed major transit corridor.
Medium	Efforts to prepare local capital improvement programs and development initiatives that support station area plans have begun.
Low	Limited consideration has been given to local capital improvement programs and development initiatives that support station area plans.
PERFORMANCE OF LAND USE POLICIES	
High	Moderate amount of transit supportive housing and employment development is occurring in the corridor.
Medium	Proposals for transit supportive housing and employment development in the corridor are being received.
Low	Limited progress, to date, toward achieving transit supportive development in the corridor.

APPENDIX B: ECONOMIC THEORY OF MODAL CONVERGENCE

The theory presented here follows the standard model from public economics of utility maximization under a budget constraint with an external effect. Consider an individual who derives utility from consuming z units per week of a basket of commodities. In order to generate the income required to purchase the consumption good, he (or she) must take x trips per week (say, five inbound and five outbound) from a residential area to a central business district. The individual derives disutility, however, from the amount of time spent traveling. While disutility may be derived differently from different types of travel time (i.e., driving, riding, walking, waiting in congestion, etc.) for simplicity, the individual is assumed to be indifferent between travel times of different types. The individual can choose to travel by one of two modes, highway or high-capacity transit, each of which has a money price associated with the trip.

If there are I individuals, the utility maximization problem of the ith individual is expressed as:

$$\max \; u^i(z\,,\,t)$$
$$s.t. \;\; x_1^i P_1 + x_2^i P_2 + z \leq y^i \qquad \text{eq. 1}$$

where t represents time spent commuting, $x_1{}^i$ and $x_2{}^i$ are the number of trips taken by the highway and the transit modes, respectively. The prices P_1 and P_2 are the money cost of a trip by each mode, y^i is the individual's income and z is a numeraire representing all other goods.

The utility function is assumed to be continuous and twice differentiable, having the following properties:

$$u^i_z > 0\,,\; u^i_{zz} < 0\,,\; u^i_t < 0 \text{ and } u^i_{tt} < 0 \qquad \text{eq. 2}$$

The conditions on z are the regular strong concavity conditions for consumption goods. Time spent traveling is a "bad" which the individuals would be willing to pay to avoid. Concavity with respect to t implies an increasing marginal disutility -- the more time spent traveling, the greater the disutility from additional travel time.

The individual must allocate his total number of trips among the two modes:

$$x^i = x^i_1 + x^i_2 \qquad \text{eq. 3}$$

The trip time by the highway mode is an increasing function of the number of trips taken by all travelers:

$$t_1 = d + a\left(\frac{X_1}{v - X_1}\right)^b \text{ where } X_1 = \sum_{i=1}^{I} x_1^i \qquad \text{eq. 4}$$

d represents an uncongested, "freeflow" travel time and v represents the capacity constraint of the highways, i.e., the upper bound on the number of trips which could be taken by highway which would result in gridlock and an infinite trip time (the extreme case, of course, is not actually observed but this formulation represents a stylized version of the congestion dynamic). a and b are structural parameters reflecting the speed-volume relationship of the highway network. X_1 represents the total number of trips by all travelers via the highway mode.

The high-capacity transit mode is assumed to be completely unaffected by additional trips and the trip time is a fixed value:

$$t_2 = c \qquad \text{eq. 5}$$

The transit mode is assumed to be a "high-speed" mode where the linehaul segment of a journey is rapid relative to, say, the expressway segment of a highway journey thus compensating for slower speeds accessing the high-capacity mode including walk and wait times.

The absence of an external effect from additional riders on the high-capacity mode is expressed by eq. 5. Of course, crowding on transit results in some riders standing and other inconvenience. However, the key operational assumption is that travel times on the high speed mode are unaffected by changing volumes of passengers which corresponds to the actual scheduling practice in rail transit systems.

Time spent commuting is given by the sum of trips weighted by the average time per trip. The ith commuter's total travel time is given by:

$$t^i = x_1^i t_1 + x_2^i t_2 \qquad \text{eq. 6}$$

The total trip time by the individual can be expressed as a function of the number of highway trips by substituting eq. 4 and eq. 5 into eq. 6:

$$t^i(x_1^i) = x^i c + (d - c) + a \left(\frac{X_1}{v - X_1} \right)^b x_1^i \qquad \text{eq. 7}$$

The first order conditions of utility maximization are given by:

$$P_1 - P_2 = \frac{u_{x_1}^{\ i}}{u_z^i} = \frac{u_t^i}{u_z^i} \frac{\partial t^i}{\partial x_1^i} \qquad \text{eq. 8}$$

Where:

$$\begin{aligned} \frac{\partial t^i}{\partial x_1^i} &= (d - c) + a \left[\frac{X_1}{v - X_1} \right]^b \left[1 + \frac{x_1^i \ b \ v}{(v - X_1) \ X_1} \right] \\ &= t_1 - t_2 + \left[\frac{abv}{v - X_1} \right] \left[\frac{x_1^i}{X_1} \right] \left[\frac{X_1}{v - X_1} \right]^b \end{aligned} \qquad \text{eq. 9}$$

Some individuals will maximize utility by choosing all trips by one mode or another. However, some individuals will find their optimum allocation of trips by a mix of trips on both modes. These are "casual" switchers -- that is, their circumstances or preferences do not lock them into a particular mode -- and they correspond to the modal explorers discussed in the introduction. Note that eq. 9 can be re-arranged to give:

$$\left[(P_1 - P_2) \frac{u_z^i}{u_t^i} \right] - \left[\left(\frac{abv}{v - X_1} \right) \left(\frac{x_1^i}{X_1} \right) \left(\frac{X_1}{v - X_1} \right)^b \right] = t_1 - t_2 \qquad \text{eq. 10}$$

or, the condition under which door-to-door journey times across modes will be equal is given by:

$$\left[(P_1 - P_2) \frac{u_z^i}{u_t^i} \right] = \left[\left(\frac{abv}{v - X_1} \right) \left(\frac{x_1^i}{X_1} \right) \left(\frac{X_1}{v - X_1} \right)^b \right] \qquad \text{eq. 11}$$

Condition 11 tells us what combinations of prices, congestion, personal preferences and highway speed-flow relationship will result in equal travel times. However, it can be readily shown that under the assumptions described above -- especially the assumption of an growing marginal disutility with respect to travel time -- that with sufficient levels of congestion both the left and right hand sides of eq. 11 approach zero.

