TCRP

REPORT 167

TRANSIT
COOPERATIVE
RESEARCH
PROGRAM

Sponsored by
the Federal
Transit Administration

Making Effective Fixed-Guideway Transit Investments: Indicators of Success

Volume 1: Handbook

Volume 2: Research Report

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 167

Making Effective Fixed-Guideway Transit Investments: Indicators of Success

Volume 1: Handbook

Volume 2: Research Report

Daniel G. Chatman
Robert Cervero
Emily Moylan
Ian Carlton
Dana Weissman
Joe Zissman
Erick Guerra
Jin Murakami
Paolo Ikezoe
Institute of Urban and Regional Development
University of California, Berkeley
Berkeley, CA

in association with

Donald Emerson
Parsons Brinckerhoff
San Francisco, CA

with contributions by

Dan Tischler
Daniel Means
Sandra Winkler
Kevin Sheu
Sun Young Kwon
University of California, Berkeley
Berkeley, CA

Research sponsored by the Federal Transit Administration in cooperation with the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2014
www.TRB.org

TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), Transportation 2000, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

TCRP REPORT 167

Project H-42
ISSN 1073-4872
ISBN 978-0-309-28405-9

Published reports of the

TRANSIT COOPERATIVE RESEARCH PROGRAM

are available from:

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

and can be ordered through the Internet at

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

COOPERATIVE RESEARCH PROGRAMS

CRP STAFF FOR TCRP REPORT 167

Christopher W. Jenks, *Director, Cooperative Research Programs*
Lawrence D. Goldstein, *Senior Program Officer*
Anthony Avery, *Senior Program Assistant*
Eileen P. Delaney, *Director of Publications*
Sharon Lamberton, *Editor*

TCRP PROJECT H-42 PANEL
Field of Policy and Planning

Sharon Greene, *Sharon Greene & Associates, Laguna Beach, CA* (Chair)
Eric Christian Bruun, *University of Pennsylvania, Philadelphia, PA*
Ron Fisher, *R Fisher Consult, San Francisco, CA*
Gregory Roman Krykewycz, *Delaware Valley Regional Planning Commission, Philadelphia, PA*
Peter C. Martin, *CDM Smith, San Francisco, CA*
Jacob O. Oluwoye, *Alabama A&M University, Meridianville, AL*
Naomi Renek, *New York Metropolitan Transportation Authority, New York, NY*
Wendy P. Stern, *Port Authority of Allegheny County (PA), Pittsburgh, PA*
David Vozzolo, *HDR Engineering, Inc., Alexandria, VA*
Stephen Woelfel, *Massachusetts DOT, Boston, MA*
Patrick Centolanzi, *FTA Liaison*
James Garland, *FTA Liaison*
Chris Nutakor, *FTA Liaison*
Dwayne Weeks, *FTA Liaison*
Rich Sampson, *Community Transportation Association of America Liaison*
Richard Weaver, *APTA Liaison*

FOREWORD

By Lawrence D. Goldstein
Staff Officer
Transportation Research Board

TCRP Report 167: Making Effective Fixed-Guideway Transit Investments: Indicators of Success provides a data-driven, indicator-based model for predicting the success of a fixed-guideway transit project based on expected project ridership and resulting changes in transit system usage. Applying this analytical model can help local, regional, and state transportation planning agencies determine whether a proposed improvement project merits investment in more detailed planning analysis. The analytical model encompasses a spreadsheet tool and a handbook detailing its application. The handbook and final research report make up Parts 1 and 2 of *TCRP Report 167,* and the spreadsheet tool is available separately for download from the report web page at www.trb.org by searching for "TCRP Report 167".

An earlier landmark study, titled *Urban Rail in America: An Exploration of Criteria for Fixed-Guideway Transit* (authored by Boris Pushkarev with assistance from Jeffrey Zupan and Robert Cumella and published by Indiana University Press in 1982), defined corridor-level conditions deemed sufficient to generate threshold levels of passenger volume and therefore able to support different types of fixed-guideway investment. This study also offered an initial assessment of the nationwide potential for fixed-guideway facilities, focusing on local planning requirements for promising locations. Since the release of *Urban Rail in America,* numerous research efforts have continued to assess conditions necessary and sufficient for successful performance of different types of fixed-guideway investments. In addition, new systems have been constructed that were not addressed in the original study and new transit modes, policy issues, and analytical tools have emerged. As a result, it was determined that a fresh look at the concepts and approaches originally addressed in *Urban Rail in America* and subsequent research would contribute substantially to an informed planning process. The need for this review and re-evaluation provided a framework for identifying effective indicators to support local, regional, and federal decision-making applied to consideration of fixed-guideway transit investment projects.

Under TCRP Project H-42, the University of California at Berkeley conducted research to (1) identify conditions and characteristics necessary to support alternative fixed-guideway transit system investments and (2) provide guidance on evaluating proposed investments based on these conditions and characteristics. To meet these objectives, the research team first identified and defined indicators of fixed-guideway transit system success. In support of the indicator-based approach, the research team developed a geographic database of fixed-guideway transit projects built in the United States between 1974 and 2008, collected at the metropolitan, corridor, and station-area levels, as well as details about routes and stops of nearly all fixed-guideway transit systems in the United States. An additional data set used as input contained demographic and physical characteristics of affected communities and transit projects. Two different sets of statistical models correlated these data to both project-level ridership and to system-wide passenger miles traveled (PMT). A comprehensive literature review and a set of detailed case studies were also used to help formulate and test the analytical model.

The product of this research includes the handbook, the spreadsheet tool, and a comprehensive report of the study process. The comprehensive report includes the detailed literature review, a presentation of the conceptual framework for the analytical model, a summary of the quantitative analysis methods and findings, and an overview of the case studies used to formulate and test the analytical model. The final research report also includes a set of appendices that present the data used in the analysis.

CONTENTS

SUMMARY

Making Effective Fixed-Guideway Transit Investments: Indicators of Success

Fixed-guideway transit projects, such as urban rail and bus rapid transit (BRT) lines, are among the largest infrastructure investments that cities and metropolitan areas make. With capital costs ranging from tens of millions to several billion dollars, decisions on whether to build a fixed-guideway transit project, and what kind of project to build, are not taken lightly by local officials or their funding partners. Such decisions may follow many years of planning and analysis at the system, corridor, and project levels. It can cost millions of dollars just to develop and apply the analysis tools that are typically used to evaluate alternative projects.

TCRP Project H-42, "An Exploration of Fixed-Guideway Transit Criteria Revisited," was undertaken to develop a relatively sophisticated, data-driven, indicator-based method for predicting the potential success of a fixed-guideway transit project. The goal was to develop a method that would predict the likelihood of project success based on the conditions present in the corridor and the metropolitan area. The project was partly intended to define success measures. For this research, success measures were defined based on project ridership and the change in transit system usage, and a set of indicators was identified that are strongly related to these measures based on an intensive data collection and statistical analysis process.

Background

To develop a basis and context for the analysis, the research team

- Reviewed literature on the connection between a transit project's success (such as ridership) and the characteristics of its service, measures of its connectivity, and features of the surrounding area;
- Evaluated factors that have been studied in the past in both defining and predicting transit success, particularly system ridership, as well as the tools used to measure and evaluate those factors;
- Catalogued data sources from which a research database could be built; and
- Conducted focus groups and interviews with transportation professionals to identify the factors that practitioners use to evaluate and predict the success of transit investments in real-world situations.

Analysis

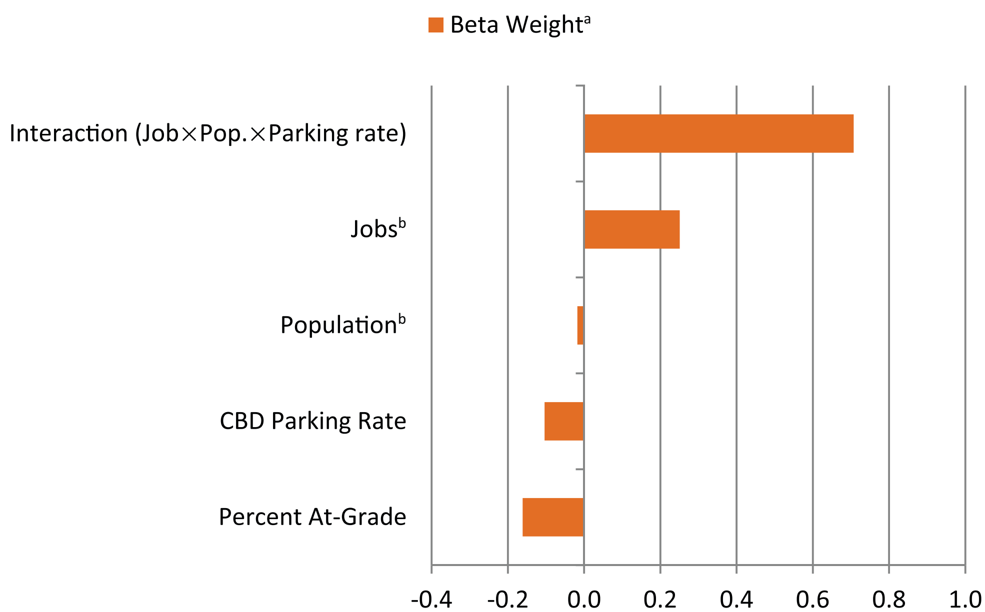
The research team developed a geographic database of fixed-guideway transit projects built between 1974 and 2008, the corridors and stations where they operate, and the metropolitan areas they serve, as well as the routes and stops of almost all fixed-guideway transit systems in the United States. The team collected data on project and system ridership capital cost, service frequencies, measures of connectivity to the larger transit network, regional and local demographics, and the relative costs of driving in terms of parking and congestion.

The project team created two data sets. The project data set included 55 projects, primarily heavy rail transit (HRT) and light rail transit (LRT), with small numbers of commuter rail (CR) and BRT investments. The projects were either entirely new fixed-guideway systems (i.e., starter lines), expansions of a system through new corridors and services, or extensions of existing transit lines. The researchers also created a metropolitan statistical area (MSA) data set consisting of 244 MSAs across the United States where transit operates; 18 MSAs in this data set have some form of fixed-guideway transit.

Using these data sets, the research team developed statistical models to predict two success metrics: the average weekday ridership on the project, and the change in annual passenger-miles traveled (PMT) for all transit in the metropolitan area including bus and rail. The researchers aimed to develop simple yet highly explanatory models and tested a large number of variables before settling on the final set of factors that best explain ridership and PMT change.

Project Ridership Model

The project team tested how the average daily ridership on a project was affected by hundreds of measured factors. The purpose of this part of the analysis was to provide further information about which factors are consistently associated with higher ridership on new fixed-guideway transit investments. As shown in Figure S.1, the researchers found that employment and population near stations, the cost of parking in the central business district (CBD), and grade separation were highly influential—more so than many other measures that might be thought to have strong influences, such as the walk score near stations, whether the project is located in the CBD, or even the size and accessibility of the existing transit network. The fit of the model was high, as shown in Figure S.2. Previous research



[a]The beta weight, or *beta value*, reflects the relative explanatory power of a variable in predicting ridership.
[b]Measured within 1/2 mile of project station.

Figure S.1. Influence of variables for ridership.

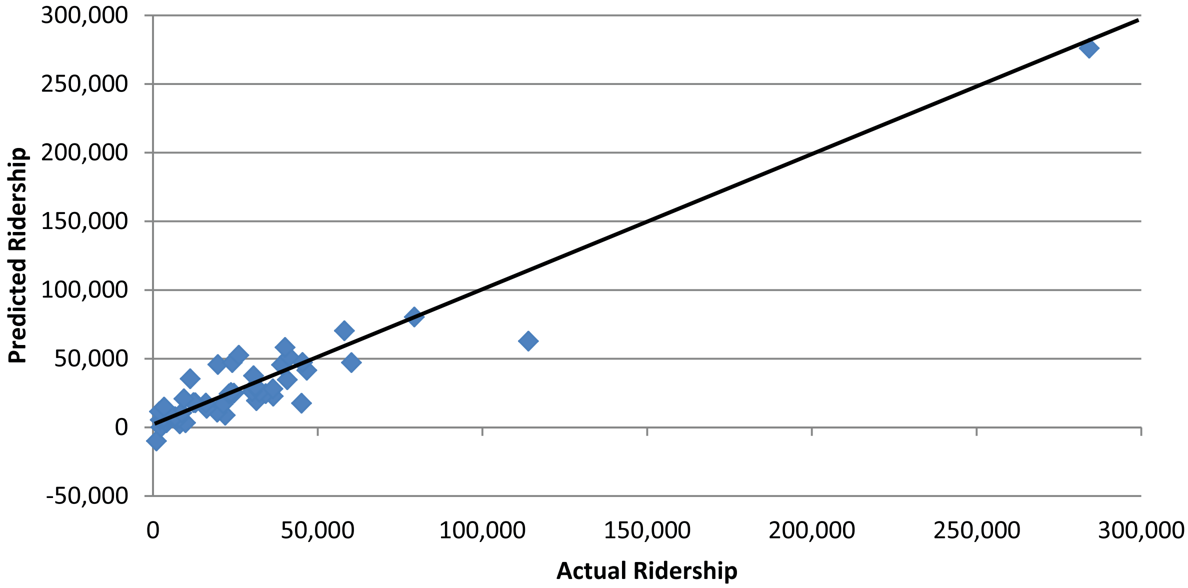


Figure S.2. Goodness of fit for ridership model.

had not compared the relative importance of these factors. The degree of grade separation is likely influential because it serves as a proxy for service variables such as speed, frequency, and reliability that may lead to greater transit ridership. By far the largest impact on project-level ridership came from the interaction of jobs and residents near stations, and parking cost in the CBD. In other words, the fixed-guideway transit investments with the greatest ridership were those that enabled good connections between workers and employers, and between customers and sellers, in cities where commuting by car was expensive.

Metropolitan Area Model of Transit Passenger-Miles Traveled

Next, the study team tested how metropolitan-wide transit passenger-miles traveled (PMT) was related to hundreds of possible indicators, using a data set of 244 MSAs over a 7-year period. Of this large set of metropolitan areas, 18 had a fixed-guideway transit investment come online during the period, and an additional 10 had some form of fixed-guideway transit available throughout the period. The PMT measure, which included both rail and bus passenger-miles, was used to investigate the net benefit of fixed-guideway transit investments to the transit system as a whole.

Jobs, population, and other indicators were measured near all fixed-guideway transit stations in the metropolitan area, not only near project stations. The researchers also tested indicators consisting of characteristics of the metropolitan area as a whole. To estimate the incremental PMT for each project (i.e., the contribution of that project to the overall system usage), the model was applied for every project in the database study set twice—with project-level contributions both included and then subtracted from the total for all stations in the metropolitan area.

As shown in Figure S.3, the presence near stations of higher-wage workers, and also of jobs in leisure industries such as dining, retail, and entertainment, were both highly correlated with system-wide increases in PMT. This likely reflects the positive influence of fixed-guideway transit that serves choice riders, as well as mixed-use environments around stations. Also, the interaction between jobs, population, and freeway congestion has a positive influence.

[a]Measured within 1/2 mile of all fixed-guideway transit stations in the metro area

Figure S.3. Influence of variables in PMT model.

Unexpectedly, lower-wage jobs and population near stations both contribute negatively to system-wide PMT if not counterbalanced by high freeway congestion and a range of other job types. After exhaustive testing of the models to account for possible additional missing factors, the researchers concluded that the results are robust though somewhat counterintuitive. As shown in Figure S.4, the fit of the model is excellent.

In about half of all cases, the PMT model predicts negative changes in system-wide patronage when a fixed-guideway transit investment is made. This prediction seems counterintuitive, but fixed-guideway investments may in some cases reduce ridership on existing bus services, more than offsetting the number of new riders. In particular, this could occur if pre-existing bus routes are converted to feeders with a transfer, and if the fixed-guideway investment is made in a place without high road congestion to provide a stronger market.

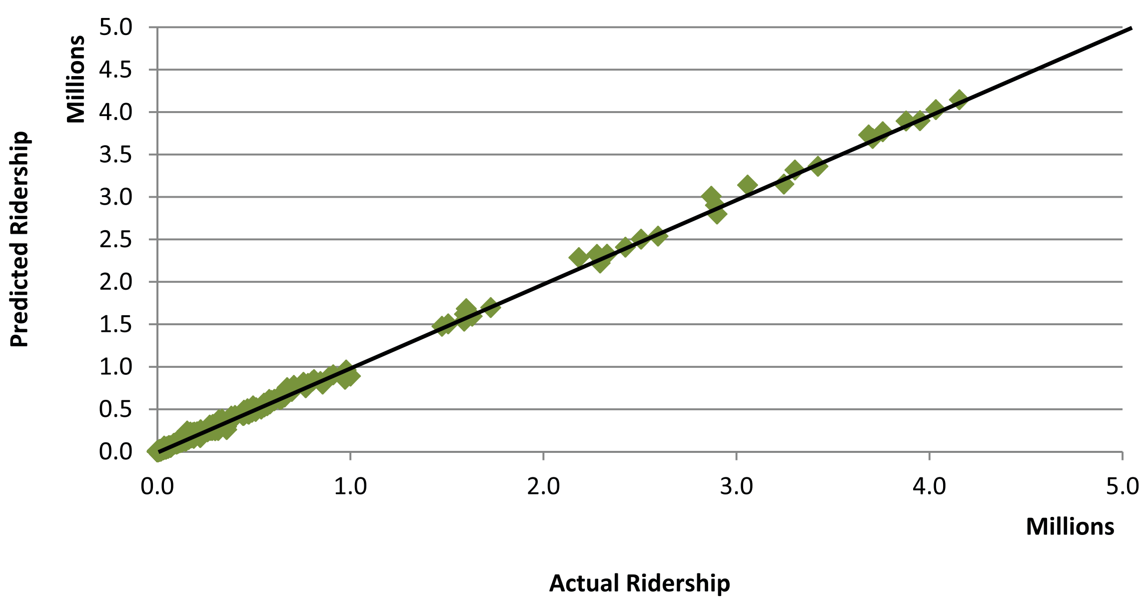


Figure S.4. Goodness of fit of final PMT model.

Case Studies

The research team conducted case studies of diverse transit projects in six metropolitan areas to gain an understanding of how transit planning decisions had been made and the nature of any indicator-based evaluations that had occurred. The indicator-based method proposed in this study would be situated within an already-robust set of indicator-based approaches. Though the transit planning literature often focuses on predicting project success based on specific technical planning approaches and sophisticated planning tools, such as four-step transportation models, the researchers identified almost 20 different simple criteria—rules of thumb—used by planners to predict if a transit proposal would be successful.

According to interviewees, during the planning of each fixed-guideway transit project, various indicator-based methods were used to propose transit alignments, compare and contrast project alternatives, or justify the selection of a particular proposal. The indicators addressed project-level goals related to ridership, environmental sustainability, real estate impacts, economic development, bus operations, automobile congestion, serving dependent riders, and overcoming common project delivery hurdles. The indicator methods were useful tools to address the interests of various groups, balance conflicting objectives, and work around the limitations of more robust technical analyses. When explaining their use of indicator-based methods, multiple interviewees stated that transit planning was an art and a political process, not a science. Though not always technically complex, the rule-of-thumb methods helped transit planners address the immense complexity of designing and building transit projects. The indicator-based method proposed in *TCRP Report 167* balances simplicity with technical accuracy, and could be used to augment these existing approaches in many cases.

Tools for Practitioners

The researchers developed a spreadsheet tool incorporating the project-level ridership model and the system-wide PMT model along with a simple capital cost calculator. The spreadsheet tool allows the user to input data about a proposed project and generate estimates of average weekday ridership, incremental PMT, capital cost per new rider, and capital cost per mile. The spreadsheet tool is available for download from the *TCRP Report 167* web page, which can be accessed at www.trb.org by searching "TCRP Report 167".

A handbook also was written to accompany the final report of TCRP Project H-42. The handbook provides a user-friendly overview of the research project and gives instructions on using the spreadsheet tool to estimate region-wide and project-level ridership outcomes for different fixed-guideway project alternatives. The handbook is presented as Volume 1 of *TCRP Report 167,* and the TCRP Project H-42 Final Report, together with technical appendices A through J, constitutes Volume 2.

VOLUME 1

Handbook

Contents

SECTION 1

Overview

1.1 Introduction

Fixed-guideway transit projects, such as urban rail and bus rapid transit (BRT) with dedicated lanes, can be among the largest infrastructure investments that cities and metropolitan areas face. The capital costs of these projects can range from tens of millions of dollars to several billion dollars. The operating and maintenance costs over many years can be substantial as well. Thus, decisions on whether to build a fixed-guideway transit system and what type of system to build are not taken lightly by local officials or their funding partners. Such decisions may follow many years of planning and analysis at the system, corridor, and project levels. Developing and applying the analysis tools that are typically used to evaluate alternative investments can cost millions of dollars.

Is your proposed transit project likely to be successful? Can you know before investing time and money into detailed studies?

This handbook is a product of Transit Cooperative Research Program (TCRP) Project H-42, which sought to

- Identify conditions and characteristics typically associated with successful fixed-guideway transit system investments, and
- Provide guidance on evaluating proposed investments based on these conditions and characteristics.

This handbook offers an analytical framework and a set of tools to determine whether a corridor may be suitable for investment in a fixed-guideway transit system. This handbook

- Offers examples of indicator-based methods applied in transit planning studies;
- Identifies those factors that, when present in a corridor, seem to be the strongest indicators of a project's potential success; and
- Introduces and provides guidance on a spreadsheet tool to apply the indicator method.

This handbook and accompanying spreadsheet tool will help you evaluate whether the conditions in your corridor are right for a successful fixed-guideway project.

The tools in this handbook will help you decide whether to invest in more detailed studies.

This handbook is intended to be useful to city, county, and regional decision-makers as well as transportation planning practitioners who are interested in conducting an initial assessment to determine whether a proposed transit project has potential, to evaluate a range of alternative fixed-guideway transit investments, or to compare different alignments for a proposed investment. It will help provide answers, at a conceptual planning level, to such questions as:

- Which corridors in our region offer the best opportunity for developing fixed-guideway transit?
- What alternative modes and alignments appear to be the most promising in a particular corridor?
- How might changes to local land use and other policies affect a corridor's potential for fixed-guideway transit?

This handbook and the TCRP Project H-42 Report (see Volume 2) serve to update and extend research by Boris Pushkarev, Jeffrey Zupan, and R.S. Cumella in the late 1970s (*1*). Their 1982 book, *Urban Rail in America*, has been widely used as a guide for identifying the type of transit investment that might be appropriate in a corridor based on development density and other conditions (*2*).

Transit systems built over the past several decades offer considerable data that can be used to evaluate a proposed project's potential to be successful.

In the 30 years since *Urban Rail in America* was published, there have been dramatic changes in metropolitan area development patterns, the work force, economic conditions, and gasoline prices, as well as a renaissance in transit. The American Public Transportation Association (APTA) reports that there are now 27 commuter rail transit systems, 15 heavy rail transit (subway) and 35 light rail transit systems in the United States. In addition, bus rapid transit (BRT) has been adopted in several municipalities as a new alternative to traditional transit modes, allowing communities historically priced out of rail technology to develop cost-effective transit networks. As of 2013, APTA counts five fixed-guideway BRT systems in the United States. Since 1980, ridership on U.S. commuter rail, heavy rail, and light rail systems has grown from 2.52 million to 4.47 million trips per year, while passenger miles on these modes have grown from 17.5 million to 29.5 million (*3*). These systems offer considerable data that enable a more complete analysis of the determinants of project success, which can be instructive for the analysis and development of future transit investments.

In addition, developments in research methods, more readily available land use and transportation data, and ubiquitous computing and geographical information system (GIS) technology have advanced our ability to analyze the effects of a host of different factors on transit performance. This research benefits from these advances.

The methods offered in this handbook will not provide final answers on whether or not a community should invest in transit, or what type of transit to build. However, these tools can help local governments decide whether a proposed project merits investment in more detailed planning analyses.

Photo courtesy of METRO

Figure 1: Phoenix LRT

Voters in Maricopa County showed their support for building a total transit network by approving regional transportation funding in 2004. As a result, in 2008 METRO began operation of the $1.4 billion, 20-mile light rail line in Phoenix, Tempe, and Mesa.
In September 2012, there were 50,000 boardings per weekday, exceeding the system's 20-year ridership projection in less than 4 years.

1.2 What Is Transit Project Success?

A challenge in predicting the success of a fixed-guideway project is defining what "success" means. Project goals vary by region, by city, and by corridor, and can be broad and multi-faceted. Standards that might be used to classify completed projects as highly successful, moderately successful, or unsuccessful simply do not exist. As a part of the research, a focus group and several interviewees—comprising transportation practitioners and academics—were asked to help define success, yielding a range of responses (see sidebar) but no definitive answer to the question, "What is success?"