What happens under congested conditions? The left hand side tends to zero due to the growing marginal disutility from increased travel time (also, the left hand side approaches zero with increasing income -- the individual becomes indifferent to the price differential as trip cost consumes a smaller portion of his income). The theory also implies that congestion pricing will be less effective as congestion becomes more severe. It can be readily shown that if u_t^i is not bounded then for any combination of prices and capacity equation parameters, and for any small value $\varepsilon > 0$, there is a level of congestion (number of total trips) sufficiently large such that:

$$|t_1 - t_2| < \varepsilon \qquad \text{eq. 12}$$

APPENDIX C: HIGHWAY USER COST REFERENCE TABLES

The travel costs savings—other than travel time—are estimated based on the vehicle miles traveled (VMT) reduction and cost factor estimated for each travel cost category: Vehicle operating costs, safety costs, and environmental costs. These cost factors are estimated based upon various relationships summarized below.

Accident Rates

Accident rates are based on relationships and data put forth in "*Highway Economic Requirements System Technical Report* ", Federal Highway Administration, U.S. Department of Transportation, Jack Faucett Associates, Bethesda, MD, July 1991.

Fatal Accidents

Fatal Accidents Per 100 Million VMT	AADT Under 1,000	AADT 1,000-2,999	AADT 3,000-5,999	AADT 6,000-11,999	AADT 12,000-19,999	AADT 20,000-29,999	AADT 30,000-46,999	AADT 47,000-66,999	AADT 67,000-87,999	AADT 88,000-124,999	AADT 125,000-174,999	AADT Above 175,000
Urban 4 Lanes Full Access Control	2.0	2.0	2.0	2.0	2.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0
Urban 6+ Lanes Full Access Control	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Urban 4 Lanes Partial Access Control	3.0	3.0	3.0	3.0	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Urban 6+ Lanes Partial Access Control	2.5	2.5	2.5	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0
Urban 2 or 3 Lanes	2.5	2.5	4.0	3.0	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Urban Multilane Undivided	6.5	6.5	6.5	4.0	3.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0
Urban Multilane Divided	4.0	4.0	4.0	3.5	3.0	2.5	2.0	2.0	2.0	2.0	2.0	2.0

Injury Only Accidents

Injury Accidents Per 100 Million VMT	AADT Under 1,000	AADT 1,000-2,999	AADT 3,000-5,999	AADT 6,000-11,999	AADT 12,000-19,999	AADT 20,000-29,999	AADT 30,000-46,999	AADT 47,000-66,999	AADT 67,000-87,999	AADT 88,000-124,999	AADT 125,000-174,999	AADT Above 175,000
Urban 4 Lanes Full Access Control	40.0	40.0	40.0	35.0	35.0	35.0	40.0	60.0	60.0	60.0	60.0	60.0
Urban 6+ Lanes Full Access Control	65.0	65.0	65.0	65.0	65.0	70.0	40.0	45.0	55.0	70.0	70.0	70.0
Urban 4 Lanes Partial Access Control	185.0	185.0	185.0	185.0	200.0	220.0	220.0	220.0	220.0	220.0	220.0	220.0
Urban 6+ Lanes Partial Access Control	365.0	365.0	365.0	365.0	365.0	365.0	225.0	225.0	225.0	225.0	225.0	225.0
Urban 2 or 3 Lanes	195.0	195.0	195.0	270.0	330.0	395.0	395.0	395.0	395.0	395.0	395.0	395.0
Urban Multilane Undivided	580.0	580.0	580.0	365.0	365.0	365.0	335.0	335.0	335.0	335.0	335.0	335.0
Urban Multilane Divided	275.0	275.0	275.0	275.0	325.0	335.0	335.0	335.0	335.0	335.0	335.0	335.0

Property Damage Only Accidents

PDO Accidents Per 100 Million VMT	AADT Under 1,000	AADT 1,000-2,999	AADT 3,000-5,999	AADT 6,000-11,999	AADT 12,000-19,999	AADT 20,000-29,999	AADT 30,000-46,999	AADT 47,000-66,999	AADT 67,000-87,999	AADT 88,000-124,999	AADT 125,000-174,999	AADT Above 175,000
Urban 4 Lanes Full Access Control	70.0	70.0	70.0	65.0	65.0	65.0	80.0	120.0	140.0	140.0	140.0	140.0
Urban 6+ Lanes Full Access Control	140.0	140.0	140.0	140.0	140.0	125.0	90.0	90.0	100.0	120.0	120.0	120.0
Urban 4 Lanes Partial Access Control	275.0	275.0	275.0	275.0	300.0	350.0	375.0	375.0	375.0	375.0	375.0	375.0
Urban 6+ Lanes Partial Access Control	515.0	515.0	515.0	515.0	515.0	515.0	375.0	375.0	375.0	375.0	375.0	375.0
Urban 2 or 3 Lanes	345.0	345.0	345.0	490.0	590.0	660.0	660.0	660.0	660.0	660.0	660.0	660.0
Urban Multilane Undivided	785.0	785.0	785.0	685.0	685.0	685.0	590.0	590.0	590.0	590.0	590.0	590.0
Urban Multilane Divided	415.0	415.0	415.0	415.0	490.0	590.0	590.0	590.0	590.0	590.0	590.0	590.0

Vehicle Operating Costs

The Vehicle Operating Cost (VOC) consumption rates presented in the tables below are drawn from the "*Technical Memorandum for National Cooperative Highway Research Program (NCHRP) Project 7-12* ", Texas Transportation Institute, The Texas A&M University System, College Station, Texas, January 1990. The VOC consumption rates are given as: units of consumption (as indicated by the tables) per 1,000 miles.