From an economics standpoint, a successful project is one whose benefits exceed its costs. Yet a full accounting of a transit project's direct and indirect costs and benefits is analytically challenging. Many of the benefits and externalities—such as a transit project's contribution to making a city more livable—are difficult to quantify or value in dollar terms.

During the planning process, proposed fixed-guideway transit projects are often evaluated by comparing their costs and transportation benefits with those of lower-cost alternatives. Relative comparisons in terms of cost effectiveness can be more manageable because they do not depend on a full accounting of all costs and all benefits. For example, if the same level and quality of transit service can be provided less expensively by bus than by rail, then

When asked how to determine the success of a fixed-guideway transit project, members of a focus group and other interviewees responded:

"Corridors and projects are different. I suggest you look at a typology of corridors first, then look at measures of success."

"Circulators and line haul facilities, for example, have very different purposes."

"Success metrics ought to depend on the market and what you're trying to do—not just the mode."

"Elected officials seem to care most about the number of riders."

"My agency would say they didn't have any failures—our rail projects have all been successful."

Figure 2: Cleveland HealthLine BRT

Photo courtesy of GCRTA

The Greater Cleveland Regional Transportation Authority (GCRTA) considers its $200 million HealthLine Bus Rapid Transit (BRT) to be a success because:

- *It has led to a 75 percent ridership increase in the corridor.*
- *After six months, the HealthLine had a customer approval rating of more than 90 percent.*
- *More than $4 billion in development has occurred near the project.*
- *The project has received numerous awards.*

the rail alternative may not be the most cost-effective way to achieve these transportation benefits. The success of a completed project might also be assessed by considering how fully it meets the ridership forecasts and other goals it was intended to achieve.

Transit projects are undertaken for a range of reasons. Success comes in many forms and is inherently difficult to define.

Our focus groups, interviews, and case studies confirmed that the goals of fixed-guideway projects are many and varied. For example, the motivations for building an urban circulator system within a central business district (CBD) might be to enhance access, or to help make the area more attractive for development, while the reasons for building a rail line extending far from downtown might be to offer people an alternative to driving on congested roadways, or to improve transit speed and reliability.

A person's view of a project's success may also depend on his or her perspective. A transit agency general manager or board of directors may define success differently than a transit rider, a taxpayer, or a funding partner. Some suggest that a project is successful if it results in widespread support for expanding the system.

Identifying a comprehensive and widely acceptable definition of success proved to be elusive. Thus, as further discussed in Section 2.3, this research focused on measures of success that can be quantified and that generally correspond with a range of project goals: project-level ridership, changes in system-wide transit use, and project-level cost. Though incomplete as a measure of success, the expected ridership on the project and the expected effect on the system's usage as a whole, in combination with the expected cost of the project, provide valuable information to help establish a corridor's potential for fixed-guideway transit.

Users of this handbook will be able to determine, relatively quickly and easily, whether the conditions that are typically associated with transit ridership exist or do not exist within their region or corridor. Users can develop a range of potential ridership forecasts without the use of complex travel demand forecasting models, and then balance the ridership benefits against the costs of achieving them. Proposed projects can be compared with similar fixed-guideway projects built across the United States in terms of ridership and cost per rider.

For projects driven by land use and economic development goals, *TCRP Report 16: Transit and Urban Form* (*4*), provides additional insight into measuring project success.

1.3 TCRP Project H-42 Research Summary

The research upon which this handbook is based was sponsored by the Transit Cooperative Research Program (TCRP) and performed by a team at the University of California at Berkeley, with assistance from Parsons Brinckerhoff. As part of the research, the team completed the following tasks:

- Reviewed prior research and available data to identify ways that transit system success is measured.
- Conducted two rounds of focus groups and interviews with transit professionals in the public and private sectors and in academia.
- Prepared a preliminary list of transit investment success measures and possible indicators of that success.
- Compiled and assembled a dataset of fixed-guideway transit stations and networks in the United States, covering 3,244 transit stations in 27 metropolitan areas. Data collected at the station, investment, and metropolitan area levels included system and station ridership, agency operating costs, project capital costs, regional and local demographics, employment, gross metropolitan product, gas prices, parking availability and pricing in downtowns and in private lots, restrictiveness of land use regulations, rail and highway networks, and transit service characteristics.
- Conducted regression analyses to identify corridor, network, and metropolitan area factors that are most significantly correlated with project-level ridership and system-level passenger-miles traveled (PMT).
- Conducted case studies of transit projects in six different U.S. metropolitan areas, reviewing public reports and other materials, conducting site visits, and interviewing transit planners, metropolitan planning organization (MPO) officials, and consultants who worked on the projects.
- Developed a spreadsheet tool, using coefficients produced by the regression analyses, which can provide initial predictions of ridership, PMT, and capital cost.

This handbook is based on analysis of data from 27 U.S. metropolitan areas and the input of transit professionals from the public and private sectors and academia.

Details on the research are provided in the Research Report, which is included as Volume 2 in *TCRP Report 167* (*5*).

SECTION 2

The Indicator-Based Method

2.1 Goals of the Indicator-Based Method

Indicators are characteristics of the corridor and the proposed transit service.

Indicators are characteristics of a corridor and a proposed project that may affect the project's success. As discussed in Section 1 and in more detail in Section 2.3, for the purposes of this handbook, success is defined primarily in terms of producing sufficient project-level and system-level ridership to justify the cost of the project.

The indicator-based method offers a simplified way to analyze the potential success of a proposed fixed-guideway transit project in a particular corridor, given a certain set of corridor conditions and assumptions about the project. While not meant as a substitute for more detailed planning methods and analysis, the indicator-based method can be useful for conducting an initial evaluation of corridors and fixed-guideway transit alternatives. For example, local agencies might use this method to

This approach is useful for conducting initial assessments of potential projects and corridors.

- Assess whether it is worthwhile to expend funds on detailed project planning studies,
- Compare various corridors within a region to see which offers the greatest potential for a transit investment,
- Test various project and land use scenarios within a particular corridor to identify those that deserve more detailed study, or
- Advocate for changes in transit service and land use policies that would enhance transit ridership.

2.2 Previous Applications of Indicator-Based Methods

Planners have used indicator-based methods to evaluate transit opportunities for many years. A few such methods are described in this section, followed by a description of the method developed in this study. The method developed in TCRP Project H-42 differs from other indicator-based methods in that it generates estimates of project ridership and change in system-level patronage based on statistical analysis, using data from fixed-guideway systems built over the last 40 years. It is more quantitative than other indicator-based methods that use a limited number of somewhat subjective factors, yet it produces a ridership forecast without relying on complex regional travel demand forecasting models.

In 1976, New York's Regional Plan Association suggested certain transit mode suitability criteria based on density (Table 1) (*6*).

Table 1: Transit Mode Suitability Criteria by Regional Plan Association

Transit Vehicle Mode	Minimum Downtown Size, Square Feet of Contiguous Non-Residential Floor Space (millions)	Minimum Residential Density, Dwelling Units per Acre
Local Bus	**2.5**	**4 to 15***
Express Bus	**7**	**3 to 15***
Light Rail	**21**	**9**
Heavy Rail	**50**	**12**
Commuter Rail	**70**	**1 to 2***

**Varies with type of access and frequency of service*

Source: Regional Plan Association, Where Transit Works: Urban Densities for Public Transportation. *New York, 1976.*

The Regional Plan Association's recommendations were followed by Pushkarev and Zupan's research, leading to *Urban Rail in America* several years later. Pushkarev and Zupan recommended a set of minimum threshold residential densities that would support various levels of service across different modes. Larger CBDs and higher residential densities along corridors were found to support higher levels of transit service. Pushkarev and Zupan found that the success of a transit system depends on other factors as well, including, "its service and its price, [and] the availability, convenience, and price of the competing mode—the automobile." (*1*)(*2*)

Pushkarev and Zupan found that the density of residents along a corridor and the amount of non-residential development in the CBD were significant indicators of ridership, while noting that other factors also contribute to transit project success.

Table 2: Transit-Supportive Density Levels adapted from Pushkarev and Zupan *(1)*

Mode: Service	Minimum Units-per-Acre Thresholds	CBD Size
Local Bus: Minimum (20 buses/day)	4	10 million non-residential CBD s.f.
Local Bus: Frequent (120 buses/day)	15	35 million non-residential CBD s.f.
Light Rail: 5-minute peak-hour headways	9 (corridor of 25 to 100 square miles)	20 to 50 million non-residential CBD s.f.
Heavy Rail Rapid Transit: 5-minute peak-hour headways	12 (corridor of 50 to 100 square miles)	50+ million non-residential CBD s.f.
Commuter Rail: 20 trains/day	1 to 2	Only to largest downtowns

Today, transit planners rely on guidelines such as these when they develop system plans, identify potential new transit corridors and routes, and decide how to allocate available funds.

One example is *A Toolbox for Alleviating Traffic Congestion,* published by the Institute for Transportation Engineers (ITE) in 1989. The report offers general guidelines as follows:

- Light rail transit is most suitable for service to non-residential concentrations of 35 to 50 million square feet. If rights-of-way can be obtained at grade, thereby lowering capital costs, this threshold can be lowered to the 20 million square foot range. Average residential densities of about 9 dwelling units per acre over the line's catchment area are most suitable. For longer travel distances where higher speeds are needed, rapid transit is most suitable for non-residential concentrations beyond 50 million square feet and in corridors averaging 12 dwelling units per acre or more.
- Commuter rail service, with its high speed, relatively infrequent service (based on a printed schedule rather than regular headways) and greater station spacing is suitable for low density residential areas—1 to 2 dwelling units per acre. However, the volumes required are only likely in corridors leading to non-residential concentrations of 100 million square feet or more, found only in the nation's largest cities. (*7*)

As shown in Table 3, the San Francisco Bay Area's Metropolitan Transportation Commission (MTC) has adopted a set of housing density thresholds by transit mode that projects are expected to meet before the MTC programs funds (*8*). According to the MTC's Resolution 3434, "Each proposed physical transit extension project seeking funding through Resolution 3434 must demonstrate that the thresholds for the corridor are met through existing development and adopted station area plans that commit local jurisdictions to a level of housing that meets the threshold."

Table 3: Housing Density Thresholds, MTC, San Francisco Bay Area

	BART Heavy Rail Transit	Light Rail Transit	Bus Rapid Transit	Commuter Rail	Ferry
Housing Threshold (Average Housing Units per Station Area)	3,850	3,300	2,750	2,200	750

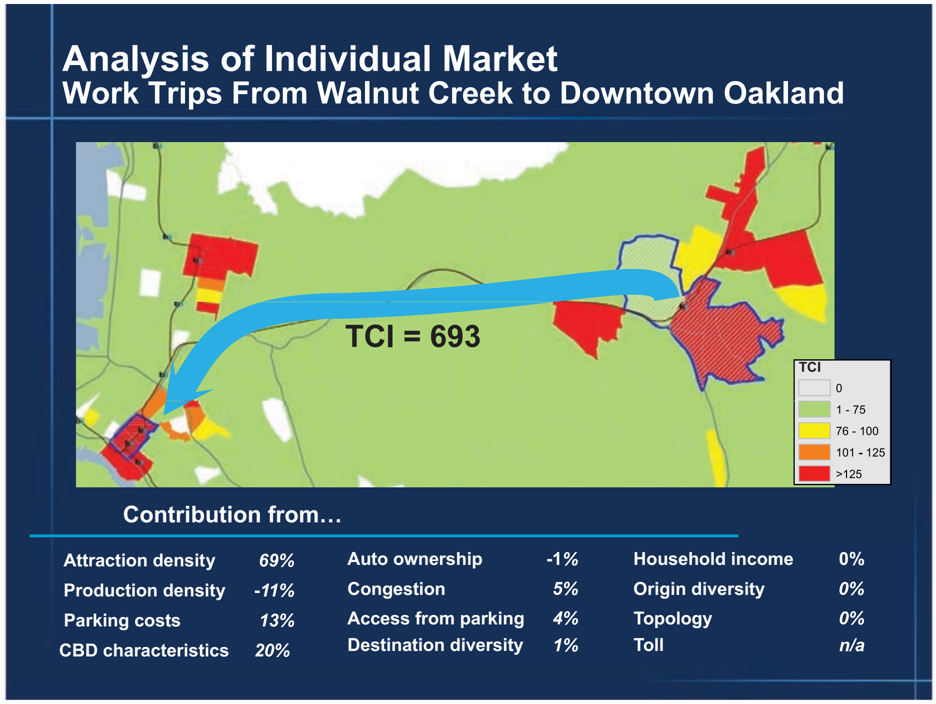
Source: MTC Resolution 3434, Attachment D-2, *as revised July 27, 2005*

The Utah Transit Authority calculates a Transit Preparedness Index to identify those parts of its service area that have the characteristics to support a successful transit investment. The index relies on five criteria to identify the best places in the region for improving transit service:

1. Transit-oriented development (TOD) or mixed use zoning (up to 40 points),
2. TOD or mixed use in general plan (up to 10 points),
3. Bike/pedestrian plan (up to 10 points),
4. Amenity Proximity Score based on walkscore.com (up to 10 points), and
5. Intersection Density based on walkscore.com (up to 30 points).

Indicators are generally evaluated in combination to provide a more complete picture of an area's readiness for fixed-guideway transit.

Figure 3: Use of the Transit Competitiveness Index by MTC

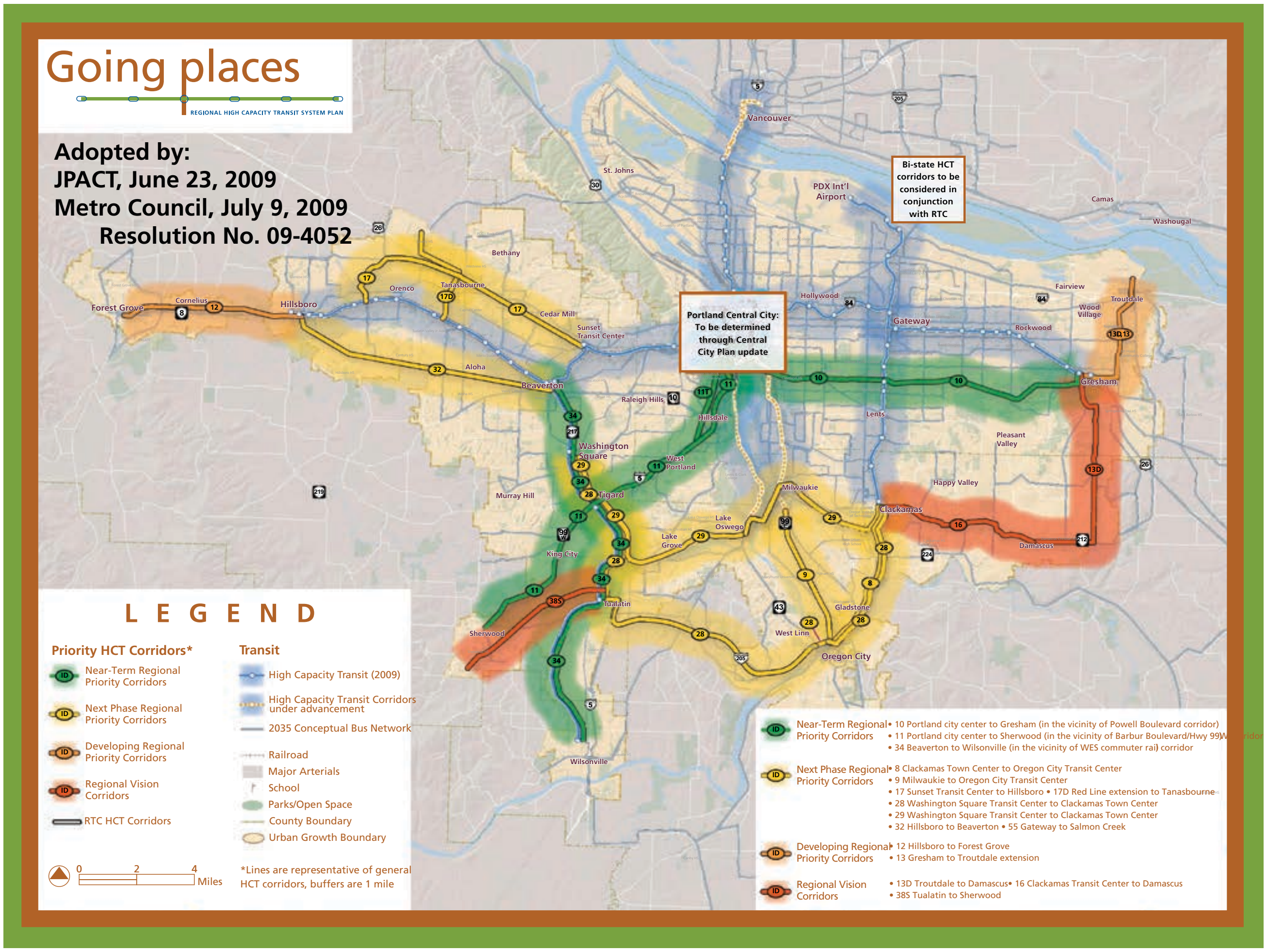


Source: San Francisco MTC and Cambridge Systematics, Inc.

Consulting firms have developed proprietary indicator-based tools such as the Transit Competitiveness Index (TCI) (*9*). This tool, depicted in Figure 3, offers a way to score different travel markets in terms of how well transit is likely to compete with the automobile. The TCI accounts for various transportation and land use characteristics—trip volumes, land use density, parking cost, and congestion—along with trip purpose and household characteristics to produce a numeric score. Depending on the score, individual markets are characterized as strongly competitive, marginally competitive, marginally uncompetitive, and uncompetitive. Further information is available at:

http://www.mtc.ca.gov/planning/tsp/TCI-DRAFT-PRIMER.pdf

Figure 4: Setting Transit Corridor Priorities in Portland



Source: Metro, used by permission

When developing the Regional High Capacity Transit System Plan for metropolitan Portland, the region's MPO (known as Metro) used an online "build-a-system" questionnaire to solicit public input. The results told decision-makers that residents wanted ridership potential to be the main factor in deciding corridor priority.

Metro, the MPO for the Portland, Oregon, region, applied an interactive web-based "build-a-system tool" as part of the public involvement process for its High Capacity Transit System Plan (Figure 4). According to the plan,

> [The] tool allowed community members to explore trade-offs between corridors and build their own high capacity transit system. With the build-a-system tool, community members learned about centers that could be served by high capacity transit and to compare corridors based on ridership, travel time, operations cost, capital cost, and environmental benefits. (*10*)

Metro's tool is more fully described at:

http://www.oregonmetro.gov/index.cfm/go/by.web/id=26680

The six case studies documented in the TCRP Project H-42 final report identified a number of other rules of thumb used to evaluate fixed-guideway transit projects (Table 4). Several of these relate to ridership, and some are specifically meant to consider either *choice* or *dependent* ridership. Others relate to the potential for economic development and real estate impacts, and to the potential to complete projects within a finite budget.

Though not technically complex, the rule-of-thumb methods helped transit planners address the immense complexity of designing and building a transit project. The case studies, summarized in Volume 2 of *TCRP Report 167* (*5*), illustrate several balancing acts among various interest groups, among conflicting objectives, and between technical analysis and heuristic evaluations.

In addition to analyzing quantifiable indicators, transit agencies consider various rules of thumb in developing transit systems.

Table 4: Success Indicators from TCRP Project H-42 Case Studies

Criterion (Rule of Thumb)	Measure of Project Success	Charlotte	Dallas	Eugene	Portland	Salt Lake City	D.C./MD
Provide fixed-guideway transit where bus ridership is already high	Ridership / Consolidated bus operations		●	●	●	●	●
Select high-visibility corridors where patrons will feel safe	Ridership				●		
Connect CBD with suburban park-and-rides near a congested belt loop	Ridership / Sustainability / Congestion relief / Consolidated bus operations	●	●				●
Minimize stations to maximize speed	Ridership / Sustainability / Congestion relief	●		●			
Minimize grade crossings and in-street operations to maximize speed	Ridership / Sustainability / Congestion relief	●	●	●	●		●
Provide fixed-guideway transit in corridors where parallel highway infra-structure is heavily congested	Ridership / Sustainability / Congestion relief	●	●		●		
Connect multiple employment centers	Ridership / Sustainability / Congestion relief		●	●		●	●
Connect major regional destinations	Ridership / Economic development			●	●	●	
Place alignment in close proximity to commercial property	Ridership / Economic development				●	●	
Place stations in busy locations where "eyes on the street" provide sense of safety	Ridership				●		
Provide service that has average travel speeds greater than existing bus routes	Ridership / Consolidated bus operations	●	●			●	●
Provide transit in high-demand travel corridors where alternative capacity is prohibitively expensive	Economic development	●	●		●	●	
Maximize the number of stations	Economic development / Real estate values	●		●	●		●
Place alignment along corridors with ample development potential to fa-cilitate urban growth as described by local land use plans or regional plans	Real estate values	●		●	●	●	
Provide fixed-guideway transit in corridors where inexpensive right-of-way can be easily accessed	Construction completion / Minimized impacts	●	●	●	●	●	●
Maximize distance between alignment and single family neighborhoods; Minimize taking of residential property	Minimized impacts / Public support	●		●	●		●
Identify corridors that can help garner local political support for further transit system investment	Public support	●		●			●
Select corridors that garner congressional support	Public support	●			●		●
Locate stations in low income areas or in communities of color	Dependent riders / Economic development			●	●		●
Provide substantial bus layover facilities at stations	Consolidated bus operations		●			●	●

2.3 Ridership as a Proxy for Project Benefits

Ridership was chosen as the primary measure of project benefit in the TCRP Project H-42 research. When a new transit project is proposed, one of the first questions people ask is how many people will use it. Once a project opens for service, often the first question asked is whether the forecast levels of ridership were achieved. Transit projects are often deemed to be successful when their forecast ridership level is met.

Ridership is a useful proxy for a wide range of transit project benefits.

Ridership is a useful proxy for a wide range of transit project benefits. Those who ride on a new transit line are likely to directly benefit in one way or another. Existing transit riders—such as people who previously took the bus but who now ride the new fixed-guideway system—may benefit from faster travel time, improved reliability, or greater comfort. New riders—those who started using transit only when the project opened—offer another measure of the project's mobility/accessibility benefits. New riders might be people who previously commuted by car but who switched to the new transit line upon realizing that it offered them travel time or other benefits. Changes in ridership can also serve as a measure of reductions in congestion, air pollutant emissions, and energy consumption. To some degree, ridership can also be viewed as a proxy for land use and economic development benefits. A project that attracts few riders is unlikely to stimulate much development, while projects that do stimulate development are likely to attract additional ridership. For this research, ridership proved to be a convenient indicator of success because transit ridership data are readily available and can be statistically correlated with corridor conditions.

When comparing the transit potential of different corridors, or the potential of different alternatives within a corridor, there are two complementary measures of ridership:

1. Project-level ridership is the number of trips that would be made on a proposed project on a daily basis. Project-level ridership includes both existing riders and new riders attracted to transit.
2. System-wide patronage change is the expected change in system-wide daily passenger-miles traveled (PMT) on transit once the proposed project is in service. System-wide PMT takes into account the greater regional mobility that may occur when a single guideway project links riders into a regional system. System-wide PMT captures the number of new riders and the length of their trips. It does not include existing riders whose trip length on transit does not change, even if these riders benefit from faster travel time. Compared with project-level ridership, the change in system-level PMT offers a better indicator of a project's likely impact on overall highway congestion, emissions, and energy consumption, but it does not indicate how a guideway investment would benefit existing users.

Project-level ridership and system-level PMT are complementary and offer different perspectives on a project's benefits. An urban circulator, for example, may attract a significant number of new riders, many of whom may have walked before. Since circulator trips are typically short, circulators may have little impact on PMT unless they also provide the "last mile" connection that makes longer-distance transit travel more attractive. A commuter rail project with the same project-level ridership as the circulator could have a larger impact on PMT, because commuter rail trips tend to be much longer.

Evaluating both project-level ridership and changes in system-wide passenger miles provides a more complete picture of a project's benefits than one of these measures alone.

The PMT estimate includes all transit travel in the region, including miles traveled on the bus network. A bus rider who simply switches a routine trip to a new, parallel rail line of the same length would not produce any change in PMT. A trip attracted from auto to transit, however, would add to PMT on the transit system. If the new rail line is more direct than the pre-existing bus route, or if it leads to bus service reductions or forced transfers, the PMT increase from new riders could be muted or even offset as riders defect from the transit system.

Figure 5: WMATA Orange Line

Photo courtesy of Arlington County
(markings by Kaid Benfield)

In 2008, WMATA's Orange Line carried 79,000 riders per day in Virginia. The line connects concentrated development near the subway stations in Arlington with the District of Columbia, just across the Potomac River. Relatively high residential and commercial densities in Arlington and the District, together with good transit access, contribute to Orange Line ridership and PMT on the Metrorail system. The Orange Line has also played a key role in shaping development in Arlington.

2.4 Research Findings: Indicators of Potential Ridership

Researchers analyzed 55 completed transit projects to find correlations between ridership and more than 140 factors.