Fuel Consumption (Gallons)

	Auto					Bus					Truck				
	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%
5	52.17	58.39	74.02	73.99	80.23	120.22	232.62	354.39	407.67	452.27	138.09	220.03	419.94	510.94	589.13
10	39.87	48.92	56.89	59.20	64.20	82.84	168.44	258.96	327.80	380.54	86.75	135.36	306.85	410.84	495.70
15	31.62	40.71	45.29	48.79	52.90	65.59	141.70	217.65	289.96	345.10	58.66	103.96	257.90	363.40	449.53
20	26.03	33.77	37.33	41.41	44.90	54.69	125.10	194.40	267.16	323.08	40.81	88.09	230.36	334.84	420.85
25	22.23	28.09	31.87	36.20	39.26	47.02	112.77	180.01	252.07	308.08	29.09	79.21	213.31	315.92	401.31
30	19.70	23.68	28.17	32.59	35.34	41.61	103.19	170.91	241.70	297.42	21.71	74.30	202.52	302.92	387.42
35	18.11	20.54	25.80	30.23	32.78	38.14	96.25	165.40	234.55	289.77	17.69	72.04	195.99	293.97	377.45
40	17.29	18.66	24.46	28.87	31.30	36.56	92.32	162.59	229.82	284.36	16.44	71.79	192.66	288.04	370.41
45	17.12	18.05	24.02	28.40	30.79	36.92	91.78	161.96	227.01	280.72	17.61	73.27	191.92	284.51	365.67
50	17.59	18.70	24.42	28.77	31.20	39.24	94.76	163.25	225.80	278.57	20.92	76.42	193.45	283.00	362.87
55	18.76	20.63	25.72	30.02	32.55	43.53	100.98	166.32	226.01	277.69	26.20	81.30	197.09	283.26	361.72
60	20.75	23.81	28.06	32.26	34.99	49.63	109.80	171.13	227.50	277.96	33.32	88.10	202.78	285.12	362.07
65	23.83	28.26	31.69	35.71	38.73	57.25	120.25	177.71	230.20	279.27	42.17	97.17	210.58	288.51	363.78
70	28.39	33.98	37.07	40.71	44.15	65.97	131.32	186.17	234.07	281.57	52.68	109.00	220.60	293.37	366.78

Oil Consumption (Quarts)

	Auto					Bus					Truck				
	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%
5	4.216	4.138	3.817	8.007	9.274	14.024	9.759	8.418	31.103	37.379	27.233	17.574	17.574	65.476	79.373
10	2.486	2.440	2.364	5.944	6.884	7.794	6.330	6.703	17.636	21.195	19.497	13.894	13.894	38.412	46.565
15	1.907	1.872	1.859	4.542	5.261	5.631	4.983	5.501	12.846	15.438	14.507	11.286	11.286	28.118	34.086
20	1.630	1.600	1.612	3.573	4.138	4.561	4.267	4.651	10.367	12.458	11.217	9.418	9.418	22.535	27.318
25	1.478	1.451	1.475	2.893	3.351	3.954	3.841	4.053	8.850	10.635	9.014	8.074	8.074	18.980	23.008
30	1.392	1.366	1.395	2.412	2.793	3.592	3.579	3.639	7.828	9.407	7.528	7.111	7.111	16.496	19.997
35	1.344	1.320	1.352	2.070	2.397	3.384	3.426	3.367	7.096	8.527	6.534	6.435	6.435	14.651	17.761
40	1.323	1.299	1.332	1.828	2.118	3.283	3.351	3.210	6.549	7.870	5.894	5.982	5.982	13.220	16.026
45	1.321	1.297	1.330	1.663	1.926	3.267	3.339	3.153	6.127	7.363	5.525	5.714	5.714	12.075	14.638
50	1.335	1.310	1.342	1.556	1.803	3.324	3.383	3.192	5.795	6.964	5.382	5.606	5.606	11.135	13.498
55	1.361	1.336	1.365	1.500	1.737	3.451	3.479	3.330	5.529	6.645	5.449	5.652	5.652	10.347	12.544
60	1.398	1.372	1.398	1.488	1.723	3.651	3.628	3.579	5.314	6.386	5.733	5.853	5.853	9.677	11.731
65	1.445	1.418	1.440	1.519	1.760	3.931	3.832	3.965	5.138	6.175	6.269	6.228	6.228	9.099	11.031
70	1.502	1.474	1.491	1.597	1.850	4.304	4.098	4.525	4.994	6.001	7.124	6.808	6.808	8.595	10.419

Tire Consumption (Percentage of Wear)

	Auto					Bus					Truck				
	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%
5	0.064	0.000	0.062	0.000	0.111	0.189	0.033	0.109	0.000	0.369	0.213	0.052	0.127	0.000	0.456
10	0.039	0.000	0.068	0.000	0.105	0.161	0.023	0.110	0.000	0.397	0.199	0.038	0.122	0.000	0.476
15	0.022	0.000	0.079	0.000	0.121	0.137	0.018	0.122	0.000	0.443	0.185	0.029	0.126	0.000	0.510
20	0.014	0.000	0.096	0.000	0.158	0.116	0.019	0.141	0.000	0.508	0.170	0.024	0.138	0.000	0.557
25	0.015	0.019	0.117	0.000	0.216	0.098	0.026	0.167	0.000	0.591	0.156	0.024	0.157	0.000	0.618
30	0.026	0.049	0.145	0.000	0.297	0.085	0.039	0.201	0.000	0.693	0.141	0.029	0.181	0.000	0.692
35	0.045	0.087	0.181	0.099	0.398	0.074	0.058	0.241	0.024	0.813	0.127	0.037	0.210	0.000	0.780
40	0.073	0.135	0.227	0.223	0.521	0.067	0.083	0.289	0.163	0.952	0.113	0.051	0.245	0.082	0.881
45	0.111	0.192	0.286	0.367	0.666	0.064	0.114	0.342	0.320	1.109	0.098	0.069	0.285	0.197	0.996
50	0.157	0.258	0.361	0.533	0.832	0.064	0.151	0.403	0.496	1.285	0.084	0.091	0.331	0.325	1.124
55	0.212	0.333	0.457	0.721	1.020	0.068	0.194	0.470	0.690	1.479	0.069	0.118	0.382	0.467	1.266
60	0.277	0.417	0.579	0.930	1.229	0.075	0.244	0.544	0.903	1.692	0.055	0.149	0.437	0.622	1.421
65	0.350	0.510	0.735	1.161	1.459	0.085	0.299	0.624	1.134	1.923	0.041	0.185	0.498	0.791	1.590
70	0.432	0.612	0.935	1.413	1.711	0.099	0.360	0.711	1.384	2.173	0.026	0.226	0.565	0.973	1.772

Maintenance and Repair (Percentage of Average M&R Cost)

	Auto					Bus					Truck				
	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%
5	38.684	42.249	47.635	43.227	44.272	31.337	16.617	46.641	47.070	47.800	32.754	17.973	52.047	38.579	39.850
10	35.999	45.335	46.970	45.989	47.101	30.604	15.867	47.064	48.397	49.856	32.530	17.619	54.577	44.184	46.725
15	36.988	48.421	48.525	48.929	50.111	29.767	15.117	47.914	50.121	52.311	32.259	17.356	58.270	49.788	53.600
20	39.481	51.506	50.988	52.056	53.314	28.829	46.991	49.190	52.244	55.163	31.940	17.131	62.673	55.392	60.475
25	42.799	54.592	53.950	55.382	56.721	27.788	47.632	50.893	54.765	58.414	31.574	15.596	67.681	60.997	67.351
30	46.638	57.678	57.226	58.922	60.346	26.644	48.764	53.022	57.684	62.062	31.161	47.293	73.277	66.601	74.226
35	50.837	60.764	60.721	62.687	64.202	25.398	50.388	55.577	61.000	66.109	30.700	50.826	79.475	72.206	81.101
40	55.300	63.850	64.374	66.694	68.306	24.049	52.503	58.560	64.715	70.553	30.191	54.581	86.309	77.810	87.976
45	59.963	66.936	68.148	70.956	72.671	22.598	55.110	61.968	68.828	75.396	29.635	58.557	93.823	83.414	94.851
50	64.785	70.022	72.019	75.491	77.315	21.044	58.209	65.804	73.339	80.636	29.032	62.756	102.071	89.019	101.726
55	69.736	73.108	75.967	80.315	82.256	53.200	61.799	70.065	78.247	86.275	28.381	67.177	111.113	94.623	108.601
60	74.792	76.194	79.979	85.448	87.513	57.200	65.880	74.753	83.554	92.311	27.682	71.820	121.020	100.228	115.477
65	79.938	79.280	84.045	90.909	93.106	61.200	70.453	79.868	89.259	98.746	60.200	76.684	131.867	105.832	122.352
70	85.159	82.366	88.157	96.719	99.057	65.200	75.517	85.409	95.362	105.578	92.718	81.771	143.740	111.436	129.227

Vehicle Depreciation (Percentage of Depreciable Value)

	Auto					Bus					Truck				
	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%
5	1.595	1.595	1.595	1.595	1.595	0.743	0.743	0.743	0.743	0.743	0.250	0.250	0.250	0.250	0.250
10	1.340	1.340	1.340	1.340	1.340	0.585	0.585	0.585	0.585	0.585	0.191	0.191	0.191	0.191	0.191
15	1.193	1.193	1.193	1.193	1.193	0.499	0.499	0.499	0.499	0.499	0.159	0.159	0.159	0.159	0.159
20	1.092	1.092	1.092	1.092	1.092	0.442	0.442	0.442	0.442	0.442	0.138	0.138	0.138	0.138	0.138
25	1.015	1.015	1.015	1.015	1.015	0.401	0.401	0.401	0.401	0.401	0.123	0.123	0.123	0.123	0.123
30	0.954	0.954	0.954	0.954	0.954	0.370	0.370	0.370	0.370	0.370	0.112	0.112	0.112	0.112	0.112
35	0.903	0.903	0.903	0.903	0.903	0.345	0.345	0.345	0.345	0.345	0.103	0.103	0.103	0.103	0.103
40	0.861	0.861	0.861	0.861	0.861	0.326	0.326	0.326	0.326	0.326	0.097	0.097	0.097	0.097	0.097
45	0.824	0.824	0.824	0.824	0.824	0.311	0.311	0.311	0.311	0.311	0.092	0.092	0.092	0.092	0.092
50	0.792	0.792	0.792	0.792	0.792	0.299	0.299	0.299	0.299	0.299	0.088	0.088	0.088	0.088	0.088
55	0.764	0.764	0.764	0.764	0.764	0.289	0.289	0.289	0.289	0.289	0.085	0.085	0.085	0.085	0.085
60	0.738	0.738	0.738	0.738	0.738	0.282	0.282	0.282	0.282	0.282	0.083	0.083	0.083	0.083	0.083
65	0.716	0.716	0.716	0.716	0.716	0.276	0.276	0.276	0.276	0.276	0.082	0.082	0.082	0.082	0.082
70	0.696	0.696	0.696	0.696	0.696	0.272	0.272	0.272	0.272	0.272	0.081	0.081	0.081	0.081	0.081

Emission Factors

Emission rates are based on relationships and data from "*Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Condition Factors*", Texas Research and Development Foundation, Austin, Texas, Federal Highway Administration, June 1982. Emission rates (in pounds of pollutants per thousand Vehicle Miles of Travel) have been derived for Hydro Carbon (HC), Carbon Monoxide (CO) and Nitrogen Oxide (NO_X).