The analysis conducted for TCRP Project H-42 considered more than 140 different factors that could possibly influence project-level or system-level ridership. To identify those factors that correlate most strongly with ridership, the researchers conducted regression analyses using data from 55 heavy rail transit (HRT), light rail transit (LRT), and fixed-guideway bus rapid transit (BRT) projects in more than 20 metropolitan areas.

The analysis found several strong and significant predictors of transit ridership, and some surprising results.

Table 5 summarizes the indicators of greatest statistical significance in explaining project ridership and PMT. A full list of the indicators considered in the research, and their value as predictors of success, is presented in the Appendix.

Table 5: Most Significant Indicators of Project Ridership and System-Wide PMT

Indicators of Project Ridership	Indicators of Change in PMT on System
• Employment within one-half-mile of project stations • Population within one-half-mile of project stations • Combination of employment and population within one-half-mile of stations and daily parking rate in the CBD • Percent of the project alignment at grade	• Metropolitan area population • Employment density within one-half-mile of fixed-guideway stations in the metropolitan area • Population density within one-half-mile of fixed-guideway stations in the metropolitan area • Higher wage jobs within one-half-mile of fixed-guideway stations in the metropolitan area • Average congestion in the metropolitan area (daily vehicle-miles traveled (VMT) per freeway lane-mile) • Retail, entertainment, and food jobs within one-half-mile of fixed-guideway stations in the metropolitan area • Interaction of jobs and population within one-half-mile of fixed-guideway stations in the metropolitan area

Like Pushkarev and Zupan, the researchers for this study found that the amount of population near stations is highly predictive of a proposed transit project's success in attracting ridership. Unlike that previous work, this analysis showed that employment near stations was at least as important as population. More importantly, perhaps, the analysis demonstrated that those projects with the highest ridership have a combination of dense population near stations, dense employment near stations, and relatively high CBD parking costs.

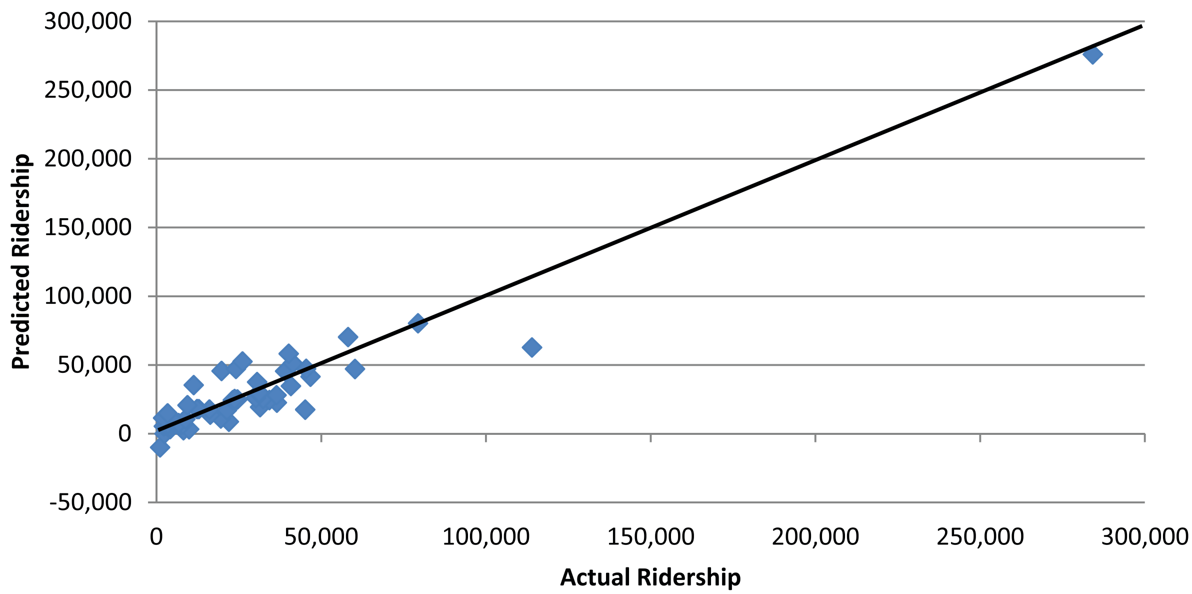
The percentage of the project's alignment that is at grade proved to be a negative indicator of project-level ridership. At-grade projects may be more prevalent in places that are lower in density, while transit is more likely to be grade-separated in places with higher density or land value. Thus, this indicator may be reflective of density. It may also be true that at-grade systems are slower than grade-separated systems. At-grade status may reflect a bundle of operational characteristics such as speed, frequency, and reliability, although the analysis did not find that these factors individually had a statistically significant effect on ridership.

Transit travel speed and frequency were less significant predictors of a transit project's ridership compared to other variables such as density and parking costs downtown. Another surprise related to central business district (CBD) employment. While the number of jobs near stations was an important indicator of ridership, there was no significant difference between jobs within a CBD and other jobs near stations.

Figure 6 illustrates the goodness-of-fit plot for the ridership model in the spreadsheet tool and shows the high predictiveness of the model. The black line represents a perfect match between predicted and actual values; the actual values are tightly clustered around the line.

Transit travel speed and frequency were not found to be the most significant predictors of ridership.

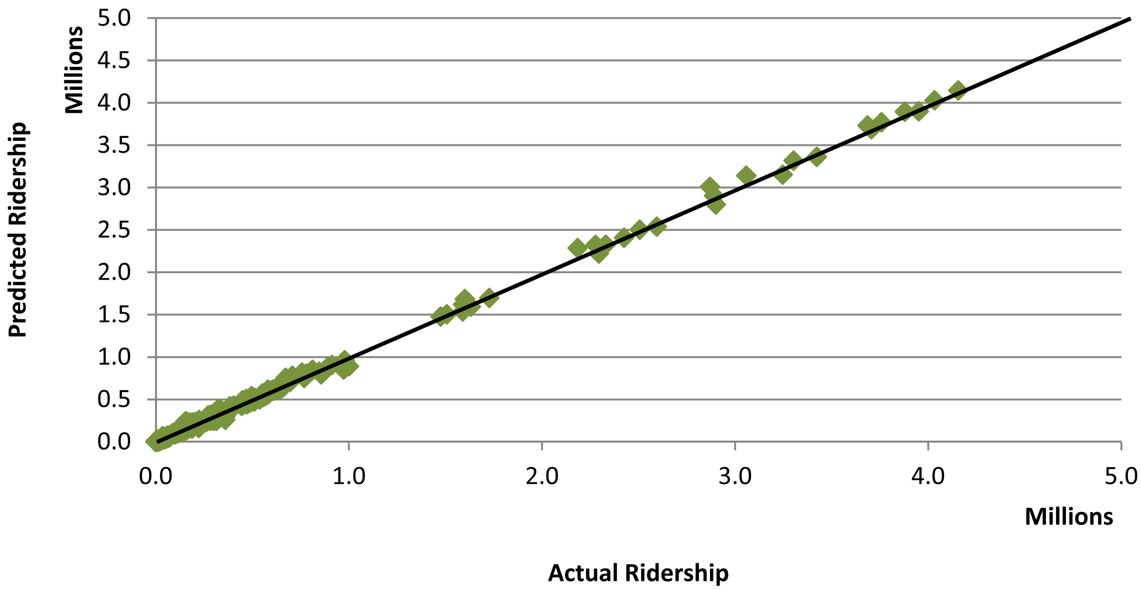
Figure 6: Ridership Model Goodness-of-Fit Plot



In contrast to the ridership model's focus on characteristics of individual projects, the PMT model widens the scope to forecast overall ridership on the full transit system of a metropolitan statistical area (MSA), including all modes and lines. Each MSA is represented by a different data point for each year data was available, for a total of 1,390 observations.

The indicators for system-wide PMT change relate to how the proposed project can affect metropolitan area transit use. Projects in larger metropolitan areas, with a fixed-guideway system in place serving relatively dense populations and employment, tend to see the greatest benefit from incremental additions to the system. The number of retail, entertainment, and food jobs near transit stations is a positive indicator of regional PMT. A high number of jobs in these categories means that the system serves a significant number of non-work activities, such as shopping and restaurants, that attract riders to the system. The number of higher-wage jobs near transit stations is another positive indicator. The goodness of fit for the PMT model is clear, as shown in Figure 7.

Figure 7: PMT Model Goodness-of-Fit Plot



The capital cost model used by the spreadsheet tool was developed by Guerra and Cervero. We recommend that users curious about the theoretical underpinnings of that model read its documentation (*11*).

2.5 Ridership Indicators Database

The database developed as part of TCRP Project H-42 is summarized in the appendix to this handbook (Volume 1) and further described in the Research Report (Volume 2). For each of the projects in the database, the Appendix provides values for the most significant indicators identified in Table 5. Planners can use this database to identify projects that are similar to their own. If one or more similar projects can be identified in a corridor with similar densities and other characteristics, an initial estimate of the project-level ridership and PMT change can be inferred or interpolated. Although a perfect match is unlikely, a reasonably close match can be informative. If none of the database projects comes reasonably close to the one proposed, however, that finding may caution that the proposed project may not be a suitable match for the corridor.

To illustrate, all of the initial LRT projects in the database serve corridors that have at least 65,000 employees and a population density of more than 13,000 people per square mile. If a proposed LRT project would serve a corridor with fewer jobs and less density than these projects, it may not attract as many riders.

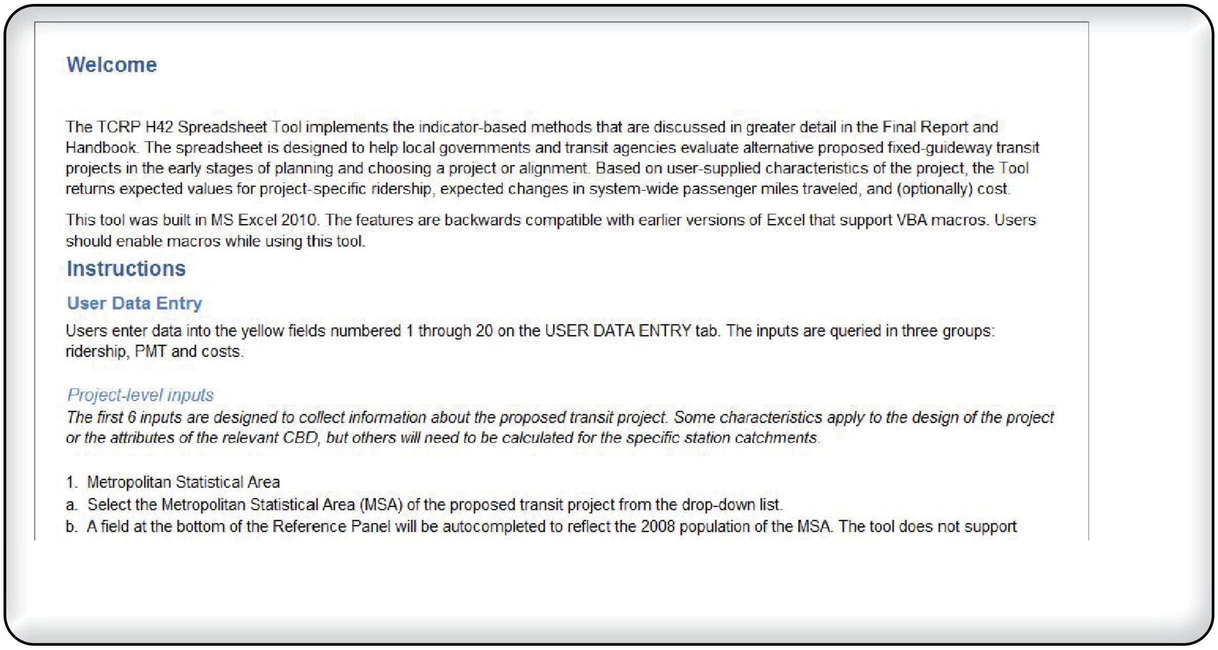
The database may also offer a useful tool for checking the reasonableness of travel demand model forecasts. If the regional model predicts that a project will attract 50,000 riders per day but the database shows that all projects attracting 50,000 daily riders serve more densely populated corridors, there may be reason to question the reasonableness of the model results. Similarly, caution should be used if model results are outside of or far from the data points used to determine goodness-of-fit.

2.6 Spreadsheet Tool

The spreadsheet tool applies the indicator-based method as it compares your proposed project with the completed projects studied as part of this research.

The Microsoft Excel-based spreadsheet tool developed as part of this research provides a simple way to apply the indicator method to compare different corridors and alignments in terms of their potential to attract ridership. The user enters corridor data for indicators with the strongest correlation to ridership. The tool runs calculations using coefficients derived from the statistical analysis of fixed-guideway transit projects built in the United States between 1974 and 2008. The output of the tool is a preliminary estimate of how many riders could be expected on a new fixed guideway in a given corridor. It also offers an estimate of the change in PMT on the entire system. When a capital cost estimate is entered into the tool, the spreadsheet calculates the cost per rider and cost per new PMT. Users can compare the ridership forecast for their corridor with the ridership on similar completed projects elsewhere in the United States. They can also compare their project with others in terms of cost per rider and cost per new PMT.

Figure 8: Spreadsheet Tool Opening Screen



Welcome

The TCRP H42 Spreadsheet Tool implements the indicator-based methods that are discussed in greater detail in the Final Report and Handbook. The spreadsheet is designed to help local governments and transit agencies evaluate alternative proposed fixed-guideway transit projects in the early stages of planning and choosing a project or alignment. Based on user-supplied characteristics of the project, the Tool returns expected values for project-specific ridership, expected changes in system-wide passenger miles traveled, and (optionally) cost.

This tool was built in MS Excel 2010. The features are backwards compatible with earlier versions of Excel that support VBA macros. Users should enable macros while using this tool.

Instructions

User Data Entry

Users enter data into the yellow fields numbered 1 through 20 on the USER DATA ENTRY tab. The inputs are queried in three groups: ridership, PMT and costs.

Project-level inputs

The first 6 inputs are designed to collect information about the proposed transit project. Some characteristics apply to the design of the project or the attributes of the relevant CBD, but others will need to be calculated for the specific station catchments.

1. Metropolitan Statistical Area
a. Select the Metropolitan Statistical Area (MSA) of the proposed transit project from the drop-down list.
b. A field at the bottom of the Reference Panel will be autocompleted to reflect the 2008 population of the MSA. The tool does not support

One strength of the spreadsheet tool is that rather than producing a single ridership answer, it provides a range of forecasts. The range allows the user to more meaningfully interpret the results and understand the uncertainty associated with any forecast. Transit ridership and cost are influenced by myriad factors, many of which cannot be captured in a statistical model such as this one. In fact, the database includes a number of outliers—completed projects with actual ridership outside the range that would be predicted by this model—perhaps reflecting special markets or conditions unique to a particular area.

The spreadsheet tool provides a range of ridership forecasts, recognizing the many uncertainties that come into play.

The tool has several limitations. It only estimates three success factors: project-level ridership, system-level change in PMT, and capital cost. As has been noted, these are not the only factors important in evaluating the likely success of a fixed-guideway transit project. Also, at this time, the method should only be applied to predict ridership for HRT, LRT, and fixed-guideway BRT lines.

The PMT model finds incremental changes due to the studied investment by comparing total PMT values across the system with and without the project. Because the model was built using PMT values much larger than the increments which are its outputs, the increments are on the same order of magnitude as the error in the model. This issue is an unavoidable consequence of the data and the methodology, but increments of smaller magnitude should be viewed with a critical eye.

This relatively simple tool is not meant to be a substitute for a well-calibrated local travel forecasting model that reflects the corridor's travel markets and patterns, that more fully represents the attributes of the project and competing services, and that offers useful insights into the reasons for ridership changes.

The spreadsheet tool differs from the FTA's 'STOPS' model.

TCRP Project H-42 was carried out concurrently with efforts by FTA to develop a simplified travel forecasting model for predicting transit ridership on fixed-guideway projects. The FTA model is the Simplified Trips-on-Project Software (STOPS). Compared with traditional four-step models, STOPS is simplified for the user in terms of the level of effort needed to develop and test a useful model, prepare inputs, and make forecasts. Internally, STOPS is quite detailed and uses transit components that are similar to those found in conventional models.

Some users may want to use both STOPS and the TCRP Project H-42 spreadsheet tool to see if they produce similar ridership forecasts. Using both might offer greater confidence in the result, or might provide useful insights about proposed projects. For those interested in using only one of the models, the choice may depend on how one intends to use the results, how quickly one wants the results, and the availability of necessary input data. Some users may prefer to use the faster spreadsheet tool for an initial "quick response" screening of alternatives, then turn to STOPS to prepare forecasts that will support an FTA New Starts or Small Starts rating.

SECTION 3

Using the Spreadsheet Tool

3.1 Quick-Start Guide

To use the spreadsheet tool, users input data on the corridor being studied as well as data on the fixed-guideway transit system to which it would connect. Thus, it is necessary to assume a general alignment for the proposed transit project, a mode, potential station locations, and the percent of the line that would be at grade. Also needed are reliable estimates of population and employment near stations. A GIS system containing population and employment data by job classification and income at the traffic analysis zone level or census tract level can be instrumental in assembling these data. Other data necessary for analysis are provided automatically when the user selects the metropolitan area from the drop-down menu.

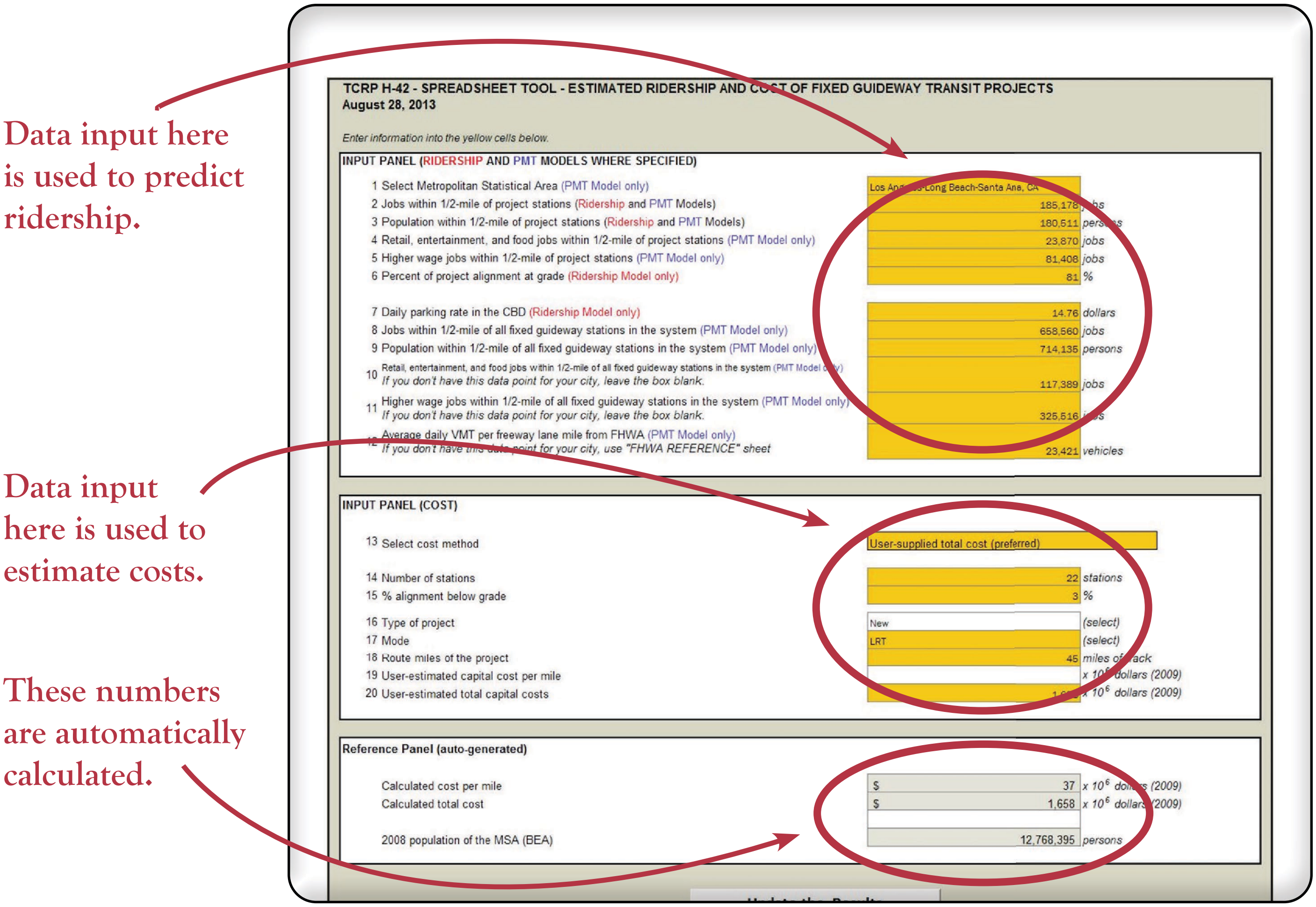
Users input information on the proposed project and corridor; certain other cost and demographic information is automatically populated when the metropolitan area is selected.

Open the spreadsheet tool in Microsoft Excel. To access data entry instructions at any time, click the Instructions tab along the bottom of the screen. Line-by-line instructions and tips are also provided in Section 3.2 of this quick-start guide.

The data entry screen, shown in Figure 9, has three parts:

1. The Input Panel (Ridership and PMT) at the top of the input screen (inputs 1 through 12) is for data used by the model to predict average weekday ridership for the proposed project, as well as changes in passenger miles.
2. The Input Panel (Cost) (inputs 13 through 20) is for entering information related to a project's capital cost. Users may enter a total cost for the project or a cost per directional route mile. If this information is not available, the default cost calculator that is part of the tool may be used, although specific local data are likely to yield more accurate results.
3. The Reference Panel contains values that are automatically generated based on user inputs in the above panels.

Figure 9: Data Entry Screen



Once these data are supplied, the spreadsheet tool will calculate the expected daily ridership on the project, the likely change in daily PMT, the estimated capital cost, the capital cost per rider, and the capital cost per new PMT. The tool will show how the proposed project compares with other U.S. fixed-guideway transit projects in the database. By benchmarking against similar projects, users can assess the likelihood that the project will be successful.

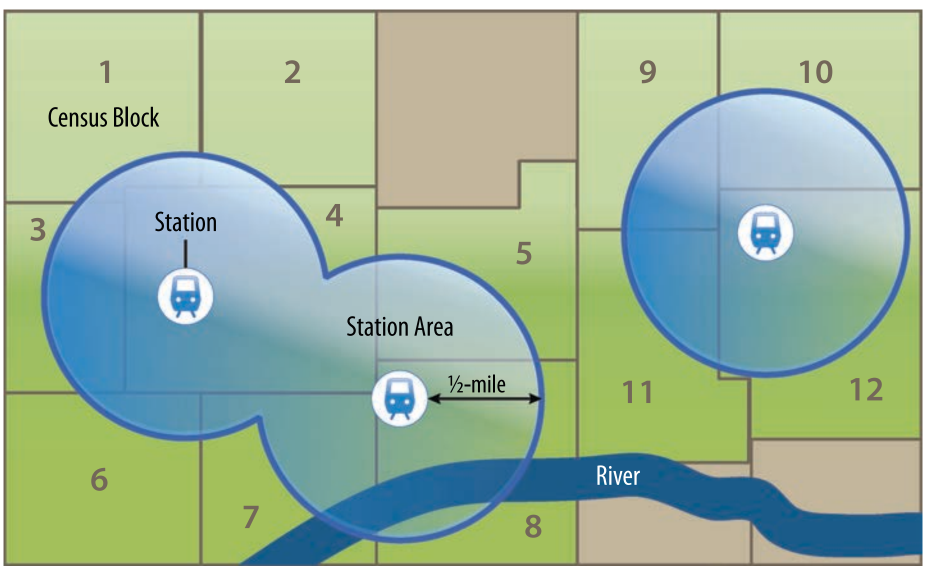
The tool can also be used to run "what-if" scenarios by testing the ridership impact of different input assumptions, such as higher population and employment concentrations.

To get the most value from the tool, it is essential to enable macros within Excel. Users can search the Excel help reference for how to enable macros in their version of Microsoft Excel.

3.2 Inputs: Line-by-Line Instructions and Tips on Data Sources

This section offers line-by-line instructions on what data to enter into the spreadsheet tool to produce an estimate of ridership and PMT change for a project. The first six inputs provide information about the proposed transit project and the corridor it would serve. Characteristics of the population and employment need to be calculated for the area within one-half-mile of the proposed stations. U.S. Census data is provided by census block. As depicted in Figure 10, each station area typically encompasses portions of multiple census blocks. Population and employment data collected by census block needs to be adjusted proportionately to estimate the values within each station area.

Figure 10: Calculations Involving Partial Census Blocks



Source: Adapted from Federal Transit Administration's Sample Methodology for Estimating Station Area Socio-Economic Statistics in Reporting Instructions for the Section 5309 New Starts Criteria.

TIP

For all figures involving U.S. Census data:

Download data for the census blocks located all or partially within the area to be analyzed (the area within one-half-mile of a proposed transit station). If a block does not fall completely within the half-mile buffer, adjust the number of jobs, residents, etc., counted within the block appropriately. If a census block falls within one-half-mile of more than one station, count the jobs within that block only once.

Figure 11: Ridership and PMT Input Panel

TCRP H-42 - SPREADSHEET TOOL - ESTIMATED RIDERSHIP AND COST OF FIXED GUIDEWAY TRANSIT PROJECTS
August 28, 2013

Enter information into the yellow cells below.

INPUT PANEL (RIDERSHIP AND PMT MODELS WHERE SPECIFIED)

1	Select Metropolitan Statistical Area (PMT Model only)	Los Angeles-Long Beach-Santa Ana, CA	
2	Jobs within 1/2-mile of project stations (Ridership and PMT Models)	185,178	*jobs*
3	Population within 1/2-mile of project stations (Ridership and PMT Models)	180,611	*persons*
4	Retail, entertainment, and food jobs within 1/2-mile of project stations (PMT Model only)	23,870	*jobs*
5	Higher wage jobs within 1/2-mile of project stations (PMT Model only)	81,408	*jobs*
6	Percent of project alignment at grade (Ridership Model only)	81	%
7	Daily parking rate in the CBD (Ridership Model only)	14.76	*dollars*
8	Jobs within 1/2-mile of all fixed guideway stations in the system (PMT Model only)	658,560	*jobs*
9	Population within 1/2-mile of all fixed guideway stations in the system (PMT Model only)	714,135	*persons*
10	Retail, entertainment, and food jobs within 1/2-mile of all fixed guideway stations in the system (PMT Model only) *If you don't have this data point for your city, leave the box blank.*	117,389	*jobs*
11	Higher wage jobs within 1/2-mile of all fixed guideway stations in the system (PMT Model only) *If you don't have this data point for your city, leave the box blank.*	325,516	*jobs*
12	Average daily VMT per freeway lane mile from FHWA (PMT Model only) *If you don't have this data point for your city, use "FHWA REFERENCE" sheet*	23,421	*vehicles*

Line 1: Select Metropolitan Statistical Area (MSA)

Select the MSA from the drop-down list as shown in Figure 11. Based on this selection, the tool draws on its internal database for relevant information from the U.S. Census Bureau, as of 2008, such as the number of people in the MSA and the number of existing jobs in the CBD. These data cannot be changed.

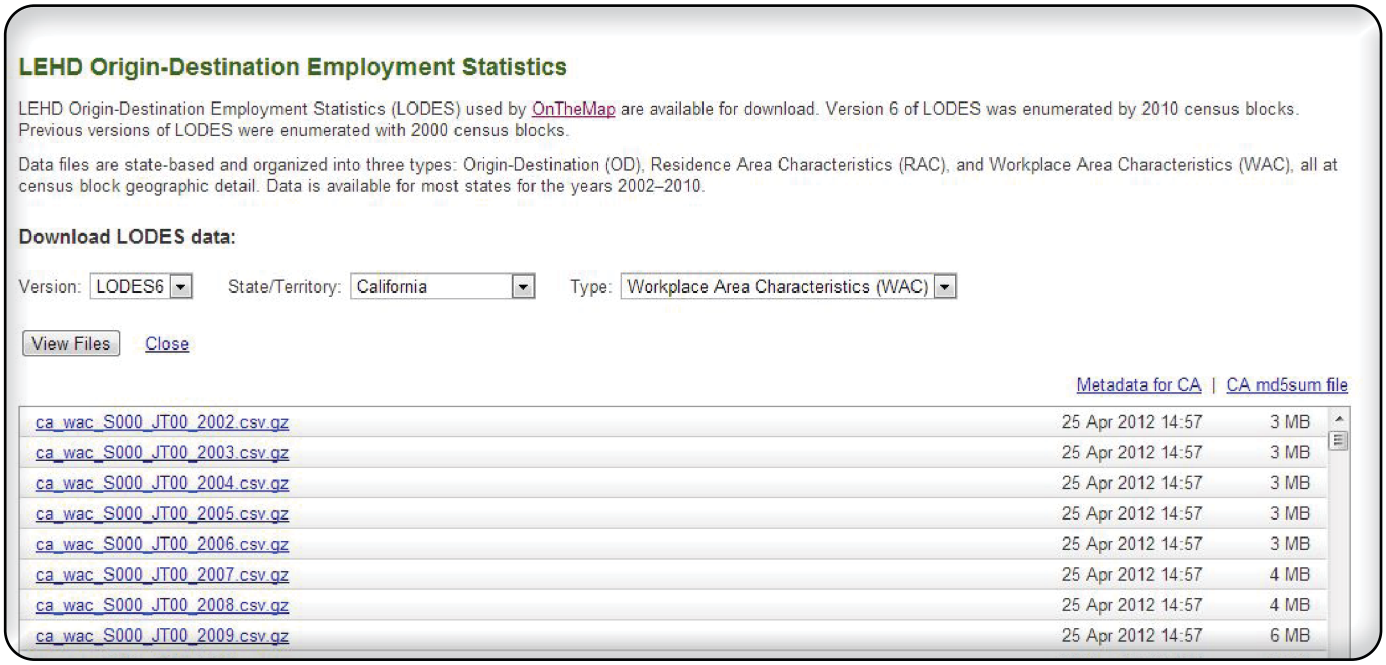
Line 2: Jobs within ½-mile of project stations

Insert current employment data on Line 2 to estimate ridership if the project were in place today. Block-level employment data for years between 2000 and 2010 are available through the following process:

1. Use the U.S. Census Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES) download site at: http://lehd.ces.census.gov/data/#lodes
2. Version = LODES7 for 2010 census blocks, LODES5 for 2000 Census Blocks
3. Select state
4. Type = Workplace Area Characteristics
5. The file name structure is: [STATE]_wac_[SEGMENT]_JT00_[YEAR]
   a. [SEGMENT] = S000 for totals, SE03 for high-wage

Figure 12 shows the LODES interface with representative selections.

Figure 12: LODES Interface



To convert the block-level LEHD data to a value that can be entered on Line 2 (or any other line using catchment-area employment), it is necessary to select only those blocks that lie inside the one-half-mile catchment area around stations. When this process was performed in creating the model, the catchments were clipped to exclude water and to ensure that no two catchments overlapped. This eliminated double-counting while ensuring that all of the jobs lying within one-half-mile of any project station were counted once (see Figure 10).

The process of selecting the proper blocks is easiest using GIS software, though it can be performed manually using printed maps.

To estimate ridership in some future year, it is necessary to enter job figures estimated for that year. These may be derived from forecasts the region's MPO or local jurisdictions maintain for transportation planning. Entering different employment forecasts will enable users to test "what-if" scenarios. The spreadsheet model will still assume regional conditions based on 2008 Census data, but it can show how sensitive ridership would be to changes in employment near stations.

TIP Use the spreadsheet to test what-if scenarios. For example, users can enter a higher number of jobs in the vicinity of stations to see how ridership might change if employment were more concentrated.

Line 3: Population within ½-mile of project stations

Similar to Line 2, enter the number of people residing within one-half-mile of the planned stations. Existing population can be obtained from the U.S. Census or another reliable source. Again, forecasts of future population can be obtained from the MPO or local jurisdictions. "What-if" scenarios can be tested to see how changes in population near stations would affect ridership on the project and PMT on the system.

Line 4: Retail, entertainment, and food jobs within ½-mile of project stations

On Line 4, enter the number of "attraction-based" jobs—that is, jobs included in North American Industry Classification System (NAICS) codes 44-45 (Retail Trade), 71 (Arts, Entertainment, and Recreation), and 72 (Accommodation and Food Services). Using the U.S. Census LEHD or another reliable source, calculate the number of jobs in these categories within one-half-mile of the proposed stations.

Line 5: Higher wage jobs within ½-mile of project stations

"Higher wage jobs" refers to jobs in the Earn3 category of the U.S. Census LEHD data; that is, jobs earning greater than $3,333 per month. Using LEHD or another reliable source, calculate the number of jobs in this category within one-half-mile of the proposed stations.

Line 6: Percent of project alignment at grade

Users enter the percent of the alignment that is at grade. For example, if 50 percent of the proposed alignment is going to be at grade within a highway median and 26 percent will be at grade within a street, users would enter "76" on Line 6.

TIP The higher the percentage of alignment at grade, the lower the ridership typically will be. Corridors with at-grade systems tend to have less density than corridors with grade-separated systems, and thus attract fewer riders. The at-grade mileage may also be indicative of slower transit speeds.

The spreadsheet tool uses Lines 7 through 12 and general MSA-level data based on the entry on Line 1 to estimate the PMT on the entire fixed-guideway transit network with and without the proposed transit project. The difference between these values is the incremental change in PMT attributable to the project.

Line 7: Daily parking rate in the CBD

Enter the average daily (6- to 24-hour) cost of market-rate parking in the CBD on Line 7. This should be the daily rate posted at surface lots and garages within one-half-mile of stations in the CBD. It is not necessary to take subsidized parking into account; simply enter the posted rate.

TIP The parking price may serve as a proxy for other factors in addition to the cost of parking a car during the work day. For example, parking price is also indicative of the size of the CBD and its density. Therefore, using the tool for sensitivity analyses to test the impact of changing the parking price is not advised.

Line 8: Jobs within ½-mile of all fixed-guideway stations in the system

Lines 8-11 presume that your proposed project connects to an existing fixed-guideway transit system, meaning a rail system or a BRT system with dedicated lanes. If it is the initial leg of a new fixed-guideway system, the entries for 8-11 will be zero. Using the U.S. Census LEHD or another reliable source, calculate the number of jobs within one-half-mile of all existing fixed-guideway stations on the system. This calculation should not include new stations proposed as part of the investment.

Line 9: Population within ½-mile of all fixed-guideway stations in the system

Using the U.S. Census or another reliable source, calculate the number of people residing within one-half-mile of all existing stations on the fixed-guideway transit system. This calculation should not include new stations proposed as part of the project.

TIP For this analysis, "fixed-guideway transit system" means that part of the regional transit system that operates within a dedicated, exclusive right-of-way. It may include HRT, LRT, commuter rail, or BRT that operates in exclusive lanes.

Line 10: Retail, entertainment, and food jobs within ½-mile of all fixed-guideway stations in the system

This jobs category is an aggregate of NAICS codes 41-42 (Retail Trade), 71 (Arts, Entertainment, and Recreation), and 72 (Accommodation and Food Services). Using the U.S. Census LEHD or another reliable source, calculate the number of jobs in these categories within a half-mile of all existing stations. This calculation should not include new stations proposed as part of the project.

User-supplied values are preferred. However, if the user is unable to calculate this input for all station catchments in the system, the line can be left blank. In this case, the tool uses the user-supplied value for total number of catchment jobs in the system and the fraction of jobs that fall into this category to estimate the number of retail, entertainment, food, and accommodation jobs near stations. For many metropolitan areas, a local value for the fraction is provided by the tool based on values for the principal city. For the remaining metropolitan areas, the median value from existing systems is used.

Line 11: Higher wage jobs within ½-mile of all fixed-guideway stations in the system

As in Line 5, "higher wage jobs" refers to jobs in the Earn3 category of the U.S. Census LEHD data; that is, jobs earning greater than $3,333 per month. Using LEHD or another reliable source, calculate the number of jobs in this category within one-half-mile of all existing stations. This calculation should not include new stations proposed as part of the investment.

User-supplied values are preferred. However, if the user is unable to calculate this input for all station catchments in the system, the line can be left blank. In this case, the tool uses the user-supplied value for total number of catchment jobs in the system and the fraction of jobs that have wages over $3,333 per month to estimate the number of high-wage jobs near stations. For many metropolitan areas, a local value for the fraction is provided by the tool based on values for the principal city. For the remaining metropolitan areas, the median value from existing systems is used.

Line 12: Average daily VMT per freeway lane mile from FHWA

The VMT per highway lane gives an indication of congestion on the MSA's freeway system (the competing mode). To get inputs for this line, refer to Table HM-72 (2008) from the Federal Highway Administration (FHWA), which is available at:

http://www.fhwa.dot.gov/policyinformation/statistics/2008/hm72.cfm

The right-hand column in Table HM-72 (Average Daily Traffic per Freeway Lane) gives the total VMT on freeways divided by freeway lane miles for each MSA. This information is also included in the spreadsheet tool under the FHWA REFERENCE tab.

Inputs 13 through 20, shown in Figure 13, provide the basis for a capital cost estimate.

Figure 13: Cost Input Panel

INPUT PANEL (COST)		
13 Select cost method	User-supplied total cost (preferred)	
14 Number of stations	22	stations
15 % alignment below grade	3	%
16 Type of project	New	(select)
17 Mode	LRT	(select)
18 Route miles of the project	45	miles of track
19 User-estimated capital cost per mile		x 10^6 dollars (2009)
20 User-estimated total capital costs	1,658	x 10^6 dollars (2009)

Line 13: Select cost method

Using the drop-down menu, select the approach to capital costing. A user-supplied total cost or user-supplied cost per mile estimate is preferred because it is likely to be more accurate than the costing routine within the spreadsheet tool. Where these are not available, however, the tool can provide a rough order of magnitude estimate based on the variables in the cost input panel and the other projects in the database. Complete Lines 14 through 17 only if the tool is to provide the cost estimate.

Line 14: Number of stations

Enter the number of new stations on the proposed transit investment.

Line 15: % alignment below grade

Enter the percent of the alignment that is below grade in a trench or subway. For example: If 5 percent of the proposed alignment would be in a subway and 3.5 percent would be in an open trench, the user would enter "8.5."

Line 16: Type of project

Select the type of project from the drop-down list. One of four project types can be selected:

1. New projects are those that add the first fixed-guideway transit line in the region.
2. Extensions are projects that extend an existing fixed-guideway line by adding new track and stations beyond the current terminus.
3. Expansions add a new fixed-guideway line to an existing system. The new line could be of a different mode, such as adding a fixed-guideway BRT line to a system that currently operates urban rail.
4. Enhancements improve the service of a line by adding new stations on existing rights-of-way without adding route miles to the system.

Line 17: Mode

Select the mode: HRT (heavy rail), LRT (light rail transit), or BRT (bus rapid transit).

Line 18: Route Miles of the Project

Enter the length of the proposed transit investment in miles.

Line 19: User-estimated capital cost per mile

Enter the capital cost per mile for the proposed investment in 2009 dollars.

> **TIP** For the most reliable results, the user's cost estimate should be used if at all possible. Enter it either at Line 19 or Line 20, depending on whether an estimated cost per mile or total capital cost is being used.

Line 20: User-estimated total capital cost

Enter the total capital costs for the proposed investment in 2009 dollars. If the user has an estimate for capital costs, use it rather than the estimate produced by the Cost Calculator.

When all of the yellow fields are complete, press the "Update the Results" button at the bottom of the screen. The inputs from the first pages are multiplied by coefficients determined through statistical analysis of existing systems and summed to produce estimates for average weekday riders on the project, the change in system-wide annual passenger-miles traveled (PMT), average weekday riders, and capital cost. Click the OUTPUTS tab to view the results.

3.3 Outputs: Results and What They Mean

The spreadsheet tool offers three different output screens:

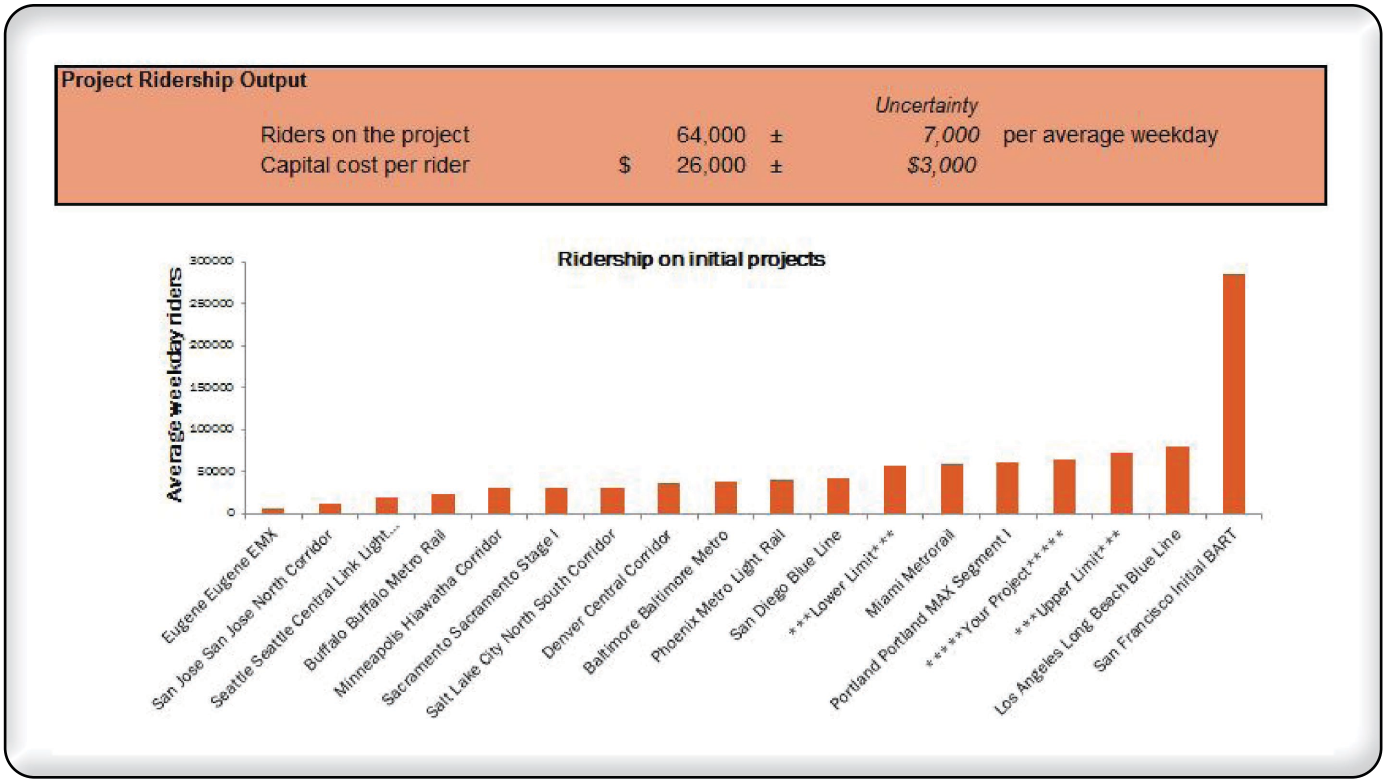
1. Project Ridership Output, showing estimated weekday project ridership and capital cost per rider, with confidence intervals.
2. Capital Costs Output, showing estimated total capital cost and capital cost per directional route mile in 2009 dollars.
3. System-wide PMT Output, showing expected new PMT on the system and capital cost per new PMT.

To arrive at these outputs, the spreadsheet tool relies on coefficients derived from the regression analysis. The tool calculates the project-level ridership and cost by multiplying each input by its relevant coefficient and then summing the results. The incremental PMT is calculated by subtracting an estimate of PMT on the committed network from the PMT on a network that includes both the proposed project and the committed network. The model outputs are based on a fit to data which shows natural variation, or scatter. To take this into account, the output panel presents not only the ridership estimate for Your Project but also a range of uncertainty. The Upper Limit and Lower Limit forecasts are derived from a variance-covariance matrix generated during the modeling process. The uncertainty in the ridership estimates is on the order of 20 percent.

> **TIP** Although it is possible to navigate to the OUTPUTS tab using the worksheet tabs at the bottom of the screen, users should use the "Update the Results" button when they want to see their results. The button initiates a macro that updates the column chart on the OUTPUTS tab. The spreadsheet tool may not reflect the user's most recent inputs if the Update button is not used.

If the input data is for a recent year—e.g., if 2010 census data was the source of the population and employment inputs—then the ridership estimate would be for that year, as if the project were already in place. If the corridor-level input data is a forecast for a future year, then the project-level ridership estimate would be for that future year. The spreadsheet tool does not account for regional growth, however, so an estimate of future year ridership reflecting anticipated growth in station-area jobs and population will tend to be conservative.

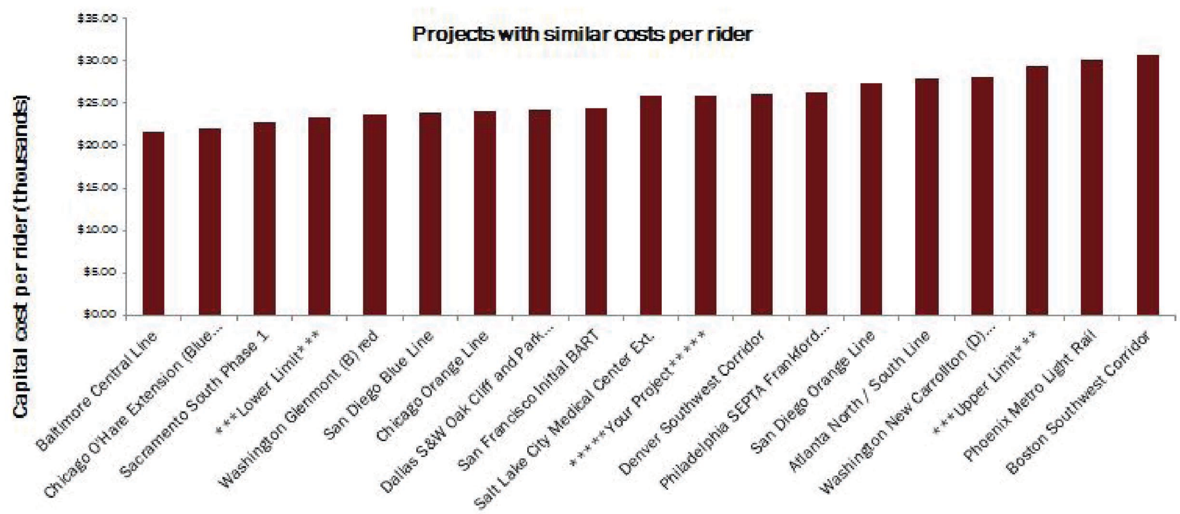
Figure 14: Output Panel on Project Ridership



The output screen in Figure 14 compares the average weekday riders estimated for a hypothetical project (Your Project) with the ridership on similar projects in the database. The estimated number of riders predicted for Your Project on an average weekday is shown in the bar chart alongside the actual ridership on projects of the same type (new projects, extensions, expansions, and enhancements as described in the Line 16 instructions above). An Upper Limit and Lower Limit are also provided to illustrate the range of uncertainty in the forecast. Users can compare ridership on Your Project with all projects in the database by referring either to Table A-1 in the appendix to this handbook or to the REFERENCE VALUES tab in the spreadsheet tool.

Since the database includes a wide variety of projects in different modes and city sizes, users may choose to focus on a subset of projects that are similar to the one being evaluated. For example, if the user is considering an LRT project in a medium-sized regional city, the forecast ridership would best be compared with the Portland Interstate MAX and Minneapolis Hiawatha Corridor projects as opposed to the Miami Metrorail or the Chicago Orange Line.

Figure 15: Output Panel on Capital Costs



Capital Costs Output		
Capital cost (total)	$1,658	MILLION (2009)
Capital cost per mile	$36.84	MILLION/Mile (2009)

The output panel in Figure 15 shows the proposed project's estimated capital cost per average weekday rider along with other projects in the database with a similar capital cost per rider. Your Project appears likely to have a capital cost per rider similar to other projects, giving users confidence in their project's potential for success. Users can compare Your Project's capital cost per rider with that of all projects in the database using Table A-1 in the appendix.

Capital cost per rider can be useful in a multi-criteria evaluation, but as has been noted previously, this one metric should not be considered to be the ultimate determinant of a project's success. The Bay Area Rapid Transit (BART) extension to San Francisco Airport has the second-highest capital cost per rider of the projects in the database. Nevertheless, many consider the project to be successful because its operating costs are covered by fares and the project saves users from paying the much higher cost of airport parking or taxi service.

The capital cost per rider computed by the spreadsheet is not directly comparable with FTA's cost effectiveness metric and breakpoints. The FTA's cost per rider metric for cost effectiveness annualizes both the capital cost and the ridership projection, and includes annual operating and maintenance costs as well. The spreadsheet tool simply divides the total estimated capital cost by the anticipated average weekday ridership.

In a similar fashion to Figure 11, Figure 16 compares the project being considered with the database projects in terms of its potential to change PMT. It should be noted that in cases where the forecast PMT increment is less than zero, the output panel will display Negligible in place of the estimate. All other values on the panel will be displayed as NA and the plot will show the incremental PMT as being equal to zero. As the cost and ridership are projected by entirely different models, none of the other outputs are affected and those values are still entirely legitimate even if the PMT model fails to produce a valid result.