Vehicle Speed MPH	Auto			Bus			Truck		
	HC	CO	NO_X	HC	CO	NO_X	HC	CO	NO_X
5	7.46	151.00	2.32	1.31	5.56	32.00	1.31	5.56	32.00
10	3.28	61.40	1.15	1.37	5.80	33.20	1.37	5.80	33.20
15	1.93	33.20	1.38	1.44	6.12	35.20	1.44	6.12	35.20
20	1.30	20.60	1.96	1.55	6.56	37.60	1.55	6.56	37.60
25	0.95	14.12	2.68	1.67	7.10	40.80	1.67	7.10	40.80
30	0.75	10.74	3.46	1.82	7.74	44.40	1.82	7.74	44.40
35	0.62	9.10	4.30	2.00	8.48	48.80	2.00	8.48	48.80
40	0.55	8.58	5.14	2.20	9.32	53.60	2.20	9.32	53.60
45	0.51	8.78	6.02	2.42	10.28	59.00	2.42	10.28	59.00
50	0.49	9.50	6.90	2.68	11.34	65.00	2.68	11.34	65.00
55	0.49	10.58	7.80	2.94	12.50	71.80	2.94	12.50	71.80
60	0.51	11.96	8.68	3.24	13.74	79.00	3.24	13.74	79.00
65	0.53	13.54	9.58	3.56	15.12	86.80	3.56	15.12	86.80
70	0.57	15.30	10.50	3.92	16.58	95.20	3.92	16.58	95.20

The emission factors for greenhouse gases - Carbon Dioxide (CO), Nitrous Oxide (N2O) and Methane (CH4) - used in the model are summarized in the table below:

Pollutant	Central Estimate	Unit
CH4	0.00335	Lbs per gallon of fuel
N2O	0.00144	Lbs per gallon of fuel
CO2	18.35276	Lbs per gallon of fuel

Derived from USEPA Mobile 5 Emission Model

APPENDIX D: SUMMARY OF ASSUMPTIONS

Congestion Management Model Assumptions

Variable	Period	Median Estimate	10% Lower Limit	10% Upper Limit
Average Annual VMT Growth (%)	2000 - 2008	1.90%	1.40%	2.9%
	2008 - 2015	1.67	1.03%	2.27%
	2015 - 2020	1.37%	0.93%	1.8%
	2020 - 2037	1.00%	1.00%	1%
Free Flow Travel Time for 22 miles (min)		37	30.67	41.27
Door-to-door Travel Time (min)				
Blue Ash to CBD (AM)	Nov. 2000	40	31	55
CBD to Blue Ash (PM)	Nov. 2000	37	27	66
Blue Ash to Covington (AM)	Nov. 2000	38	37	40
Covington to Blue Ash (PM)	Nov. 2000	33	28	36
Blue Ash to UC (AM)	Nov. 2000	41	35	51
UC to Blue Ash (PM)	Nov. 2000	38	30	58
S. Covington to CBD (AM)	Nov. 2000	21	12	32
CBD to S. Covington (PM)	Nov. 2000	15	12	20
Light Rail Ridership (#)	2008	26,267	20,500	29,667
Ridership Growth (%)	2008 - 2015	1.25%	-0.56%	5.63%
	2016 - 2020	1.03%	-0.81%	3.88%
	2020 - 2037	1.03%	-0.81%	3.88%
Trips diverted from cars to light rail (%)	2008	54%	48%	60%
Average Trip Length in the Corridor (miles)	2001	11.8	8.16	14.4
Average Number of Passenger per Car (#)	2001	1.05	1.04	1.09
Value of Travel Time ($/Hr.)	2001	$10.25	$8.50	$15.7
Emission Costs ($/ton)	2001			
Hydro Carbon	2001	$3,045	$1,774	$6,258
Carbon Monoxide	2001	$3,889	$3,394	$5,939
Nitrogen Oxide	2001	$6,072	$3,731	$12,028
Parking Rate ($)	2001	$6.5	$6	$8.00
Accident Costs ($/accident)	2001			$6,258
Fatal Accident	2001	$3,384,300	$2,621,923	$3,984,094
Injury Accident	2001	$94,866	$57,430	$101,963
Property Damage	2001	$3,195	$2,603	$6,569
Consumer Price Index Annual Growth (%)	2000 - 2008	2.8%	1.6%	4.1%
Real Discount Rate (%)	N/A	4%		

Affordable Mobility Model Assumptions

Variable	Period	Median Estimate	10% Lower Limit	10% Upper Limit
Average light rail fare ($)	2001 Dollars	$1.03	$0.84	$1.40
Average bus fare ($)	2001 Dollars	$0.79	$0.65	$1.75
Average taxi fare per trip ($)	2001 Dollars	$7.8	$5.40	$11.40
Elasticity of light rail with respect to Fare (%)	2001	-0.8	-0.4	-1.2
Percentage of light rail trips for medical purpose (%)	2001	15%	10%	20%
Percentage of bus trips for medical purpose (%)	2001	10%	5%	15%
Percentage of light rail Trips for work purpose (%)	2001	40%	25%	50%
Percentage of bus trips (%)	2001	25%	20%	35%
Percentage of lost med trips to home care (%)	2001	10%	5%	15%
Cost of additional home care visit ($)	2001	$75	$50	$100
Percentage of lost trips leading to unemployment (%)	2001	30%	20%	45%
Cost per recipient per year. ($)	2001	$852	$840	$864