The negligible assumption was made because it is possible that negative predictions fall within the error of the model and therefore are in actuality zero. Alternatively, it is possible to explain legitimate negative increments through diversion of service or increased efficiency of the overall system. For a complete discussion of how TCRP Project H-42 investigated negative PMT increments, see the full report in Volume 2.

Figure 16: Output Panel on System-wide PMT

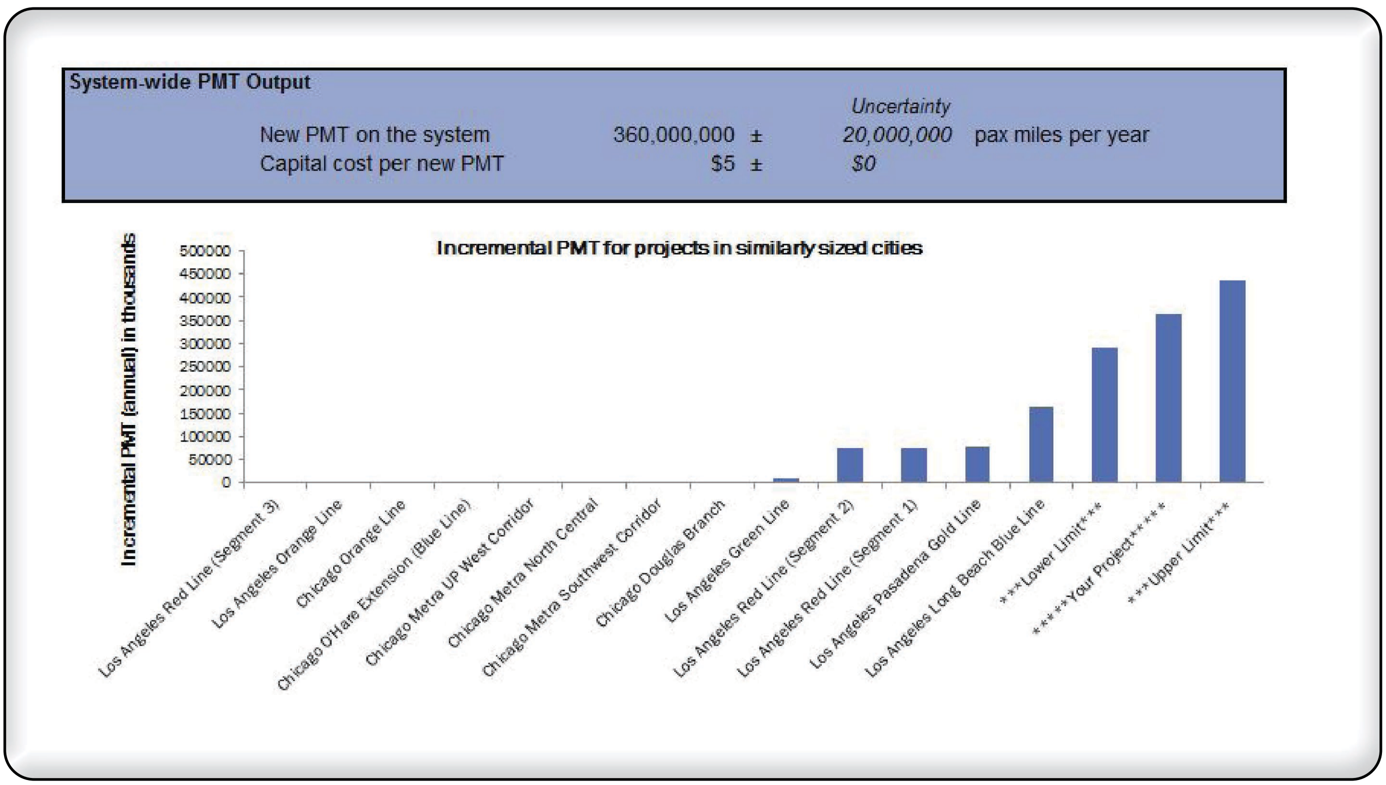


Figure 16 compares Your Project with projects in metropolitan areas of similar size in terms of its potential to change PMT. The estimate for Your Project shows that it will have a positive effect on ridership system-wide, and that the impact on PMT is comparable to other projects in similar sized areas, offering further evidence that the project can be a success.

3.4 Using the Tool to Compare Scenarios

Although the initial outputs resulting from a single scenario of project and corridor characteristics can be of interest as a starting point for analysis, the spreadsheet offers additional value as a tool for comparing different What-if? scenarios. By changing the inputs, the user can test how project-level ridership and the amount of new PMT might change under a different set of assumptions. New scenarios might include:

- Changes to the project characteristics, such as adding more stations or moving the stations to locations with different densities.
- Changes to the corridor characteristics, such as the assumed population and employment density. In such a way, the ridership outcome from different forecast years and public policy options can be assessed.
- Comparing the ridership potential of different corridors within the same region. The results might help prioritize corridors.

The spreadsheet tool does not currently include a save function, nor does it allow the user to compare the results of different scenarios side-by-side. Thus, users will need to record the results of each scenario and compare them outside the tool, perhaps in a Microsoft Word or Excel file.

To enter a new scenario, click on the Adjust the Inputs button. This button will take users back to the USER DATA ENTRY tab. After making any necessary adjustments, navigate back to the OUTPUTS tab using the Update the Results button.

SECTION 4

Other Factors

4.1 Other Factors Affecting Ridership

The quantitative factors included in the spreadsheet tool capture many, but not all, of the factors that can lead to the success of a transit project. The literature search and case studies conducted as part of TCRP Project H-42 identified other and somewhat less quantifiable factors that can also contribute to the ridership on a fixed-guideway transit project. These factors may explain some of the outliers in Figure 14, and would be expected to increase (or decrease) ridership in comparison to levels estimated by the spreadsheet tool.

Understanding the qualitative factors that can enhance or hinder ridership can help you interpret the spreadsheet's output for your project.

- Transit service and pricing – Transit ridership tends to be particularly sensitive to service levels and the cost paid by riders. The typical demand forecasting model is highly sensitive to such variables as transit travel time, peak and off-peak headways, average fares, and parking fees, reflecting research on travel behavior. Section 2.4 noted that one of the unexpected results of this research was that the regression analysis did not show transit service levels or pricing to be significant indicators of ridership. It is assumed that this is because service levels and fares are implicit to some of the other indicators, such as density, highway congestion levels, and percent of the line that is at grade. If your project would have higher (or lower) service than is typical for projects in the database, or lower (or higher) cost paid by the user, it may attract higher (or lower) ridership.
- "Transit First" policies – Those places that give transit priority for funding and street capacity, that impose tolls on automobiles, and that limit the supply of parking or raise the price of parking, can attract higher ridership by reducing the relative cost of transit, or increasing its relative speed, compared to automobiles.
- Special generators – Sporting venues, universities and colleges, and other special generators can increase ridership. Forecasts produced by the spreadsheet tool assume that a corridor has about the same number of special generators as the projects in the database. Where there are more (or fewer) special generators than average for the other projects, ridership is likely to be higher (or lower).

- Walkability near stations – Transit ridership tends to be higher where stations are easily accessible on foot, including access that is direct, safe, and interesting.
- Preference for rail – The spreadsheet tool predicts ridership based on the input variables described in Section 3.2, and is agnostic with regard to the transit technology (e.g., LRT, HRT, or fixed-guideway BRT). However, FTA has found that fixed-guideway projects in general and rail in particular can attract riders based on certain attributes—such as a rider's perception of comfort and reliability—that are not well represented in traditional travel forecasting models. When these unincluded attributes are taken into account, ridership forecasts for a rail alternative and a BRT alternative may differ even if they are identical in terms of frequency, travel time, station locations, and fares.

4.2 Other Goals Beyond Ridership and Capital Cost

As noted throughout this handbook, ridership and capital cost per rider are not the only measures of success for a fixed-guideway transit project. Other motivations for considering a fixed-guideway transit project, or for selecting one alternative over another, can include:

The reasons for undertaking a transit project extend beyond achieving a certain ridership target.

- Shaping future growth and development – Transit success is often defined in terms of its ability to shape settlement patterns and increase land values. An important consideration can thus be the development potential around existing and proposed stations. This potential can be greatly affected by land availability, land use regulations, and the real estate market.
- Reducing operating costs – A project that increases transit vehicle speed can mean that fewer vehicles are needed to provide the same frequency of service. BRT with such features as skip stop service, level boarding, signal priority, and off-board fare collection can reduce run time, meaning that fewer buses are needed to provide the same passenger-carrying capacity. Fewer buses might be needed to offer the same number of bus runs in a day, thus offering greater service while lowering operating costs.
- Promoting social and geographic equity – This can include mobility improvement for disadvantaged individuals, populations, or regions, as well as an equitable allocation of benefits and resources. Some transit agencies, such as Sound Transit in the Seattle metropolitan area, are required to spend funds in the jurisdiction where they are collected.

Although project-level ridership and PMT change can be related to these goals, they may not be the best indicators of potential success in achieving them.

SECTION 5

What Next?

5.1 Examining Expectations in Light of Fixed-Guideway Success Indicators

If spreadsheet analysis shows promise, it may be appropriate to invest in a more detailed corridor-level planning study.

The indicators of success presented in this handbook are only the beginning. If a corridor or project is shown to have good potential for attracting ridership commensurate with its cost, the next step may be more detailed corridor-level planning studies of transit needs and alternative solutions. These studies would typically include the use of travel demand forecasting models, conceptual engineering, environmental studies, and stakeholder involvement. Potential funding sources might be identified. Transit visioning at the regional scale may help put the project in context and facilitate funding support.

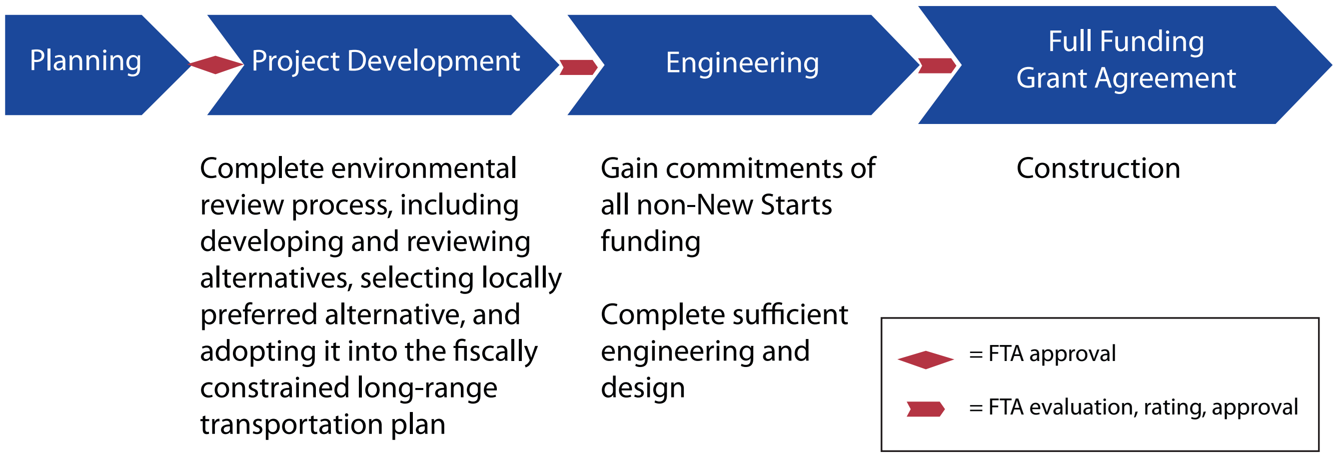
If ridership results do not appear to be favorable at this time, an incremental approach to transit system development could be valuable.

If the spreadsheet analysis yields less-favorable results, the story may not be over either. Consider the goals of the proposed transit project, and what success would look like. Consider whether or not those expectations are realistic. It may be that a different type of transit project—perhaps with a lower cost—would be a better fit for the travel markets and available funding. Success can often be achieved by starting with a smaller initial transit investment, building up ridership over time as the corridor grows and as transit supportive policies take effect, and incrementally adding to the system's service and infrastructure.

5.2 Conducting a More Detailed Study

In the United States, the MAP-21 (Moving Ahead for Progress in the 21st Century Act) legislation enacted in 2012 lays out a new procedural structure for the planning and development of fixed-guideway transit projects that utilize federal funds under the FTA's New Starts and Small Starts program. Specific guidance from the FTA is not available at this writing, but Figure 17 illustrates the major steps.

Figure 17: New Starts Planning and Development Process under MAP-21



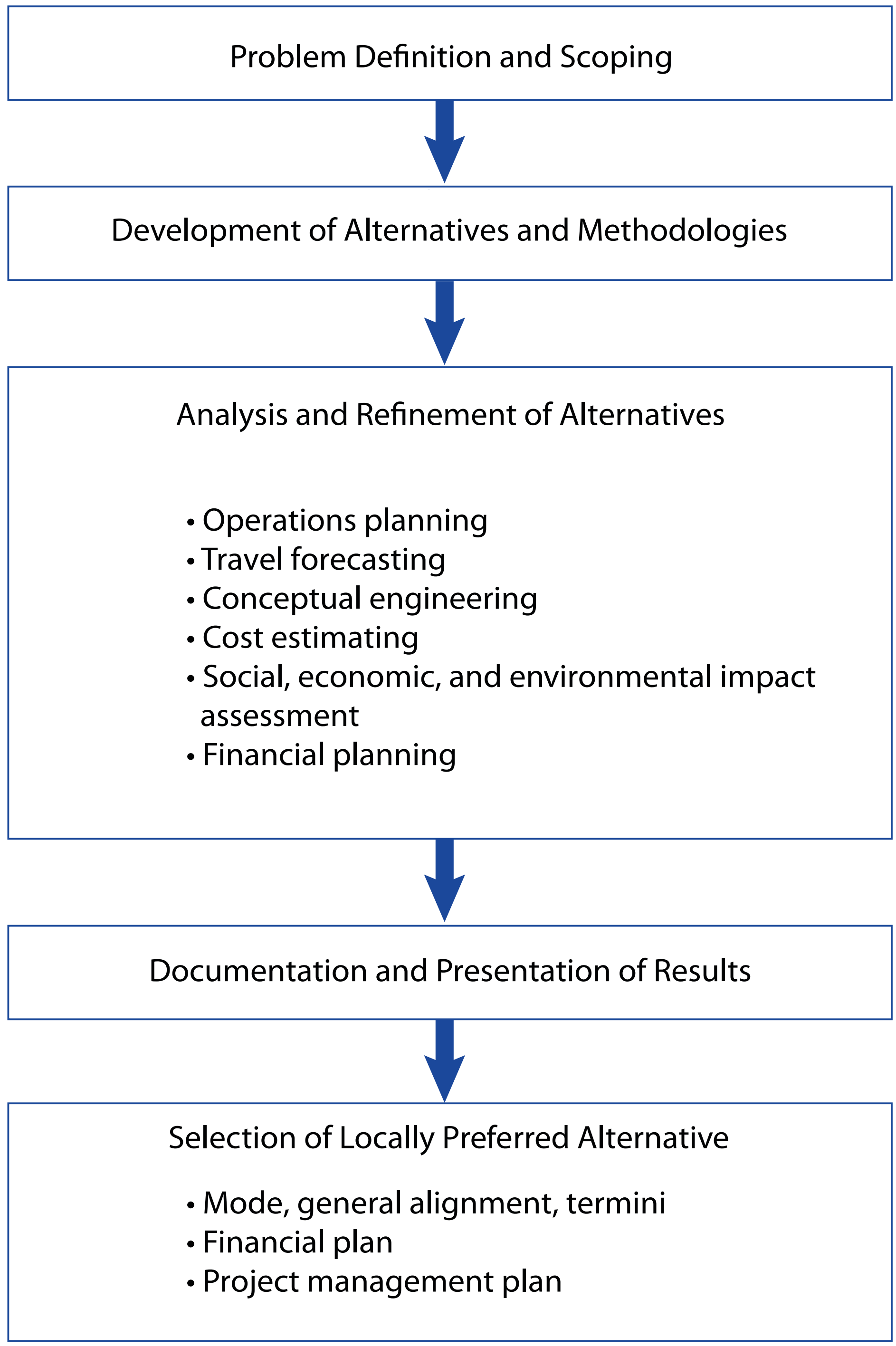
Source: Adapted from Federal Transit Administration, Capital Investment Program Listening Session, September 2012

Transit planning typically involves both regional system-level studies and corridor-level studies. Regional visioning and system planning can play an important role in understanding travel markets, understanding needs, and setting policies and priorities. Corridor studies offer the focus needed to develop service strategies and to examine alternative modes, alignments, station locations, termini, etc., at an appropriate scale for decision-making. Conventional wisdom among transit planners is that there are usually too many options—too many potential combinations and permutations of service levels, mode, and alignment—to reach mode and alignment decisions in a considered fashion at a regional scale.

While MAP-21 removes the federal requirement for stand-alone corridor-level alternatives analysis studies, FTA's alternatives analysis framework still offers one model for conducting corridor-level planning studies to reach decisions on the mode, general alignment, and termini for a transit project. Corridor-level transit planning following similar approaches is widely practiced around the world. The alternatives analysis framework for corridor-level planning studies includes the steps shown in Figure 18, with agency and stakeholder involvement continuing throughout.

Depending on the complexity of the corridor, corridor planning can precede or be folded in with more detailed project development, which considers design options (e.g., the precise alignment, station locations, yard and shop, etc.). Under MAP-21, the National Environmental Policy Act (NEPA) process is completed during the project development phase, along with the engineering necessary to support NEPA. FTA's approval of a project into the subsequent engineering phase hinges on how well the project meets statutory criteria for project justification and local financial commitment.

Figure 18: Technical Framework for Corridor-Level Planning Study



Source: Parsons Brinckerhoff, based on FTA's Procedures and Technical Methods for Transit Project Planning (12)

5.3 Overview of Funding Options for Fixed-Guideway Transit

Next steps include identifying and securing funds to build the project, as well as to operate and maintain it. In the United States, the primary federal funding source for fixed-guideway transit is the New Starts and Small Starts program administered by FTA. Funds are awarded on a discretionary basis, and projects must meet certain criteria defined in law and regulation in order to compete successfully for funds. The New Starts share for successful projects tends to be no more than 50 percent of the capital cost, with most of the operating and maintenance cost covered by fares and local funds. Nevertheless, the opportunity for discretionary funds makes the program very appealing, and the demand for funds exceeds the money available.

Other federal funding sources and financial support mechanisms are available. Flexible funds authorized under Title 23 (Highways) may be used for transit projects. These include funds made available to states and MPOs under the Surface Transportation Program (STP) and the Congestion Mitigation and Air Quality (CMAQ) Program. In recent years, federal funds have been available through the discretionary TIGER (Transportation Investment Generating Economic Recovery) grant program. Financing help is available through TIFIA (Transportation Infrastructure Finance and Innovation Act).

State and local funding sources for transit are many and varied, ranging from beer taxes in Alabama to video poker in Oregon. Dedicated sales taxes and excise taxes are often used, as they are stable and reliable and provide a robust enough funding stream to support a transit capital program while also supporting operations. Value capture tools such as assessment districts and tax increment financing are of interest in many places.

Reports on federal, state, and local funding options for fixed-guideway transit are available online at such websites as:

http://www.trb.org/publications/pubstcrppublications.aspx

http://apta.com/resources/reportsandpublications/Pages/default.aspx

http://t4america.org

http://www.cfte.org

REFERENCES

1. Pushkarev, B., and J. Zupan. *Public Transportation and Land Use Policy.* Indiana University Press, Bloomington, 1977.
2. Pushkarev, B., J. Zupan, and R.S. Cumella. *Urban Rail in America: An Exploration of Criteria for Fixed-Guideway Transit.* Indiana University Press, Bloomington, 1982.
3. American Public Transportation Association. *2012 Public Transportation Fact Book, Appendix A: Historical Tables.* Washington, D.C., 2012.
4. Parsons Brinckerhoff. *TCRP Report 16: Transit and Urban Form, Volume 2, Part III, A Guidebook for Practitioners.* TRB, National Research Council, Washington, D.C., 1996.
5. Chatman, D., et al. *TCRP Report 167: Making Effective Fixed-Guideway Transit Investments: Indicators of Success, Vol. 2: Research Report.* Transportation Research Board of the National Academies, Washington, D.C., 2014.
6. Regional Plan Association. *Where Transit Works: Urban Densities for Public Transportation.* New York, 1976.
7. Institute of Transportation Engineers. *A Toolbox for Alleviating Traffic Congestion.* Washington, D.C.,1989.
8. Metropolitan Transportation Commission Resolution 3434: Regional Transit Expansion Program, 2008. www.mtc.ca.gov/planning/rtep/
9. Cambridge Systematics, Inc. and Transportation Analytics. *Draft Transit Competitive Index Primer.* Metropolitan Transportation Commission, Transit Sustainability Project. San Francisco, Calif., 2012.
10. Metro. Regional High Capacity Transit System Plan 2035: Summary Report. Portland, Ore., 2010.
11. Cervero, R., and E. Guerra. "To T or Not to T: A Ballpark Assessment of the Costs and Benefits of Urban Rail Transportation," *Public Works and Management*, April 2011.
12. Federal Transit Administration, U.S. Department of Transportation. Procedures and Technical Methods for Transit Project Planning. www.fta.dot.gov/12304_2396.html, accessed September 2012.

ABBREVIATIONS AND ACRONYMS

APTA – American Public Transportation Association

BART – Bay Area Rapid Transit (San Francisco)

BEA – Bureau of Economic Affairs

BRT – Bus Rapid Transit

CBD – Central Business District

CMAQ – Congestion Mitigation and Air Quality

CR – Commuter Rail

DRM – Directional Route Miles

FFGA – Full Funding Grant Agreement

FHWA – Federal Highway Administration

FTA – Federal Transit Administration

GDP – Gross Domestic Product

GIS – Geographical Information System

HRT – Heavy Rail Transit

LEHD – Longitudinal Employer-Household Dynamics

LRT – Light Rail Transit

MAP-21 – Moving Ahead for Progress in the 21st Century Act

MPO – Metropolitan Planning Organization

MSA – Metropolitan Statistical Area

MTC – San Francisco Bay Area's Metropolitan Transportation Commission

NAICS – North American Industry Classification System

NEPA – National Environmental Policy Act

NCDC – National Climatic Data Center

NHTS – National Household Travel Survey

NTD – National Transit Database

PMT – Passenger-Miles Traveled

ROW – Right-of-Way

STP – Surface Transportation Program

TCRP – Transit Cooperative Research Program

TIFIA – Transportation Infrastructure Finance and Innovation Act

TIGER – Transportation Investment Generating Economic Recovery (Discretionary Grant Program)

TOD – Transit-Oriented Development

TRB – Transportation Research Board of the National Academies

TTI – Texas Transportation Institute

VMT – Vehicle-Miles Traveled

APPENDIX: SUMMARY OF THE TCRP PROJECT H-42 DATABASE

Table A-1: Overview of Projects

Key and Notes

- BRT – Bus Rapid Transit
- CR – Commuter Rail
- HRT – Heavy Rail Transit
- LRT – Light Rail Transit

Type:

- Initial – first fixed-guideway transit line in the region
- Extension – makes an existing line longer
- Expansion – adds a new line to an existing system
- Enhancement – adds stations (without extending line)

City & Project	Type	Average Weekday Ridership	Annual System PMT	Capital Cost (millions)	Cost per Route Mile (millions)	Cost per Rider (millions)
Cleveland Healthline	Expansion	12,850	276,271	$197	$29	$0.0153
Eugene EMX	Initial	6,600		$26	$6	$0.0039
Los Angeles Orange Line	Expansion	21,940	3,098,253	$371	$27	$0.0169
Chicago Metra North Central	Expansion	2,201	3,880,511	$247	$4	$0.1123
Chicago Metra South Central	Extension	4,125	3,880,511	$211	$19	$0.0512
Miami South Florida Tri-Rail Upgrades	Enhancement	36,510	822,877	$394	$5	$0.0108
Atlanta North / South Line	Expansion	113,948	861,297	$3,194	$144	$0.0280
Atlanta North Line Dunwoody Extension	Extension	9,381	861,297	$611	$328	$0.0651
Baltimore Metro	Initial	39,023	680,319	$2,040	$170	$0.0523
Chicago Douglas Branch	Extension	16,035	3,880,511	$503	$76	$0.0313
Chicago O'Hare Extension (Blue Line)	Extension	21,350	3,880,511	$469	$62	$0.0220
Chicago Orange Line	Expansion	32,334	3,880,511	$778	$86	$0.0241
Los Angeles Red Line (Segment 1)	Expansion	26,073	3,098,253	$2,566	$755	$0.0984
Los Angeles Red Line (Segment 2)	Expansion	45,410	3,098,253	$2,891	$445	$0.0637
Los Angeles Red Line (Segment 3)	Expansion	30,138	3,098,253	$1,733	$259	$0.0575
Miami Metrorail	Initial	58,121	822,877	$2,366	$113	$0.0407
Philadelphia SEPTA Frankford Rehab.	Enhancement	45,103	1,588,477	$1,186	$235	$0.0263
San Francisco BART Extension	Extension	19,501	2,372,623	$1,598	$184	$0.0820
Baltimore – Three Extensions	Extension	4,448	680,319	$140	$21	$0.0314
Baltimore Central Line	Expansion	24,541	680,319	$531	$23	$0.0216
Buffalo Metro Rail	Initial	24,076	78,709	$951	$149	$0.0395
Dallas North Central	Extension	12,304	478,539	$450	$36	$0.0366
Dallas S&W Oak Cliff and Park Lane	Extension	46,713	478,539	$1,137	$57	$0.0243
Denver Central Corridor	Expansion	36,403	454,082	$161	$30	$0.0044
Denver Southeast (T-REX)	Expansion	16,298	454,082	$876	$46	$0.0538
Denver Southwest Corridor	Initial	8,728	454,082	$228	$26	$0.0262
Los Angeles Green Line	Expansion	30,935	3,098,253	$1,225	$61	$0.0396

Table A-1: Overview of Projects, cont'd.