Community Economic Development Model Assumptions

Variable	Period	Median Estimate	10% Lower Limit	10% Upper Limit
Area of Impact (Miles from station)	N/A	0.5	0.5	0.5
Number of Residential Properties within 1 mile (#)	2001	167,254	167,254	167,254
Number of Commercial Properties within 1 mile (#)	2001	41,728	41,728	41,728
Residential Property Premium (%)	2001			
High Development Potential	N/A	3.38%	1.25%	4.75%
Medium Development Potential	N/A	3.21%	1.19%	4.51%
Low Development Potential	N/A	3.05%	1.13%	4.29%
Commercial Property Premium (%)	2001			
High Development Potential	N/A	7.0%	3.0%	10.0%
Medium Development Potential	N/A	6.65%	2.85%	9.50%
Low Development Potential	N/A	6.32%	2.71%	9.03%

Economic Effects Analysis Model Assumptions

Variable	Period	Median Estimate	10% Lower Limit	10% Upper Limit
Light Rail Proportion of Total Construction Cost				
Labor Share	N/A	36.6%	32.0%	48.0%
Materials/Equipment Share	N/A	45.3%	40.0%	51.0%
Services & Other Share	N/A	18.2%	16.0%	22.0%
Light Rail Proportion of Total Annual Operating Cost				
Labor Share	N/A	60.4%	54.0%	66.0%
Materials/Equipment Share	N/A	28.4%	23.0%	31.0%
Services & Other Share	N/A	11.2%	8.0%	13.0%
Regional Unemployment Rate	N/A	3.4%	3.3%	6.6%
Regional Purchase Coefficients				
Construction	N/A			
Labor	N/A	75%	60%	85%
Materials & Equipment	N/A	35%	31%	39%
Services	N/A	80%	75%	85%
Operations	N/A			
Labor	N/A	95%	93%	97%
Materials and Equipment	N/A	60%	55%	65%
Services	N/A	90%	85%	93%
Impact Multipliers/Construction				
Output	N/A	1.87	1.83	1.95
Employment	N/A	2.28	2.22	2.33
Personal Income	N/A	1.98	1.92	2.05
Impact Multipliers/Light Rail Operations				
Output	N/A	2.08	1.98	2.15
Employment	N/A	2.00	1.95	2.08
Personal Income	N/A	1.76	1.70	1.90
State Income Tax Rates				
Kentucky	2000	4.26%	4.00%	4.75%
Ohio	2000	2.76%	2.5%	3.25%
Regional Sales Tax Rates				
Kentucky (No county taxes)	2000	6.00%	5.95%	6.5%
Ohio (Average of 4 Counties)	2000	5.75%	5.70%	7.0%

Cost Model Assumptions

Variable	Period	Median Estimate	10% Lower Limit	10% Upper Limit
Guideway Costs ($ 000)	2001	$250,595	$205,377	$310,107
Stations Cost ($ 000)	2001	$77,316	$65,459	$86,630
Systems Cost ($ 000)	2001	$76,012	$65,188	$94,023
Special Conditions Cost ($ 000)	2001	$50,824	$40,028	$90,000
Right-of-Way Cost ($ 000)	2001	$31,372	$22,807	$50,719
Yards and Shops Cost ($ 000)	2001	$27,984	$20,000	$51,083
Vehicles Cost ($ 000)	2001	$120,233	$110,343	$135,850
Add-ons Cost ($ 000)	2001	$170,847	$158,432	$267,261
Operating and Maintenance Cost ($ 000)	2001	$18,002	$16,575	$20,500

APPENDIX E: ALTERNATIVE SCENARIO SIMULATION RESULTS

Scenario Definition

Scenario	Description
Opening Year 2008	Light rail opens in 2008 (baseline scenario)
Opening Year 2010	Two-year delay: light rail opens in 2010, no cost overrun
Opening Year 2012	Four-year delay: light rail opens in 2012, no cost overrun
2.4% Traffic Growth	Increased AADT growth to an average 2.4 percent per year
No Traffic Growth After 2008	No traffic growth after the opening year, 2008 to 2037
No Traffic Growth After 2001	No traffic growth
3% Discount Rate	Benefits and costs are discounted with a 3 percent real discount rate
4% Discount Rate	Benefits and costs are discounted with a 4 percent real discount rate (baseline scenario)
5% Discount Rate	Benefits and costs are discounted with a 5 percent real discount rate
No Ridership Growth	Zero ridership growth between 2001 and 2037
25-Year Analysis	Period of analysis reduced from 30 to 25 years (after opening)
20-Year Analysis	Period of analysis reduced from 30 to 20 years (after opening)

Summary of Results, Mean Expected Outcomes

Scenario	Net Present Value ($millions)	Rate of Return (%)	First Year BC Ratio (%)	Payback Period (# years after opening)
Opening Year 2008	$786.6	8.12%	5.86%	16.1
Opening Year 2010	$807.1	8.00%	6.15%	15.9
Opening Year 2012	$854.0	7.99%	6.57%	15.4
2.4% Traffic Growth	$2,260.0	12.26%	8.05%	11.1
No Traffic Growth After 2008	$2.2	4.17%	5.16%	24.5
No Traffic Growth After 2001	-$160.9	-3.79%	3.85%	27.6
3% Discount Rate	$1,131.4	8.12%	5.86%	14.4
4% Discount Rate	$786.6	8.12%	5.86%	16.1
5% Discount Rate	$523.2	8.12%	5.86%	18.0
No Ridership Growth	$728.1	7.89%	6.04%	16.6
25-Year Analysis	$516.2	7.30%	5.86%	15.7
20-Year Analysis	$274.3	6.12%	5.86%	14.8