City & Project	Type	Average Weekday Ridership	Annual System PMT	Capital Cost (millions)	Cost per Route Mile (millions)	Cost per Rider (millions)
Los Angeles Long Beach Blue Line	Initial	79,349	3,098,253	$1,658	$37	$0.0209
Minneapolis Hiawatha Corridor	Initial	30,518	387,148	$454	$38	$0.0149
New York – Newark Elizabeth MOS-1	Expansion	1,065		$214	$214	$0.2009
New York Hudson-Bergen MOS 1 and 2	Expansion	40,100		$1,809	$117	$0.0451
Pasadena Gold Line	Expansion	23,681	3,098,253	$1,022	$73	$0.0432
Phoenix Metro Light Rail	Initial	40,772		$1,231	$62	$0.0302
Portland Airport Max	Expansion	3,005	460,769	$156	$28	$0.0520
Portland Interstate MAX LRT	Expansion	7,992	460,769	$333	$57	$0.0417
Portland MAX Segment I	Initial	60,229	460,769	$508	$33	$0.0084
Portland Westside/Hillsboro MAX	Expansion	34,223	460,769	$1,320	$74	$0.0386
Sacramento Folsom Corridor	Extension	6,587	161,049	$274	$25	$0.0417
Sacramento Mather Field Road Extension	Extension	6,711	161,049	$44	$7	$0.0066
Sacramento South Phase 1	Expansion	9,877	161,049	$225	$36	$0.0228
Sacramento Stage I	Initial	31,071	161,049	$360	$20	$0.0116
Salt Lake City Medical Center Extension	Extension	3,358	241,549	$87	$57	$0.0259
Salt Lake City North South Corridor	Initial	31,405	241,549	$412	$27	$0.0131
Salt Lake City University Extension	Expansion	7,285	241,549	$111	$44	$0.0152
San Diego Blue Line	Initial	41,361	544,326	$986	$39	$0.0238
San Diego Mission Valley East	Expansion	4,203	544,326	$521	$88	$0.1241
San Diego Orange Line	Expansion	23,113	544,326	$633	$29	$0.0274
San Jose North Corridor	Initial	11,272	188,422	$757	$46	$0.0672
San Jose Tasman East	Expansion	3,340	188,422	$335	$68	$0.1003
San Jose Tasman West	Expansion	1,977	188,422	$416	$55	$0.2106
San Jose VTA Capitol Segment	Extension	2,385	188,422	$205	$64	$0.0860
San Jose VTA Vasona Segment	Expansion	3,848	188,422	$374	$73	$0.0973
Seattle Central Link	Initial	19,719		$2,583	$186	$0.1310
Trenton – Southern New Jersey Light Rail Transit System	Expansion	8,150		$1,166	$42	$0.1430

Table A-2: Project Area Characteristics (within 1/2-mile of proposed stations)

Key and Notes

Table counts people and jobs within 1/2-mile radius of proposed stations

BRT – Bus Rapid Transit

CR – Commuter Rail

HRT – Heavy Rail Transit

LRT – Light Rail Transit

Job Categories:

- Leisure – all jobs in retail, entertainment, food
- Higher-income – more than $3,333 per month

CBD parking rate is price for 6- to 24-hour stay

City & Project	Total Jobs	Total Population	Leisure Jobs	Higher-income Jobs	Percent of Project At Grade	CBD Parking Rate
Cleveland Healthline	114,837	32,797	11,148	58,791	100.00%	$11.71
Eugene EMX	27,994	17,128	4,811	11,112	1	4
Los Angeles Orange Line	46,107	83,112	9,642	21,627	100.00%	$14.76
Chicago Metra North Central	23,971	34,463	2,189	10,632		$28.80
Chicago Metra South Central	14,978	35,312	1,668	6,544		$28.80
Miami South Florida Tri-Rail Upgrades	74,554	48,714	6,817	31,830		$9.00
Atlanta North / South Line	176,597	47,472	24,577	95,131	38.00%	$6.78
Atlanta North Line Dunwoody Extension	16,327	4,253	1,561	10,915	36.00%	$6.78
Baltimore Metro	72,145	59,848	7,766	39,443	25.00%	$13.86
Chicago Douglas Branch	28,652	115,554	3,319	11,273	11.00%	$28.80
Chicago O'Hare Extension (Blue Line)	30,026	10,811	4,556	16,076	93.00%	$28.80
Chicago Orange Line	20,176	65,718	6,946	5,635	0.00%	$28.80
Los Angeles Red Line (Segment 1)	136,311	48,170	16,566	86,502	15.00%	$14.76
Los Angeles Red Line (Segment 2)	70,634	174,905	14,419	27,012	0.00%	$14.76
Los Angeles Red Line (Segment 3)	25,292	28,817	6,234	10,461	0.00%	$14.76
Miami Metrorail	146,439	109,235	22,758	69,812	2.00%	$9.00
Philadelphia SEPTA Frankford Rehab.	21,056	102,181	3,432	8,007	0.00%	$24.00
San Francisco BART Extension	20,583	10,727	5,677	9,479	16.00%	$30.40
Baltimore – Three Extensions	27,985	5,510	3,009	17,482	99.00%	$13.86
Baltimore Central Line	68,690	57,014	12,125	32,949	99.00%	$13.86
Buffalo Metro Rail	65,298	45,417	6,249	28,857	18.00%	$6.79
Dallas North Central	57,228	20,750	7,738	31,078	81.00%	$5.89
Dallas S&W Oak Cliff and Park Lane	145,557	68,864	20,663	80,905	70.50%	$5.89
Denver Central Corridor	96,104	25,269	13,039	54,758	91.00%	$12.53
Denver Southeast (T-REX)	86,349	26,811	14,152	48,337	100.00%	$12.53
Denver Southwest Corridor	16,780	9,893	2,319	6,548	83.00%	$12.53
Los Angeles Green Line	66,818	74,088	7,932	45,986	62.00%	$14.76

Table A-2: Project Area Characteristics, cont'd.

City & Project	Total Jobs	Total Population	Leisure Jobs	Higher-income Jobs	Percent of Project At Grade	CBD Parking Rate
Los Angeles Long Beach Blue Line	185,178	180,511	23,870	81,408	81.00%	$14.76
Minneapolis Hiawatha Corridor	167,692	42,224	23,664	102,871	72.00%	$10.83
New York – Newark Elizabeth MOS-1	7,742	8,894	789	4,307	85.00%	$37.71
New York Hudson-Bergen MOS 1 and 2	88,742	211,414	13,418	54,265	83.00%	$37.71
Pasadena Gold Line	80,661	93,893	20,988	35,331	71.00%	$14.76
Phoenix Metro Light Rail	187,816	74,135	25,006	91,832	96.00%	$5.09
Portland Airport Max	5,319	3,108	1,507	1,672	100.00%	$8.75
Portland Interstate MAX LRT	16,343	18,279	3,286	7,122	88.00%	$8.75
Portland MAX Segment I	116,225	63,679	21,139	55,390	65.00%	$8.75
Portland Westside/Hillsboro MAX	64,900	50,141	16,215	27,163	81.00%	$8.75
Sacramento Folsom Corridor	40,202	15,579	7,145	22,082	99.00%	$11.83
Sacramento Mather Field Road Extension	7,599	18,996	1,664	3,111	97.00%	$11.83
Sacramento South Phase 1	9,559	27,610	1,729	3,703	98.00%	$11.83
Sacramento Stage I	63,851	42,573	10,007	32,000	100.00%	$11.83
Salt Lake City Medical Center Extension	22,057	1,709	110	10,862		$12.00
Salt Lake City North South Corridor	74,476	27,619	16,805	28,614	99.00%	$12.00
Salt Lake City University Extension	17,532	15,945	3,463	7,583	100.00%	$12.00
San Diego Blue Line	143,832	88,169	34,071	69,035	85.00%	$16.25
San Diego Mission Valley East	10,650	18,710	2,510	3,369	56.00%	$16.25
San Diego Orange Line	38,798	81,575	14,465	12,719	97.00%	$16.25
San Jose North Corridor	99,786	49,992	13,308	64,700	100.00%	$14.17
San Jose Tasman East	17,452	20,494	3,269	11,198	73.00%	$14.17
San Jose Tasman West	38,728	15,101	1,367	32,813	95.00%	$14.17
San Jose VTA Capitol Segment	4,819	29,645	1,847	1,654	100.00%	$14.17
San Jose VTA Vasona Segment	26,618	36,163	6,641	14,572	92.00%	$14.17
Seattle Central Link	161,394	61,817	22,591	99,498	41.50%	$21.96
Trenton – Southern New Jersey Light Rail Transit System	24,910	64,862	2,233	13,548	100.00%	$24.00

Table A-3: Existing Fixed-Guideway Area Characteristics (within 1/2-mile of existing stations)

Key and Notes

Table counts people and jobs within 1/2-mile radius of previously existing stations

- BRT – Bus Rapid Transit
- CR – Commuter Rail
- HRT – Heavy Rail Transit
- LRT – Light Rail Transit

Job Categories:
- Leisure – all jobs in retail, entertainment, food
- Higher-income – more than $3,333 per month

City & Project	Total Jobs	Total Population	Leisure Jobs	Higher-income Jobs
Cleveland Healthline	82,231	101,616	8,489	33,812
Eugene EMX				
Los Angeles Orange Line	748,613	762,662	117,217	326,956
Chicago Metra North Central	1,588,959	2,177,973	233,255	752,772
Chicago Metra South Central	1,597,952	2,177,124	233,775	756,861
Miami South Florida Tri-Rail Upgrades	128,135	112,926	24,489	48,829
Atlanta North / South Line	136,456	57,930	18,398	51,520
Atlanta North Line Dunwoody Extension	296,727	101,149	41,415	135,736
Baltimore Metro	205,248	116,964	28,730	89,147
Chicago Douglas Branch	1,584,278	2,096,882	232,124	752,131
Chicago O'Hare Extension (Blue Line)	1,582,904	2,201,625	230,887	747,328
Chicago Orange Line	1,592,754	2,146,718	228,497	757,769
Los Angeles Red Line (Segment 1)	658,409	797,604	110,292	262,082
Los Angeles Red Line (Segment 2)	724,086	670,870	112,440	321,572
Los Angeles Red Line (Segment 3)	769,428	816,957	120,625	338,122
Miami Metrorail	56,251	52,405	8,548	10,847
Philadelphia SEPTA Frankford Rehab.	938,729	1,395,396	143,566	427,490
San Francisco BART Extension	671,496	803,545	127,592	357,201
Baltimore – Three Extensions	249,408	171,302	33,487	111,108
Baltimore Central Line	208,703	119,798	24,371	95,641
Buffalo Metro Rail	4,215	0	-259	-1,916
Dallas North Central	222,912	94,852	30,467	107,135
Dallas S&W Oak Cliff and Park Lane	134,584	46,738	17,541	57,308
Denver Central Corridor	70,396	23,181	12,085	30,892
Denver Southeast (T-REX)	80,152	21,639	10,972	37,313
Denver Southwest Corridor	149,720	38,557	22,805	79,102
Los Angeles Green Line	727,902	771,686	118,927	302,598

Table A-3: Existing Fixed-Guideway Area Characteristics, cont'd.

City & Project	Total Jobs	Total Population	Leisure Jobs	Higher-income Jobs
Los Angeles Long Beach Blue Line	609,542	665,263	102,989	267,176
Minneapolis Hiawatha Corridor	-7,927	52	-1,733	-11,514
New York – Newark Elizabeth MOS-1	-7,742	-8,894	-789	-4,307
New York Hudson-Bergen MOS 1 and 2	-88,742	-211,414	-13,418	-54,265
Pasadena Gold Line	714,059	751,881	105,871	313,252
Phoenix Metro Light Rail	-187,816	-74,135	-25,006	-91,832
Portland Airport Max	193,341	143,860	41,236	78,332
Portland Interstate MAX LRT	182,317	128,689	39,456	72,882
Portland MAX Segment I	82,435	83,289	21,603	24,615
Portland Westside/Hillsboro MAX	133,760	96,827	26,528	52,841
Sacramento Folsom Corridor	81,085	81,537	11,959	28,538
Sacramento Mather Field Road Extension	113,689	78,120	17,441	47,509
Sacramento South Phase 1	111,729	69,506	17,375	46,917
Sacramento Stage I	57,437	54,543	9,097	18,621
Salt Lake City Medical Center Extension	92,701	46,178	23,481	29,405
Salt Lake City North South Corridor	40,282	20,268	6,787	11,652
Salt Lake City University Extension	97,225	31,942	20,129	32,683
San Diego Blue Line	119,953	123,686	27,149	43,156
San Diego Mission Valley East	253,134	193,145	58,710	108,823
San Diego Orange Line	224,986	130,280	46,754	99,472
San Jose North Corridor	170,017	179,540	24,113	108,436
San Jose Tasman East	252,350	209,038	34,152	161,938
San Jose Tasman West	231,075	214,431	36,054	140,323
San Jose VTA Capitol Segment	264,984	199,887	35,574	171,482
San Jose VTA Vasona Segment	243,184	193,370	30,780	158,565
Seattle Central Link	-161,394	-61,817	-22,591	-99,498
Trenton – Southern New Jersey Light Rail Transit System	-24,910	-64,862	-2,233	-13,548

Table A-4: Project Characteristics

Key and Notes
BRT – Bus Rapid Transit
CR – Commuter Rail
HRT – Heavy Rail Transit
LRT – Light Rail Transit

City & Project	Number of New Stations	Percent of New Alignment Below Grade	New Route Miles
Cleveland Healthline	30	0.00%	7
Eugene EMX	8	0.00%	4
Los Angeles Orange Line	14	0.00%	14
Chicago Metra North Central	22		55
Chicago Metra South Central	12		11
Miami South Florida Tri-Rail Upgrades	11		72
Atlanta North / South Line	18	32.00%	22
Atlanta North Line Dunwoody Extension	2	43.00%	2
Baltimore Metro	12	50.00%	12
Chicago Douglas Branch	11	0.00%	7
Chicago O'Hare Extension (Blue Line)	4	7.00%	8
Chicago Orange Line	8	0.00%	9
Los Angeles Red Line (Segment 1)	5	85.00%	3
Los Angeles Red Line (Segment 2)	8	100.00%	7
Los Angeles Red Line (Segment 3)	3	100.00%	7
Miami Metrorail	21	0.00%	21
Philadelphia SEPTA Frankford Rehab.	11	0.00%	5
San Francisco BART Extension	5	70.00%	9
Baltimore – Three Extensions	8	0.00%	7
Baltimore Central Line	22	0.00%	23
Buffalo Metro Rail	14	82.00%	6
Dallas North Central	9	0.00%	13
Dallas S&W Oak Cliff and Park Lane	21	18.20%	20
Denver Central Corridor	12	0.00%	5
Denver Southeast (T-REX)	13	0.00%	19
Denver Southwest Corridor	5	4.00%	9
Los Angeles Green Line	14	0.00%	20

Table A-4: Project Characteristics, cont'd.

City & Project	Number of New Stations	Percent of New Alignment Below Grade	New Route Miles
Los Angeles Long Beach Blue Line	22	3.00%	45
Minneapolis Hiawatha Corridor	17	28.00%	12
New York – Newark Elizabeth MOS-1	4	15.00%	1
New York Hudson-Bergen MOS 1 and 2	23	6.00%	15
Pasadena Gold Line	13	14.00%	14
Phoenix Metro Light Rail	28	3.00%	20
Portland Airport Max	4	0.00%	6
Portland Interstate MAX LRT	10	12.00%	6
Portland MAX Segment I	25	0.00%	15
Portland Westside/Hillsboro MAX	20	17.00%	18
Sacramento Folsom Corridor	10	0.00%	11
Sacramento Mather Field Road Extension	6	0.00%	6
Sacramento South Phase 1	7	0.00%	6
Sacramento Stage I	24	0.00%	18
Salt Lake City Medical Center Extension	3		2
Salt Lake City North South Corridor	16	0.00%	15
Salt Lake City University Extension	4	0.00%	3
San Diego Blue Line	31	1.00%	25
San Diego Mission Valley East	4	8.00%	6
San Diego Orange Line	24	0.00%	22
San Jose North Corridor	22	0.00%	17
San Jose Tasman East	7	0.00%	5
San Jose Tasman West	11	5.00%	8
San Jose VTA Capitol Segment	4	0.00%	3
San Jose VTA Vasona Segment	8	6.00%	5
Seattle Central Link	11	19.10%	14
Trenton – Southern New Jersey Light Rail Transit System	20	0.00%	28

Table A-5: Project Area Characteristics per square mile of catchment area

Key and Notes

Catchment area is area within 1/2-mile radius of new stations

BRT – Bus Rapid Transit
CR – Commuter Rail
HRT – Heavy Rail Transit
LRT – Light Rail Transit

Job Categories:
- Leisure – all jobs in retail, entertainment, food
- Higher-income – more than $3,333 per month

City & Project	Total Jobs	Total Population	Leisure Jobs	Higher-income Jobs
Cleveland Healthline	572,176	163,411	55,547	292,926
Eugene EMX	66,838	40,896	11,486	26,531
Los Angeles Orange Line	63,848	115,092	13,352	29,949
Chicago Metra North Central	30,964	44,517	2,827	13,734
Chicago Metra South Central	19,361	45,647	2,156	8,459
Miami South Florida Tri-Rail Upgrades	95,609	62,472	8,742	40,819
Atlanta North / South Line	273,123	73,419	38,010	147,128
Atlanta North Line Dunwoody Extension	22,034	5,739	2,106	14,730
Baltimore Metro	117,502	97,475	12,649	64,240
Chicago Douglas Branch	55,777	224,947	6,461	21,944
Chicago O'Hare Extension (Blue Line)	38,292	13,788	5,810	20,502
Chicago Orange Line	26,605	86,657	9,159	7,430
Los Angeles Red Line (Segment 1)	242,707	85,769	29,497	154,020
Los Angeles Red Line (Segment 2)	107,117	265,243	21,866	40,964
Los Angeles Red Line (Segment 3)	33,451	38,112	8,245	13,836
Miami Metrorail	229,941	171,523	35,735	109,620
Philadelphia SEPTA Frankford Rehab.	42,122	204,408	6,865	16,017
San Francisco BART Extension	26,250	13,680	7,239	12,088
Baltimore – Three Extensions	51,590	10,157	5,548	32,228
Baltimore Central Line	131,139	108,849	23,149	62,905
Buffalo Metro Rail	144,416	100,446	13,821	63,820
Dallas North Central	74,110	26,871	10,021	40,245
Dallas S&W Oak Cliff and Park Lane	236,706	111,988	33,603	131,569
Denver Central Corridor	271,463	71,377	36,831	154,674
Denver Southeast (T-REX)	110,792	34,401	18,158	62,020
Denver Southwest Corridor	21,551	12,706	2,978	8,410
Los Angeles Green Line	92,609	102,684	10,993	63,735

Table A-5: Project Area Characteristics per square mile of catchment area, cont'd.

City & Project	Total Jobs	Total Population	Leisure Jobs	Higher-income Jobs
Los Angeles Long Beach Blue Line	286,109	278,898	36,880	125,778
Minneapolis Hiawatha Corridor	304,704	76,723	42,999	186,922
New York – Newark Elizabeth MOS-1	44,034	50,588	4,490	24,497
New York Hudson-Bergen MOS 1 and 2	163,320	389,086	24,694	99,869
Pasadena Gold Line	116,018	135,050	30,188	50,818
Phoenix Metro Light Rail	337,800	133,337	44,976	165,166
Portland Airport Max	7,483	4,373	2,120	2,352
Portland Interstate MAX LRT	31,059	34,739	6,246	13,535
Portland MAX Segment I	259,272	142,054	47,157	123,562
Portland Westside/Hillsboro MAX	117,276	90,607	29,301	49,085
Sacramento Folsom Corridor	62,138	24,079	11,044	34,131
Sacramento Mather Field Road Extension	11,722	29,303	2,566	4,799
Sacramento South Phase 1	13,391	38,679	2,422	5,188
Sacramento Stage I	139,523	93,027	21,867	69,924
Salt Lake City Medical Center Extension	48,771	3,779	244	24,016
Salt Lake City North South Corridor	131,701	48,840	29,717	50,600
Salt Lake City University Extension	34,733	31,587	6,861	15,023
San Diego Blue Line	252,054	154,510	59,707	120,979
San Diego Mission Valley East	14,029	24,647	3,306	4,437
San Diego Orange Line	60,751	127,733	22,650	19,916
San Jose North Corridor	217,027	108,730	28,945	140,719
San Jose Tasman East	28,352	33,294	5,311	18,191
San Jose Tasman West	74,520	29,058	2,631	63,140
San Jose VTA Capitol Segment	7,114	43,767	2,727	2,442
San Jose VTA Vasona Segment	46,461	63,121	11,592	25,434
Seattle Central Link	258,497	99,010	36,183	159,361
Trenton – Southern New Jersey Light Rail Transit System	40,457	105,343	3,626	22,004

Table A-6: Metropolitan Statistical Area Characteristics per square mile of catchment area

Key and Notes

Catchment area is area within 1/2-mile radius of new stations

- BRT – Bus Rapid Transit
- CR – Commuter Rail
- HRT – Heavy Rail Transit
- LRT – Light Rail Transit

Job Categories:

- Leisure – all jobs in retail, entertainment, food
- Higher-income – more than $3,333 per month

City & Project	Total Jobs	Total Population	Leisure Jobs	Higher-income Jobs
Cleveland Healthline	9,727	6,634	969	4,571
Eugene EMX				
Los Angeles Orange Line	9,457	10,065	1,510	4,148
Chicago Metra North Central	6,821	9,357	996	3,229
Chicago Metra South Central	6,821	9,357	996	3,229
Miami South Florida Tri-Rail Upgrades	5,907	4,711	912	2,351
Atlanta North / South Line	12,185	4,102	1,673	5,708
Atlanta North Line Dunwoody Extension	12,185	4,102	1,673	5,708
Baltimore Metro	7,846	5,001	1,032	3,637
Chicago Douglas Branch	6,821	9,357	996	3,229
Chicago O'Hare Extension (Blue Line)	6,821	9,357	996	3,229
Chicago Orange Line	6,821	9,357	996	3,229
Los Angeles Red Line (Segment 1)	9,457	10,065	1,510	4,148
Los Angeles Red Line (Segment 2)	9,457	10,065	1,510	4,148
Los Angeles Red Line (Segment 3)	9,457	10,065	1,510	4,148
Miami Metrorail	5,907	4,711	912	2,351
Philadelphia SEPTA Frankford Rehab.	5,791	9,036	887	2,628
San Francisco BART Extension	9,852	11,592	1,897	5,220
Baltimore – Three Extensions	7,846	5,001	1,032	3,637
Baltimore Central Line	7,846	5,001	1,032	3,637
Buffalo Metro Rail	10,981	7,175	946	4,256
Dallas North Central	9,408	3,882	1,283	4,642
Dallas S&W Oak Cliff and Park Lane	9,408	3,882	1,283	4,642
Denver Central Corridor	8,377	2,438	1,264	4,309
Denver Southeast (T-REX)	8,377	2,438	1,264	4,309
Denver Southwest Corridor	8,377	2,438	1,264	4,309
Los Angeles Green Line	9,457	10,065	1,510	4,148

Table A-6: Metropolitan Statistical Area Characteristics per square mile of catchment area, cont'd.

City & Project	Total Jobs	Total Population	Leisure Jobs	Higher-income Jobs
Los Angeles Long Beach Blue Line	9,457	10,065	1,510	4,148
Minneapolis Hiawatha Corridor	11,133	2,946	1,528	6,366
New York – Newark Elizabeth MOS-1				
New York Hudson-Bergen MOS 1 and 2				
Pasadena Gold Line	9,457	10,065	1,510	4,148
Phoenix Metro Light Rail				
Portland Airport Max	5,700	4,217	1,226	2,295
Portland Interstate MAX LRT	5,700	4,217	1,226	2,295
Portland MAX Segment I	5,700	4,217	1,226	2,295
Portland Westside/Hillsboro MAX	5,700	4,217	1,226	2,295
Sacramento Folsom Corridor	4,721	3,780	744	1,970
Sacramento Mather Field Road Extension	4,721	3,780	744	1,970
Sacramento South Phase 1	4,721	3,780	744	1,970
Sacramento Stage I	4,721	3,780	744	1,970
Salt Lake City Medical Center Extension	7,955	3,319	1,635	2,791
Salt Lake City North South Corridor	7,955	3,319	1,635	2,791
Salt Lake City University Extension	7,955	3,319	1,635	2,791
San Diego Blue Line	5,420	4,353	1,258	2,305
San Diego Mission Valley East	5,420	4,353	1,258	2,305
San Diego Orange Line	5,420	4,353	1,258	2,305
San Jose North Corridor	5,978	5,086	829	3,836
San Jose Tasman East	5,978	5,086	829	3,836
San Jose Tasman West	5,978	5,086	829	3,836
San Jose VTA Capitol Segment	5,978	5,086	829	3,836
San Jose VTA Vasona Segment	5,978	5,086	829	3,836
Seattle Central Link				
Trenton – Southern New Jersey Light Rail Transit System				

Table A-7: Project Area Characteristics per station

Key and Notes

Table shows jobs and population within 1/2-mile radius of proposed stations, divided by number of proposed stations.

- BRT – Bus Rapid Transit
- CR – Commuter Rail
- HRT – Heavy Rail Transit
- LRT – Light Rail Transit

Job Categories:

- Leisure – all jobs in retail, entertainment, food
- Higher-income – more than $3,333 per month

City & Project	Total Jobs	Total Population	Leisure Jobs	Higher-income Jobs
Cleveland Healthline	3,378	965	328	1,729
Eugene EMX	3,499	2,141	601	1,389
Los Angeles Orange Line	3,547	6,393	742	1,664
Chicago Metra North Central	1,598	2,298	146	709
Chicago Metra South Central	1,248	2,943	139	545
Miami South Florida Tri-Rail Upgrades	4,142	2,706	379	1,768
Atlanta North / South Line	9,811	2,637	1,365	5,285
Atlanta North Line Dunwoody Extension	8,164	2,126	780	5,457
Baltimore Metro	6,012	4,987	647	3,287
Chicago Douglas Branch	2,605	10,505	302	1,025
Chicago O'Hare Extension (Blue Line)	7,507	2,703	1,139	4,019
Chicago Orange Line	2,522	8,215	868	704
Los Angeles Red Line (Segment 1)	45,437	16,057	5,522	28,834
Los Angeles Red Line (Segment 2)	8,829	21,863	1,802	3,376
Los Angeles Red Line (Segment 3)	8,431	9,606	2,078	3,487
Miami Metrorail	6,973	5,202	1,084	3,324
Philadelphia SEPTA Frankford Rehab.	1,914	9,289	312	728
San Francisco BART Extension	5,146	2,682	1,419	2,370
Baltimore – Three Extensions	3,498	689	376	2,185
Baltimore Central Line	2,748	2,281	485	1,318
Buffalo Metro Rail	4,664	3,244	446	2,061
Dallas North Central	6,359	2,306	860	3,453
Dallas S&W Oak Cliff and Park Lane	6,931	3,279	984	3,853
Denver Central Corridor	8,009	2,106	1,087	4,563
Denver Southeast (T-REX)	6,642	2,062	1,089	3,718
Denver Southwest Corridor	3,356	1,979	464	1,310
Los Angeles Green Line	5,140	5,699	610	3,537

Table A-7: Project Area Characteristics per station, cont'd.

City & Project	Total Jobs	Total Population	Leisure Jobs	Higher-income Jobs
Los Angeles Long Beach Blue Line	8,417	8,205	1,085	3,700
Minneapolis Hiawatha Corridor	9,864	2,484	1,392	6,051
New York – Newark Elizabeth MOS-1	1,548	1,779	158	861
New York Hudson-Bergen MOS 1 and 2	3,858	9,192	583	2,359
Pasadena Gold Line	6,205	7,223	1,614	2,718
Phoenix Metro Light Rail	6,708	2,648	893	3,280
Portland Airport Max	1,330	777	377	418
Portland Interstate MAX LRT	1,634	1,828	329	712
Portland MAX Segment I	4,649	2,547	846	2,216
Portland Westside/Hillsboro MAX	3,090	2,388	772	1,293
Sacramento Folsom Corridor	4,467	1,731	794	2,454
Sacramento Mather Field Road Extension	1,266	3,166	277	519
Sacramento South Phase 1	1,366	3,944	247	529
Sacramento Stage I	2,660	1,774	417	1,333
Salt Lake City Medical Center Extension	7,352	570	37	3,621
Salt Lake City North South Corridor	4,381	1,625	989	1,683
Salt Lake City University Extension	4,383	3,986	866	1,896
San Diego Blue Line	4,640	2,844	1,099	2,227
San Diego Mission Valley East	2,662	4,678	627	842
San Diego Orange Line	2,282	4,799	851	748
San Jose North Corridor	4,536	2,272	605	2,941
San Jose Tasman East	2,493	2,928	467	1,600
San Jose Tasman West	3,521	1,373	124	2,983
San Jose VTA Capitol Segment	1,205	7,411	462	414
San Jose VTA Vasona Segment	3,327	4,520	830	1,821
Seattle Central Link	12,415	4,755	1,738	7,654
Trenton – Southern New Jersey Light Rail Transit System	1,245	3,243	112	677

Table A-8: Metropolitan Statistical Area Characteristics per existing station

Key and Notes

Table shows jobs and population within 1/2-mile radius of existing stations, divided by number of existing stations.

BRT – Bus Rapid Transit
CR – Commuter Rail
HRT – Heavy Rail Transit
LRT – Light Rail Transit

Job Categories:

- Leisure – all jobs in retail, entertainment, food
- Higher-income – more than $3,333 per month

City & Project	Total Jobs	Total Population	Leisure Jobs	Higher-income Jobs
Cleveland Healthline	2,346	1,600	234	1,102
Eugene EMX				
Los Angeles Orange Line	6,678	7,107	1,066	2,929
Chicago Metra North Central	4,233	5,807	618	2,004
Chicago Metra South Central	4,233	5,807	618	2,004
Miami South Florida Tri-Rail Upgrades	3,685	2,939	569	1,467
Atlanta North / South Line	8,238	2,774	1,131	3,859
Atlanta North Line Dunwoody Extension	8,238	2,774	1,131	3,859
Baltimore Metro	4,702	2,997	619	2,179
Chicago Douglas Branch	4,233	5,807	618	2,004
Chicago O'Hare Extension (Blue Line)	4,233	5,807	618	2,004
Chicago Orange Line	4,233	5,807	618	2,004
Los Angeles Red Line (Segment 1)	6,678	7,107	1,066	2,929
Los Angeles Red Line (Segment 2)	6,678	7,107	1,066	2,929
Los Angeles Red Line (Segment 3)	6,678	7,107	1,066	2,929
Miami Metrorail	3,685	2,939	569	1,467
Philadelphia SEPTA Frankford Rehab.	2,908	4,538	445	1,320
San Francisco BART Extension	3,549	4,176	683	1,880
Baltimore – Three Extensions	4,702	2,997	619	2,179
Baltimore Central Line	4,702	2,997	619	2,179
Buffalo Metro Rail	4,965	3,244	428	1,924
Dallas North Central	6,515	2,688	888	3,214
Dallas S&W Oak Cliff and Park Lane	6,515	2,688	888	3,214
Denver Central Corridor	4,897	1,425	739	2,519
Denver Southeast (T-REX)	4,897	1,425	739	2,519
Denver Southwest Corridor	4,897	1,425	739	2,519
Los Angeles Green Line	6,678	7,107	1,066	2,929

Table A-8: Metropolitan Statistical Area Characteristics per existing station, cont'd.

City & Project	Total Jobs	Total Population	Leisure Jobs	Higher-income Jobs
Los Angeles Long Beach Blue Line	6,678	7,107	1,066	2,929
Minneapolis Hiawatha Corridor	6,657	1,761	914	3,807
New York – Newark Elizabeth MOS-1				
New York Hudson-Bergen MOS 1 and 2				
Pasadena Gold Line	6,678	7,107	1,066	2,929
Phoenix Metro Light Rail				
Portland Airport Max	2,515	1,860	541	1,013
Portland Interstate MAX LRT	2,515	1,860	541	1,013
Portland MAX Segment I	2,515	1,860	541	1,013
Portland Westside/Hillsboro MAX	2,515	1,860	541	1,013
Sacramento Folsom Corridor	2,637	2,111	415	1,100
Sacramento Mather Field Road Extension	2,637	2,111	415	1,100
Sacramento South Phase 1	2,637	2,111	415	1,100
Sacramento Stage I	2,637	2,111	415	1,100
Salt Lake City Medical Center Extension	4,098	1,710	843	1,438
Salt Lake City North South Corridor	4,098	1,710	843	1,438
Salt Lake City University Extension	4,098	1,710	843	1,438
San Diego Blue Line	3,565	2,863	827	1,516
San Diego Mission Valley East	3,565	2,863	827	1,516
San Diego Orange Line	3,565	2,863	827	1,516
San Jose North Corridor	3,504	2,981	486	2,249
San Jose Tasman East	3,504	2,981	486	2,249
San Jose Tasman West	3,504	2,981	486	2,249
San Jose VTA Capitol Segment	3,504	2,981	486	2,249
San Jose VTA Vasona Segment	3,504	2,981	486	2,249
Seattle Central Link				
Trenton – Southern New Jersey Light Rail Transit System				

VOLUME 2

Research Report

CONTENTS

CHAPTER 1

Introduction

This research report describes a method for estimating the likely success of proposed fixed-guideway rail projects. The method is more complex than typical indicator-based techniques used by transit agencies, but simpler than four-step forecasting models, FTA analysis requirements, or other advanced evaluation methods. The success metrics are based on predictions of project-level ridership, predicted changes in system-level transit usage, and estimated capital costs. The metrics can help decision-makers gauge the potential success of investments, based on the unique characteristics of the corridor and station areas to be served and the metropolitan areas in which they are located.

The research was conducted for TCRP Project H-42, "An Exploration of Fixed Guideway Transit Criteria Revisited." The objective of the project was to identify conditions and characteristics necessary to support fixed-guideway transit system projects and provide guidance on evaluating proposed projects. The researchers' task was to provide an analytical framework and a set of tools in the form of a handbook and spreadsheet tool that decision-makers at all levels could use to determine whether conditions are present to support the success of their proposed investment.

As part of the project, the research team:

- Reviewed relevant literature and data sources to identify ways that transit system success is measured.
- Conducted two rounds of focus groups and interviews with transit professionals in the private sector, public sector, and academia.
- Prepared a preliminary list of transit project success measures and possible indicators or predictors of that success.
- Assembled a geographic data set of fixed-guideway transit stations and networks in the United States, covering 3,263 transit stations in 44 metropolitan areas.
- Collected data at the station, project, and metropolitan area levels, including system and station ridership, agency operating costs, project capital costs, regional and local demographics, employment, gross domestic product (GDP), gas prices, parking availability and pricing, regulatory restrictiveness in land uses, rail and highway networks, and transit service characteristics.
- Conducted regression analyses to identify station-area, corridor, and metropolitan-area factors that are the most significant predictors of project-level ridership and system-level passenger-miles traveled (PMT).
- Developed a spreadsheet tool based on the regression analysis results.
- Carried out case studies of six transit projects in different parts of the United States, reviewing public reports and other materials, conducting site visits, and interviewing transit planners, metropolitan planning organization (MPO) officials, and consultants who worked on the projects.

Given the lengthy, costly, and uncertain process that currently guides the process of evaluating, prioritizing, and funding transit projects, the research team sought to simplify and inform a preliminary evaluation of projects by identifying a series of indicators of project success that could be applied without requiring extensive analysis. The spreadsheet tool, based on such indicators, enables local agencies to identify projects most worthy of further development and support.

The research report summarizes and discusses the literature review, data sources, focus groups, and interviews with transportation professionals conducted for the project. The data collection process is outlined, as is the rationale behind the observations and variables included in the final data set for analysis; the analysis approach is described, and the models are presented that best predict project ridership and system-wide transit usage based on information about the region, the corridor, and proposed project characteristics. Case studies are included that were conducted on selected U.S. fixed-guideway projects that provide qualitative success measures and indicators to supplement the findings from the quantitative analysis. The cases offered a reminder that other factors often weigh in project decisions, and that heuristic indicators will continue to play an important role. The case studies also helped the researchers revise the analysis and improve the usability of the spreadsheet tool.

The spreadsheet tool is available for download from the *TCRP Report 167* web page, which can be accessed at www.trb.org by searching "TCRP Report 167". The accompanying handbook, presented as Volume 1 in *TCRP Report 167*, provides an overview of the project, summarizes the use of indicator-based methods, and offers guidance on the spreadsheet tool and how to use it.

1.1 Indicator-Based Methods

The characteristics of fixed-guideway transit projects and their surrounding corridors may serve as predictors, or indicators, of project success, as defined in various ways. Indicator-based methods provide an analysis approach for predicting success that is simpler than common four-step transportation models using zonal data. Although they are not a substitute for those methods, indicator-based methods can be used to conduct an initial evaluation of corridor alternatives.

The indicator-based method developed by this study is relatively sophisticated, based on empirical research, and focused on project ridership and system usage rather than other success measures. Development of the method involved extensive original analysis of data about existing fixed-guideway transit projects in the United States.

Local agencies might use this method to:

- Assess whether it is worthwhile to expend funds on detailed project planning studies,
- Compare various corridors within a region to see which offers the greatest potential for a transit project, or
- Test various project and land use scenarios within a particular corridor to identify those that deserve more detailed study.

This report focuses on ridership, system patronage, and capital costs. The research does not deal directly with operating costs, user and non-user benefits, or hard-to-quantify impacts such as network effects, social equity, and environmental improvements, any of which could justify some projects that would not otherwise make the grade. Further, the researchers designed a mode-agnostic model, meaning that the model does not assume ridership bonuses for more desirable modes. This approach has both strengths and limitations, which are discussed at more length in Chapter 4.

Indicator-based methods for assessing transit opportunities have been used in practice for many years. For example, in 1976, New York's Regional Plan Association suggested transit mode suitability criteria based on size of the downtown and residential density (Table 1.1).

Table 1.1. Transit investment suitability criteria according to regional plan association, 1976.

Transit Vehicle Mode	Minimum Downtown Size, Square Feet of Contiguous Non-Residential Floor Space (millions)	Minimum Residential Density, Dwelling Units per Acre
Local bus	2.5	4 to 15[a]
Express bus	7	3 to 15[a]
Light rail	21	9
Heavy rail	50	12
Commuter rail	70	1 to 2[a]

[a] Varies with type of access and frequency of service.
Source: Regional Plan Association, *Where Transit Works: Urban Densities for Public Transportation.* New York, 1976.

The Regional Plan Association's recommendations were followed by Pushkarev and Zupan's research, which led to the book *Urban Rail in America.* (Pushkarev and Zupan 1982) Today, transit planners rely on guidelines such as these when they develop system plans and identify potential new transit routes, often using a variety of indicators to make relative comparisons between corridors within their regions to identify those with the greatest transit potential. Many of the indicators used are similar to those already noted—the amount of population and employment in a corridor, population and employment density—but they may also include other factors, such as the presence of transit-supportive policies, the level of highway congestion, the availability of right-of-way, and public support. For example, *A Toolbox for Alleviating Traffic Congestion* (Institute for Transportation Engineers 1989) offers general guidelines as follows:

> Light rail transit is most suitable for service to non-residential concentrations of 35 to 50 million square feet. If rights-of-way can be obtained at grade, thereby lowering capital costs, this threshold can be lowered to the 20 million square foot range. Average residential densities of about 9 dwelling units per acre over the line's catchment area are most suitable. For longer travel distances where higher speeds are needed, rapid transit is most suitable for non-residential concentrations beyond 50 million square feet and in corridors averaging 12 dwelling units per acre or more.
>
> Commuter rail service, with its high speed, relatively infrequent service (based on a printed schedule rather than regular headways) and greater station spacing is suitable for low density residential areas—1 to 2 dwelling units per acre. However, the volumes required are only likely in corridors leading to non-residential concentrations of 100 million square feet or more, found only in the nation's largest cities.

The San Francisco Bay Area Metropolitan Transportation Commission (MTC) has adopted a set of housing density

Table 1.2. MTC housing density thresholds.

	BART HRT	LRT	BRT	CR	Ferry
Housing threshold (Average housing units per station area)	3,850	3,300	2,750	2,200	750

HRT = heavy rail transit; LRT = light rail transit; BRT = bus rapid transit; CR = commuter rail
Source: San Francisco Bay Area MTC Resolution 3434, Attachment D-2, as revised July 27, 2005.

thresholds by transit mode that projects are expected to meet before the MTC programs funds (Table 1.2). According to the MTC's Resolution 3434, "Each proposed physical transit extension project seeking funding through Resolution 3434 must demonstrate that the thresholds for the corridor are met through existing development and adopted station-area plans that commit local jurisdictions to a level of housing that meets the threshold" (MTC 2006).

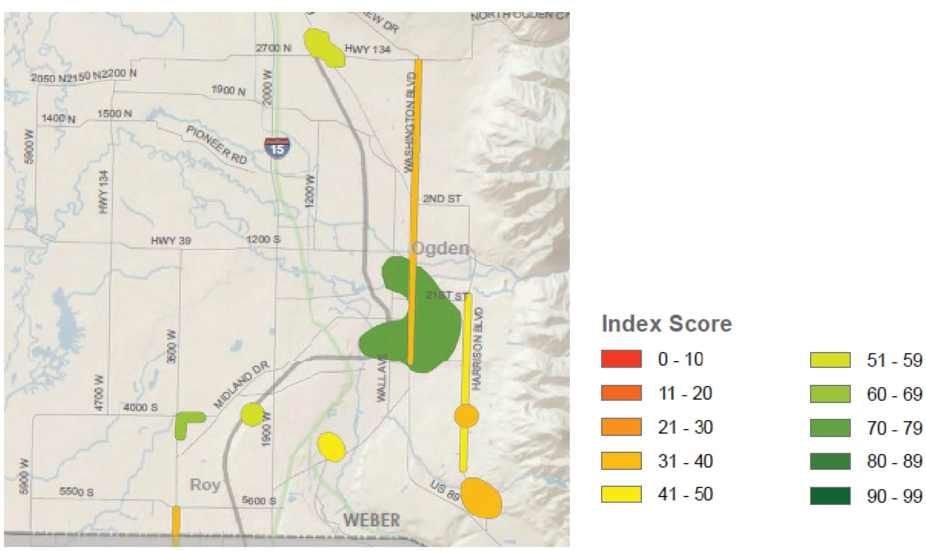
The Utah Transit Authority calculates a Transit Preparedness Index to identify those parts of its service area that have the characteristics to support a successful transit investment (Utah Transit Authority 2005). The index (see Figure 1.1) relies on five criteria to identify the best places in the region for improving transit service:

1. Transit-oriented development (TOD) or mixed-use zoning (up to 40 points);
2. TOD or mixed-use development in general plan (up to 10 points);
3. Bicycle/pedestrian plan (up to 10 points);
4. Amenity proximity score based on walkscore.com (up to 10 points); and
5. Intersection density based on walkscore.com (up to 30 points).

Consulting firms have developed proprietary indicator-based tools. One such tool is the Transit Competitiveness Index (TCI) (see Figure 1.2). This tool offers a way to score different travel markets in terms of how well transit is likely to compete with the automobile. The TCI accounts for various transportation and land use characteristics—trip volumes, land use density, parking cost, and congestion—along with trip purpose and household characteristics to produce a numeric score. Depending on the score, individual markets are characterized as strongly competitive, marginally competitive, marginally uncompetitive, or uncompetitive. Further information about the TCI is available at:

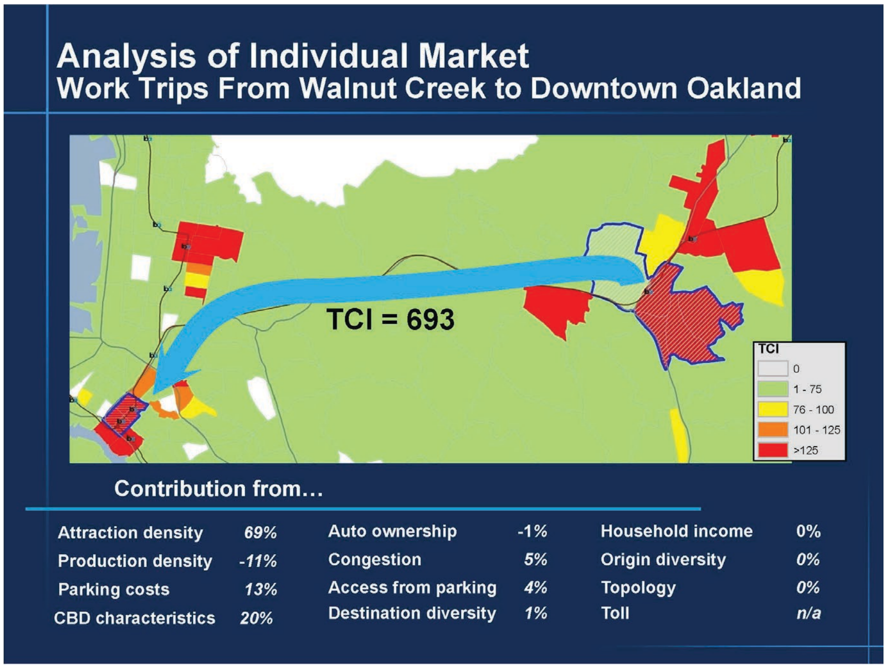
http://www.mtc.ca.gov/planning/tsp/TCI-DRAFT-PRIMER.pdf

The Portland Metro (the MPO for the Portland, Oregon region) applied an interactive web-based build-a-system tool as part of the public involvement process for its High Capacity Transit System Plan (see Figure 1.3). According to Metro's plan,



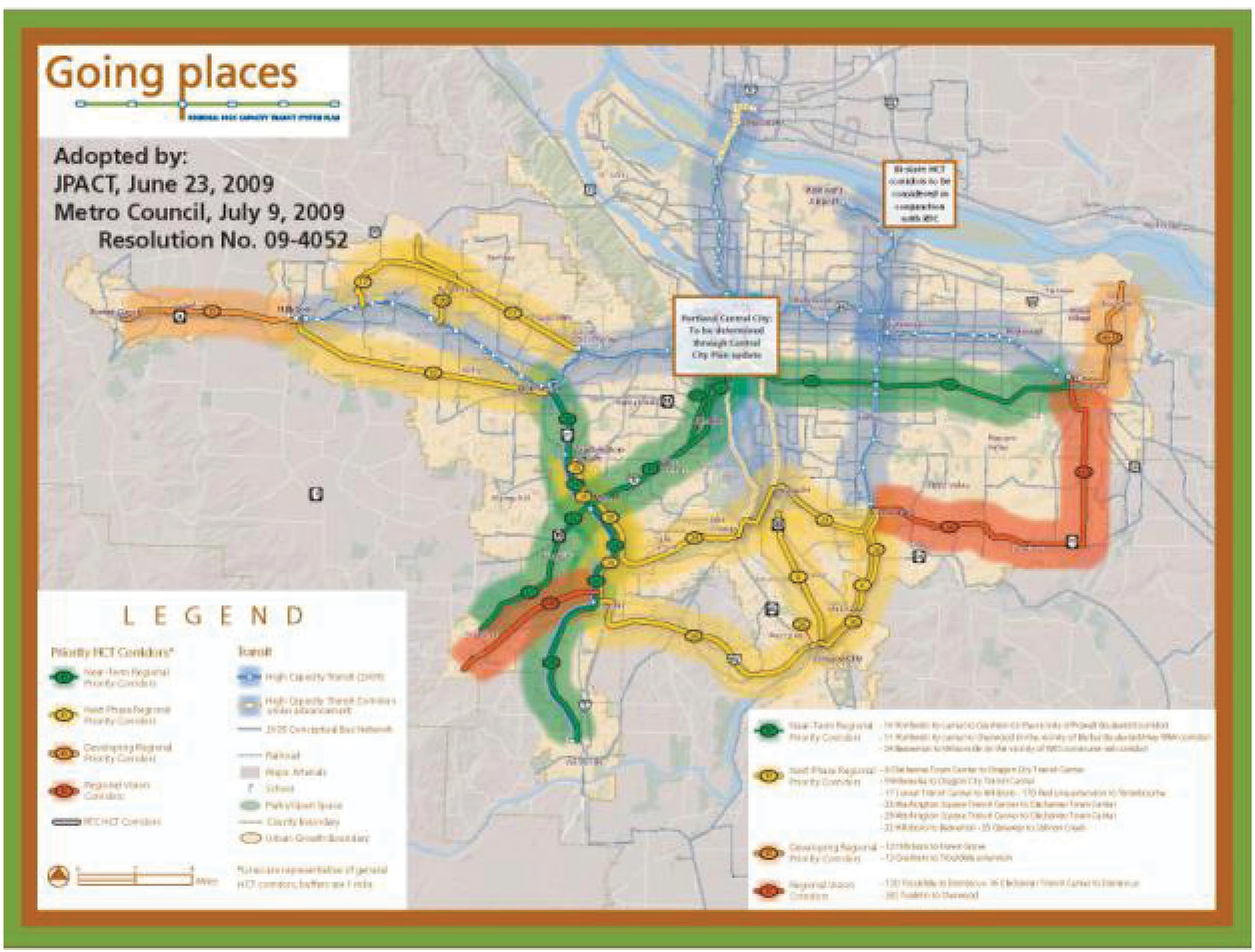
Source: Utah Transit Authority, 2005

Figure 1.1. Transit preparedness index for Weber County.