	Baseline Scenario		
	Mean	Lower	Upper
Benefit Categories:			
Affordable Mobility	$229.8	$141.0	$338.2
Cross Sector Benefits	$93.7	$31.3	$167.8
Total Affordable Mobility	**$323.5**	**$172.3**	**$505.9**
Residential Development	$57.8	$37.1	$75.5
Commercial Development	$296.1	$185.0	$389.6
Total Livable Community	**$353.9**	**$244.4**	**$451.3**
Time Savings	$838.9	$311.6	$1,481.3
VOC Savings	$136.0	$77.5	$200.6
Emission Savings	$71.8	$29.2	$126.4
Accident Cost Savings	$106.3	$45.1	$184.3
Total Congestion Management	**$1,153.0**	**$559.9**	**$1,868.1**
Grand Total Benefits	**$1,830.4**	**$1,165.5**	**$2,547.8**
Total Costs	**$1,043.7**	**$950.9**	**$1,162.5**
Net Present Value	**$786.6**	**$111.8**	**$1,516.8**
Internal Rate of Return	**8.12%**	**4.79%**	**11.38%**
First Year Benefit Cost Ratio	5.86%	3.88%	8.12%
Payback Period (Years)	16	11	26

	No Traffic Growth 2008-2037			No Traffic Growth 2001-2037		
	Mean	Lower	Upper	Mean	Lower	Upper
Benefit Categories:						
Affordable Mobility	$224.3	$143.2	$326.1	$224.5	$137.8	$311.8
Cross Sector Benefits	$94.7	$37.1	$166.2	$96.7	$36.0	$169.9
Total Affordable Mobility	**$319.0**	**$180.4**	**$492.3**	**$321.2**	**$173.8**	**$481.7**
Residential Development	$57.3	$33.5	$77.6	$57.6	$33.4	$78.7
Commercial Development	$298.4	$186.4	$392.4	$297.1	$191.7	$398.7
Total Livable Community	**$355.7**	**$240.4**	**$453.0**	**$354.7**	**$252.3**	**$459.5**
Time Savings	$130.1	$29.0	$254.3	-$8.1	-$12.4	-$5.3
VOC Savings	$93.0	$50.8	$135.9	$82.3	$43.6	$119.1
Emission Savings	$22.6	$10.8	$36.6	$14.8	$7.4	$23.0
Accident Cost Savings	$118.1	$48.7	$202.2	$112.1	$49.7	$182.1
Total Congestion Management	**$363.8**	**$171.2**	**$573.8**	**$201.0**	**$98.1**	**$299.0**
Grand Total Benefits	**$1,038.6**	**$739.5**	**$1,367.7**	**$876.9**	**$642.7**	**$1,123.6**
Total Costs	**$1,036.3**	**$944.1**	**$1,150.8**	**$1,037.7**	**$947.6**	**$1,149.8**
Net Present Value	**$2.2**	**-$301.6**	**$351.6**	**-$160.9**	**-$437.1**	**$92.4**
Internal Rate of Return	**4.17%**	**0.40%**	**6.72%**	**-3.79%**	**-1.80%**	**4.79%**
First Year Benefit Cost Ratio	5.16%	3.57%	6.99%	3.85%	2.72%	4.97%
Payback Period (Years)	25	14	29	28	22	29

	3% Discount Rate			5% Discount Rate		
	Mean	Lower	Upper	Mean	Lower	Upper
Benefit Categories:						
Affordable Mobility	$279.6	$170.9	$412.5	$190.6	$117.7	$276.1
Cross Sector Benefits	$114.0	$37.4	$202.6	$77.6	$25.8	$139.6
Total Affordable Mobility	**$393.6**	**$208.3**	**$615.1**	**$268.2**	**$143.6**	**$415.6**
Residential Development	$67.8	$43.5	$88.6	$49.4	$31.7	$64.5
Commercial Development	$346.0	$216.2	$455.4	$254.0	$158.7	$334.2
Total Livable Community	**$413.9**	**$286.0**	**$527.6**	**$303.4**	**$209.4**	**$387.0**
Time Savings	$1,063.1	$398.6	$1,886.6	$667.5	$245.7	$1,182.0
VOC Savings	$167.9	$94.8	$248.8	$111.2	$64.0	$163.0
Emission Savings	$90.7	$36.8	$159.1	$57.4	$23.4	$100.8
Accident Cost Savings	$129.3	$54.0	$226.7	$88.1	$37.5	$154.7
Total Congestion Management	**$1,451.0**	**$701.7**	**$2,343.3**	**$924.2**	**$451.7**	**$1,493.8**
Grand Total Benefits	**$2,258.5**	**$1,420.1**	**$3,150.7**	**$1,495.8**	**$962.0**	**$2,075.3**
Total Costs	**$1,127.2**	**$1,028.1**	**$1,252.5**	**$972.6**	**$884.5**	**$1,082.8**
Net Present Value	**$1,131.4**	**$299.0**	**$2,049.5**	**$523.2**	**-$31.5**	**$1,111.5**
Internal Rate of Return	**8.12%**	**4.79%**	**11.38%**	**8.12%**	**4.79%**	**11.38%**
First Year Benefit Cost Ratio	5.86%	3.88%	8.12%	5.86%	3.88%	8.12%
Payback Period (Years)	14	10	22	18	11	29

	25-Year Analysis			20-Year Analysis		
	Mean	Lower	Upper	Mean	Lower	Upper
Benefit Categories:						
Affordable Mobility	$200.5	$125.0	$291.8	$168.6	$107.8	$243.9
Cross Sector Benefits	$81.5	$26.4	$145.1	$68.4	$22.7	$118.7
Total Affordable Mobility	**$282.1**	**$151.4**	**$437.0**	**$237.0**	**$130.4**	**$362.6**
Residential Development	$57.8	$37.1	$75.5	$57.8	$37.1	$75.5
Commercial Development	$296.1	$185.0	$389.6	$296.1	$185.0	$389.6
Total Livable Community	**$353.9**	**$244.4**	**$451.3**	**$353.9**	**$244.4**	**$451.3**
Time Savings	$637.1	$221.8	$1,129.7	$460.9	$146.7	$841.0
VOC Savings	$113.4	$66.3	$165.6	$91.0	$53.7	$131.0
Emission Savings	$55.1	$22.5	$95.2	$40.6	$16.6	$69.7
Accident Cost Savings	$92.7	$40.0	$160.3	$77.9	$33.8	$132.4
Total Congestion Management	**$898.4**	**$430.3**	**$1,454.6**	**$670.5**	**$312.1**	**$1,088.9**
Grand Total Benefits	**$1,534.4**	**$1,015.1**	**$2,094.7**	**$1,261.4**	**$862.6**	**$1,683.1**
Total Costs	**$1,018.2**	**$926.8**	**$1,134.2**	**$987.1**	**$896.2**	**$1,101.5**
Net Present Value	**$516.2**	**-$32.4**	**$1,098.1**	**$274.3**	**-$165.6**	**$718.1**
Internal Rate of Return	**7.30%**	**3.74%**	**10.85%**	**6.12%**	**2.24%**	**9.80%**
First Year Benefit Cost Ratio	5.86%	3.88%	8.12%	5.86%	3.88%	8.12%
Payback Period (Years)	16	11	24	15	11	19

	Opening Year 2010			Opening Year 2012		
	Mean	Lower	Upper	Mean	Lower	Upper
Benefit Categories:						
Affordable Mobility	$210.5	$130.7	$304.0	$193.4	$122.4	$275.9
Cross Sector Benefits	$86.0	$28.8	$152.0	$79.4	$26.0	$141.8
Total Affordable Mobility	**$296.5**	**$159.5**	**$456.0**	**$272.8**	**$148.5**	**$417.7**
Residential Development	$59.2	$38.0	$77.3	$60.7	$38.9	$79.2
Commercial Development	$284.8	$177.7	$375.4	$273.8	$170.6	$361.6
Total Livable Community	**$344.0**	**$238.8**	**$436.9**	**$334.5**	**$233.8**	**$423.1**
Time Savings	$860.0	$322.0	$1,521.0	$902.6	$345.8	$1,577.6
VOC Savings	$130.2	$72.9	$193.3	$126.2	$69.3	$190.4
Emission Savings	$73.8	$29.1	$130.7	$77.0	$30.4	$138.5
Accident Cost Savings	$97.6	$40.8	$169.2	$90.0	$37.4	$152.7
Total Congestion Management	**$1,161.6**	**$549.0**	**$1,907.0**	**$1,195.9**	**$567.1**	**$1,976.8**
Grand Total Benefits	**$1,802.1**	**$1,129.3**	**$2,575.4**	**$1,803.1**	**$1,117.5**	**$2,598.9**
Total Costs	**$995.0**	**$906.3**	**$1,109.4**	**$949.1**	**$864.0**	**$1,057.6**
Net Present Value	**$807.1**	**$120.7**	**$1,602.4**	**$854.0**	**$159.8**	**$1,678.9**
Internal Rate of Return	**8.00%**	**4.79%**	**11.12%**	**7.99%**	**4.97%**	**11.03%**
First Year Benefit Cost Ratio	6.15%	3.85%	8.74%	6.57%	3.97%	9.51%
Payback Period (Years)	16	10	26	15	10	24

	No Ridership Growth			Traffic Growth at 2.4%		
	Mean	Lower	Upper	Mean	Lower	Upper
Benefit Categories:						
Affordable Mobility	$174.7	$116.2	$227.1	$229.8	$141.0	$338.2
Cross Sector Benefits	$72.8	$29.0	$121.5	$93.7	$31.3	$167.8
Total Affordable Mobility	**$247.4**	**$145.1**	**$348.6**	**$323.5**	**$172.3**	**$505.9**
Residential Development	$57.2	$33.9	$78.6	$57.8	$37.1	$75.5
Commercial Development	$296.7	$179.3	$394.6	$296.1	$185.0	$389.6
Total Livable Community	**$353.9**	**$238.7**	**$451.6**	**$353.9**	**$244.4**	**$451.3**
Time Savings	$889.0	$324.5	$1,514.3	$2,138.2	$892.9	$3,683.5
VOC Savings	$120.2	$67.5	$176.9	$204.8	$112.1	$313.9
Emission Savings	$68.0	$27.3	$128.2	$177.2	$66.8	$332.3
Accident Cost Savings	$87.3	$44.0	$136.0	$106.3	$45.1	$184.3
Total Congestion Management	**$1,164.5**	**$546.1**	**$1,884.9**	**$2,626.4**	**$1,225.5**	**$4,314.8**
Grand Total Benefits	**$1,765.8**	**$1,145.9**	**$2,521.5**	**$3,303.8**	**$1,859.4**	**$4,982.5**
Total Costs	**$1,037.7**	**$947.6**	**$1,149.8**	**$1,043.7**	**$950.9**	**$1,162.5**
Net Present Value	**$728.1**	**$72.9**	**$1,494.5**	**$2,260.1**	**$800.2**	**$3,973.7**
Internal Rate of Return	**7.89%**	**4.61%**	**11.29%**	**12.26%**	**8.13%**	**16.48%**
First Year Benefit Cost Ratio	6.04%	4.08%	8.09%	8.05%	4.94%	11.91%
Payback Period (Years)	17	11	26	11	7	15

APPENDIX F: TRANSIT ORIENTED DEVELOPMENT OPPORTUNITIES

See attached: *"Station Area Analysis for the I-71 Corridor LRT, Transit Oriented Development Opportunities"* by Basile Baumann Prost & Associates, Inc.