Source: MTC and Cambridge Systematics, Inc.

Figure 1.2. Sample use of the TCI.



Source: Portland Metro

Figure 1.3. Build-a-system tool, Portland, Oregon.

> [The] tool allowed community members to explore trade-offs between corridors and build their own high capacity transit system. With the build-a-system tool, community members learned about centers that could be served by high capacity transit and to compare corridors based on ridership, travel time, operations cost, capital cost, and environmental benefits (Portland Metro 2009).

Metro's interactive tool is more fully described at

http://www.oregonmetro.gov/index.cfm/go/by.web/id=26680.

1.2 Historical Best Practices: Pushkarev and Zupan

The research for TCRP Project H-42 has many precedents, including *Public Transportation and Land Use Policy* (Pushkarev and Zupan 1977) and *Urban Rail in America* (Pushkarev, Zupan, and Cumella 1982). These studies inspired rules of thumb regarding the feasibility of different levels of transit investment in given corridors. The 1977 study used non-residential central business district (CBD) floor space, dwelling units per residential acre near stations, and distance to the CBD to estimate transportation demand across a variety of transit modes, ranging from dial-a-ride taxis to heavy rail transit (HRT). Per-passenger operating costs were calculated for each of the modes, and on that basis the potential service frequency (based on demand) was estimated in terms of average daily trip origins produced per square mile. The authors suggested minimum threshold residential densities and downtown sizes that would be required to support various levels of cost-effective service across different modes (Table 1.3). For example, heavy rail rapid transit at 5-minute peak-hour headways along a transit corridor of 100 to 150 square miles required a minimum threshold of 12 dwelling units per residential acre along the corridor and 50 million square feet of non-residential space in the downtown. Light rail transit (LRT) operating at 5-minute peak-hour headways along a 25 to 100 square mile corridor required only nine dwelling units per residential acre and 20 to 50 million square feet of non-residential space. Thresholds to support bus service varied, based on service frequency, from four to 15 dwelling units per residential acre and 10 to 35 million square feet of non-residential space. Commuter rail transit operating 20 trains per day was supported by just one or two dwelling units per residential acre on corridors to the largest downtown in the region.

Urban Rail in America continued the previous research and focused on rail, using data from 24 CBDs in the Tri-State area of New York, New Jersey, and Connecticut. The authors calibrated a decay function demand model to estimate trips from a residential area to the downtown as a function of downtown non-residential floor space, residential area population distribution, and the distance between the two. CBD non-residential attractors that were farther away from the residential population exerted less influence and generated fewer trips to the downtown than those that were located closer. The relative importance of non-residential development outside of the CBD also influenced travel demand; areas with fewer competing attractions outside of the downtown attracted more trips to the CBD. The authors incorporated total estimated demand for downtown trips into a mode share model to determine the attractiveness of fixed-guideway transit versus the private automobile.

Dramatic changes have occurred in metropolitan area development patterns, the work force, economic conditions, and

Table 1.3. Transit-supportive residential density and employment thresholds (adapted from Pushkarev and Zupan 1977).

Mode: Service	Minimum Dwelling Units per Residential Acre	Size of Downtown
Local bus: minimum (20 buses per day)	4	10 million square feet non-residential
Local bus: frequent (120 buses per day)	15	35 million square feet non-residential
LRT: (5-minute peak-hour headways)	9 (corridor of 25 to 100 square miles)	20 to 50 million square feet non-residential
HRT (rapid): (5-minute peak-hour headways)	12 (corridor of 100 to 150 square miles)	50+ million square feet non-residential
Commuter rail: (20 trains per day)	1 to 2	Largest in region

gasoline prices since these seminal studies were carried out. There has also been a renewed investment in fixed-guideway transit projects. APTA reports that there are now 27 CR rail, 15 HRT (subway) and 27 LRT systems in the United States. In addition, BRT has been adopted in several municipalities as a new alternative to traditional transit modes, allowing communities historically priced out of rail technology to develop cost-effective transit networks. As of 2013, APTA counts five BRT systems in the United States. Since 1980, ridership on commuter, heavy, and light rail has grown from 2.52 billion to 4.47 billion trips per year, and passenger-miles have grown from 17.5 billion to 29.5 billion (APTA 2012).

Data and analysis tools also have changed. Developments in research methods, more readily available land use and transportation data, and ubiquitous computing and geographical information system (GIS) technology have pushed both the state of the art and the state of the practice of indicator development and measurement. It is now possible to incorporate or create more explicit and accurate measures such as gravity-model-based accessibility indexes for transit and auto; more-refined measurements of population and employment characteristics within specific walking-distance buffers around transit stations; congestion data; and parking prices. This research effort has benefited from these advances.

The direction the research team took in TCRP Project H-42 is in some ways quite different from previous indicator-based approaches. With more data and analysis tools have come the ability to make better estimates and more information about the uncertainty of predictions. More data and tools also made it possible to characterize ridership and cost along a continuum rather than providing thresholds at which particular technologies can be used, and to consider the effects of projects on patronage at the system level. This flexibility is useful and warranted. Ridership can vary greatly; system impacts can be distinct from project-level measures; and the capital cost and operating costs of different technologies implemented in different settings can vary greatly.

1.3 FTA Investment Criteria

The single largest source of funds for transit improvements in the United States is the FTA Capital Investment Program (49 U.S.C. § 5309). This discretionary grant program provides capital assistance for new fixed-guideway systems (New Starts and Small Starts), corridor-based BRT projects (Small Starts), and capacity expansions on existing fixed-guideways (Core Capacity). In recent years, the program has been funded at close to $2 billion per year. As local transit project sponsors typically rely on substantial funding from FTA, many state and regional transit funding policies mirror those of FTA (Deakin et al. 2002). Thus, it is important to understand the research being conducted under TCRP Project H-42 in light of FTA's Section 5309 programs.

The Section 5309 New Starts and Small Starts Program is currently the federal government's primary method of funding new fixed-guideway transit investments for both the construction of new fixed-guideway systems and extensions to existing fixed-guideway systems. Commuter rail, HRT, LRT, BRT, monorails, automated people movers, and streetcar projects are eligible to apply for financial assistance.

New Starts and Small Starts funding is allocated to major capital projects on a discretionary basis—one of the few instances when U.S. DOT funding is not distributed by formula. To help manage the competition for funds, FTA evaluates New Starts and Small Starts projects within a multicriteria analysis framework. The framework provides a structured approach for developing a project rating, based on a set of criteria and a series of weights.

Under MAP-21, FTA's rating system uses six project justification criteria, three local financial commitment criteria, and a five-point rating scale (high, medium-high, medium, medium-low, and low) for each of the criteria (Table 1.4). FTA guidance offers more specifics on the measures, recommends the weights for each criterion, and specifies the breakpoints that FTA will use when applying the five-point ratings scale. Projects must receive at least a medium rating on both justification and financial commitment to move to the next phase and ultimately be considered for a grant.

Some of the rating criteria are assessed qualitatively while others (e.g., mobility improvements, cost effectiveness, environmental benefits) are quantified using transportation planning models. Models are used, for example, to estimate the number of daily riders expected to use a project, and the change in vehicle-miles traveled (VMT). Project ridership is combined with capital and operating/maintenance cost estimates to assess

Table 1.4. FTA MAP-21 project criteria.

Project Justification Criteria	Local Financial Commitment Criteria
Mobility improvements	Current financial condition
Cost effectiveness	Commitment of funds
Environmental benefits	Reliability/capacity of the financial plan
Congestion relief	
Land use	
Economic development	

cost effectiveness. FTA reviews the models, the model inputs, and the model outputs. To reduce the burden of these reviews, in September 2013 FTA released a simplified travel forecasting model for predicting transit ridership on fixed-guideway projects. The FTA model is the Simplified Trips-On-Project Software (STOPS). A project's land use and economic development ratings are based on FTA's qualitative assessment of the current land use conditions, plans and policies for future land use, and affordable housing considerations. Financial ratings are based on projections of project costs and revenues, along with somewhat qualitative assessments of the reliability and completeness of underlying forecasts.

There has been interest in applying streamlined evaluation measures (or warrants) to FTA's project evaluation process, and MAP-21 specifically encourages the use of warrants.

TCRP Project H-42 sought a simplified way for local agencies to evaluate proposed fixed-guideway transit alternatives based on relatively simple indicators of project success or merit that might be applied, without requiring extensive analysis, at least as a screening phase. With the procedure presented in *TCRP Report 167*, local agencies can quickly develop an initial estimate of the ridership likely on a project before spending scarce resources on more detailed studies.

CHAPTER 2

Literature and Data Review

TCRP Project H-42 began with a review of previous studies and a search for data sources to (1) ascertain relevant measures of success from varying definitions of what constitutes successful transit systems, and (2) identify and describe what is currently known about indicators of success, or characteristics that determine whether a transit project will likely be successful.

2.1 Previous Studies

Recent work continues to confirm the importance of population density (Taylor et al. 2009) and employment density (Barnes 2005) as predictors of transit ridership. Income measures (Taylor et al. 2009), measures of network configuration (Thompson and Brown 2006, 2010, 2012; Thompson et al. 2012), service frequency (Evans 2004), bus line connections (Kuby et al. 2004) and park-and-ride spaces (Kuby et al. 2004) are additional indicators found by other studies. Guerra and Cervero (2011) studied more than 50 nationwide HRT, LRT, and BRT projects, and determined that jobs and population in the service area, number of park-and-ride spots, frequency of service, and GDP were correlated with transit ridership.

Additional often-cited predictors of transit use include population characteristics such as education level, immigrant status, renter status, and car ownership (Taylor et al. 2009; Chatman and Klein 2009; Kuby et al. 2004); service characteristics such as fare (Guerra and Cervero 2011; McCollom and Pratt 2004; Kohn 1999), revenue vehicle-miles (Kohn 1999) and speed (Guerra and Cervero 2011); average station distance to the CBD (Guerra and Cervero 2011; Kuby et al. 2004); transit network service coverage (Thompson and Brown 2006, 2010, 2012; Thompson et al. 2012); weather (Kuby et al. 2004); and fuel price (Guerra and Cervero 2011). Researchers have also investigated indicators such as trip destination type (Barnes 2005) and centrality, which measures relative accessibility of each station to all other stations determined by average travel times (Kuby et al. 2004). Some studies differentiate the significant indicators of transit usage by mode, and recent work has found that the strength and nature of influential factors vary by transit type (Thompson and Brown 2012). One element that might predict automobile use but that is often excluded from these studies is the cost of private auto use as measured by congestion indexes and parking prices.

Indicator-based analysis represents only one of many possible approaches to examining the likely demand for transit. Other aggregate demand methodologies might generate comparative statistics across different transit systems, though their conclusions are sometimes based on heuristic rules instead of predictive models. For example, recent reports for the Brookings Institution have emphasized the importance of job accessibility via transit as a sign of a successful transit system and formed conclusions about the lack of such transit accessibility across 371 transit providers in 100 of the nation's largest metropolitan areas (Tomer et al. 2011; Tomer 2012).

Other travel-demand estimation methods use disaggregate data on households or individuals. They might include a traditional four-step model that employs a sequential framework based on four choice dimensions, or disaggregate models that use survey data to explain individual-level behavior around discrete choices (Small and Verhoef 2007). Few travel-demand studies have investigated the importance of multimodal interactions, impacts over time, the relative costs of transit versus auto, or parking availability. Successfully carrying out an analysis of these potential indicators is a significant challenge because data are difficult to assemble. There are also relatively few systems to study and compare in order to produce robust and reliable statistical results.

In summary, previous studies of transit lines and systems have concluded that multiple indicators determine transit project success, including population concentration near transit stations, the relative cost of automobile travel, and transit service characteristics such as fares, speed, access, and frequency. They also found that household income and minority status are correlated with ridership within cities, although

Table 2.1. Summary of measures and predictors of success considered for analysis.

Measures of Success	Predictors of Success
1. Cost and Ridership Metrics (Primary) Cost (capital and operating) *Average cost per passenger, per passenger-mile, per mile, per hour of time savings, per new transit trip.* *Operating cost recovery ratio* Ridership *Ridership totals, change in ridership, ridership per capita*	**1. Transit Supply Costs/Revenues** Capital costs Change in operating costs Service supply (frequency by time of day) Transit fares Network attributes (e.g., route alignment)
2. Economic Cost-benefit Analysis (Primary) Net present value > 0 Marginal benefits > marginal costs (including external costs such as congestion and pollution)	**2. Transit Demand** Socioeconomics of user Costs and travel time of alternatives (e.g., car, local bus) Land use and transit ridership (built-environment factors) *Employment and population density* *Station-area characteristics (e.g., distance from CBD)*
3. Land Use Impacts (Secondary) Increased development and densification Higher land value & property tax revenues	**3. Development Potential** Available land Strong real estate market Permissive regulations Targeted infrastructure expansion Tax incentives
4. Equity Measures (Secondary) Benefits and costs to disadvantaged individuals, populations, or regions	

some researchers contest these two indicators. The presumed impact of household income might be influenced by the fact that fixed-guideway transit systems across the United States tend to serve commuters with higher average incomes, and minority status might merely be a proxy for other, unmeasured elements, such as transit dependence or captivity. A summary of the measures and indicators of success that were considered for inclusion in the analysis is included in Table 2.1.

2.2 Data

Before beginning the data collection and subsequent analysis, the research team catalogued and described existing data on transit capital, operating, maintenance, disposal, and life cycle costs; transit agency and private household expenditures; transit networks; car parking; employment and population densities; levels of mixed-use development; and transit- and auto-based accessibility measures (Table 2.2). For many of these measures there is considerable variation in the unit of analysis (e.g., state, transit agency, metropolitan area, census tract and block, or household), the survey period (e.g., short-, mid-, or long-term) and the update frequency (e.g., decennial, annual, quarterly, or monthly). It is challenging to find data on network attributes, intermodal facilities, parking costs and availability, BRT systems, and urban design characteristics.

For a more complete summary of the data reviewed, see Appendix A.

2.2.1 Catchment Area Analysis

The research team compiled regional demographic information for the nationwide analysis of metropolitan areas from the 2000 U.S. Census and 1-year American Community Survey (ACS) for each year from 2005 through 2009. ACS data was collected by metropolitan area and census data by county, which was then aggregated up to the metropolitan area through either a summation or weighted average. Included in the information gathered were characteristics of the population (race, median age), households (occupancy, tenure, median rent and value), the economy (median household income, per capita income, percentage of population below poverty line), and the workforce (workers per person, commute mode to work, vehicles per household). The census and ACS regional economic information was supplemented with metropolitan area economic data from the U.S. Bureau of Labor Statistics (BLS) and the U.S. Bureau of Economic Analysis (BEA), including job counts, unemployment figures, personal income levels, and GDP from 2000 through 2009.

The researchers also incorporated metropolitan area demographic information through an analysis of the characteristics of catchment areas around each station. Census 2000 block and block-group data was spatially applied to the station catchment areas that cut around or through them, and the catchment area information was then aggregated up to the metropolitan level. At the block level, census data was collected on age, race

Table 2.2. Possible predictors of transit success considered.

Indicator	Data Source	Data	Notes
Employment density and diversity; size of job centers	Census, county business patterns, Longitudinal Employer-Household Dynamics (LEHD), Bureau of Labor Statistics (BLS), Bureau of Economic Analysis (BEA)	Workers by industry, at different spatial levels	Higher density increases potential ridership and may serve as a proxy for higher road costs when concentrated in centers.
Resident and regional characteristics and income	U.S. Census, American Community Survey (ACS), Public Use Microdata Sample (PUMS) , BEA, BLS Consumer Expenditure Survey (CES)	Household and per capita income, rents, ethnicity, age	In general, lower-income neighborhoods will generate more riders. Expanding service in disadvantaged areas can also help improve social equity.
Transit network attributes	National Transportation Atlas Database (NTAD), GIS	Link-to-node ratio, accessibility indexes	
Transit service characteristics	Transit agencies, FTA, Google Earth	Route-miles, stations, park-and-ride spaces, bus line connections, service frequency, speed, track grade, opening year	
Parking	Colliers International, Parking In Motion (PIM)	North America Central Business District parking rates, individual garage rates	Less parking per capita and higher market-rate parking can prompt motorists to switch to transit.
Congestion/travel speeds	Texas A&M Transportation Institute (TTI), FHWA	Average daily traffic per freeway lane, relative travel conditions in peak period versus free-flow	Congested Corridors Report
Fuel costs	National Household Travel Survey (NHTS), GasBuddy		
Land use regulatory restrictiveness	Pendall et al.	Zoned densities, growth management Tools	
Neighborhood walkability	Walkscore.com	Walk score	
Weather conditions	National Climatic Data Center (NCDC)	Average temperature, precipitation	
Fares	NTD, transit agencies	Fare revenues/ Passenger-miles	Fares are a control for investigating impacts, not a predictor as such.

(including percent Hispanic), household occupancy, and tenure. At the block-group level, census data was collected on household size, household income, automobile ownership, commute mode, and commute duration. In addition to the census spatial demographic information, block-level data was incorporated from Longitudinal Employer-Household Dynamics (LEHD) on job counts by employment location from 2002–2008, broken down by service industry and income group.

For the first step in the station catchment area demographic analysis, maps were created of the station catchment areas. Each station was assigned to its respective block/block group using the geographic areas defined by ESRI Census 2000 TIGER/Line Data. Around each station, straight-line-distance buffers of 0.25, 0.5, and 1 mile were created for urban rail systems and 0.5, 1, and 3 miles were created for CR systems so that the researchers could test measures taken for different-sized areas around stations. Thiessen polygons were used to ensure that each station's catchment area was mutually exclusive of neighboring station catchments. Census blocks were then clipped to each buffer to create shapefiles that contained all complete and partial census blocks within 0.25, 0.5, and 1 mile of urban HRT, LRT, or BRT stations and within 0.5, 1,

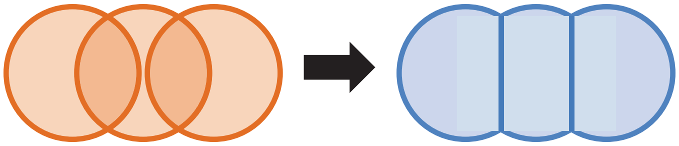


Figure 2.1. Graphical representation of GIS catchment area creation process.

and 3 miles of CR stations (Figure 2.1). To construct the panel data set, the researchers repeated this process for each year from 2000 to 2009, because the opening of a new station in a given year at times forced the realignment of the catchment area around a nearby station.

In the next step, the research team assigned demographic and employment data to each station catchment area. First, the fraction of land area of each block or block group falling within a given catchment area was calculated. Census blocks that were not clipped to coastlines were used in the catchment area analysis. Although it was initially thought that this might pose a problem with demographic data being incorrectly assigned to water areas, the team decided its analysis would not be affected, for the following reasons:

- The Census' own description of how census block geographies are created states that water areas within block groups are excluded from land areas and assigned a separate block number. Even water that is not along a coast or river (i.e., a pond located within a land census block) is taken out and assigned to the largest water block in the block group.
- Census blocks that are entirely composed of water should not have any demographic data (population, jobs, etc.) assigned to them, so they would not affect the analysis.

Some demographic indicators were available only at the block-group level. Rather than re-creating catchment areas using block-group shapefiles, the researchers aggregated the census block catchment area shapefiles up to the block-group level. In these cases, the clipped area (within the catchment area) of each block within the block group was added up and then divided by the land area (as reported by the census) of the containing block group. Demographic information was then multiplied by this fraction in a similar fashion.

The study team then assigned census data to a catchment area based on that land area ratio. If an entire block/block group was within the bounds of a catchment area, the land area fraction would be equal to 1 and the full census count for a given demographic variable would be allocated to that catchment area. If only a portion of a block/block group fell within a catchment area, the team applied the land area fraction and allocated only that percentage of the census count to the catchment area. A non-count census variable (e.g., median age) was assigned to a catchment area by taking weighted averages based on the catchment's population size. Finally, the study team aggregated the characteristics of each station catchment area up to the regional level for the nationwide analysis of metropolitan areas through either a summation or a calculated average (in some cases weighted by population or households).

CHAPTER 3

Focus Groups: Phase I

The study team carried out two rounds of focus groups and interviews with transit professionals and academics, to inform initial decisions about the research and to provide feedback on our initial results. In the first round, the researchers met with professionals in the transit industry to discuss basic concepts for framing the research, such as how to define a successful transit project, what factors have been examined in the past to help identify potentially successful projects, what factors would be useful for future informal alternatives analyses of transit projects, and what readily available data are currently used to support the incorporation of certain predictors of transit success.

Participants in the first phase of discussions agreed that defining success, and evaluating projects based on success standards, is a complex process. Some participants, particularly those working for transit agencies or consulting firms, believed that different projects should be evaluated using different criteria. Interviewees provided a wide array of potential measures of a project's success, including ridership levels, improved regional efficiency and mobility, economic development, and the creation of a transit-friendly environment. A variety of predictors of success were also suggested, including quality of service, cost savings versus the private auto, corridor density, supportive local land use policies, a demonstrated commitment to transit in the region, and the integration of the new project into the existing system.

The results from the second round of interviews and focus groups are discussed in Section 5.4.

3.1 Participants

The first meeting was a 90-minute focus group of eight participants conducted during the APTA Rail Conference in Boston in June 2011. Participation was by invitation only, with participants from transit agencies, MPOs, consulting firms, and academic institutions from various-sized metropolitan areas representing a spectrum of transit technologies (HRT, LRT, CR, and BRT). Participants were chosen from among the conference attendees based on their knowledge of transit project evaluation and their thought-leadership positions within the industry, with the goal of seeking a variety of perspectives. The focus group was followed by a series of telephone interviews with other participants to follow up on ideas presented during the focus group meeting and to help balance the range of participants.

Focus group participants at the 2011 APTA Rail Conference were:

- Alan Lehto, director of project planning, TriMet, Portland, Oregon. TriMet is the public transportation agency of the Portland metropolitan area.
- Tom Jenkins, principal consultant, InfraConsult, Los Angeles, California. InfraConsult is a firm specializing in the development and financing of infrastructure projects.
- Jim Parsons, principal consultant, Parametrix, Seattle, Washington. Parametrix is a firm specializing in the engineering, planning, and environmental elements of infrastructure projects.
- Liz Rao, vice president and public transit chair, HNTB, Denver, Colorado. HNTB is a firm specializing in the engineering, planning, construction, financing, and operations of infrastructure projects.
- Mike Shiffer, vice president for planning, strategy & technology, TransLink, Vancouver, British Columbia. TransLink is the regional transportation authority of metropolitan Vancouver.
- Kim Slaughter, senior vice president of service design & development, METRO, Houston, Texas. METRO is the metropolitan transit authority of Harris County, Houston, Texas.
- Bill Woodford, president, AECOM Consult, Arlington, Virginia. AECOM Consult is a firm specializing in the management of and technical support for infrastructure projects.

Subsequent telephone interviews were held in July 2011 with:

- Scott Rutherford, professor, Department of Civil & Environmental Engineering at the University of Washington, Seattle, Washington.
- Steve Polzin, transit research program director, Center for Urban Transportation Research at the University of South Florida, Tampa, Florida. The Center for Urban Transportation Research provides technical support, policy analysis, and research support.
- David Ory, principal transportation planner/analyst, Metropolitan Transportation Commission, Oakland, California. The Metropolitan Transportation Commission (MTC) is the transportation planning, coordinating and financing agency for the nine-county San Francisco Bay Area.
- Nat Bottigheimer, assistant general manager of planning and joint development, Washington Metropolitan Area Transit Authority (WMATA), Washington, D.C. WMATA is the transit authority of the national capital area.

3.2 Results

Both the focus group and the telephone interviewees were asked the following questions:

- How would you define success for a fixed-guideway transit project?
- How would you assess the success of the FTA New Starts program?
- Other than the FTA New Starts criteria, what indicators of success have you used or seen used in the planning phase to identify potentially successful fixed-guideway transit projects? What other indicators of success do you think should be used in planning-level evaluations of transit alternatives?
- What tools and data are needed to calculate or utilize these indicators?
- Do you have any other suggestions with regard to research direction?

Sections 3.2.1 through 3.2.5 summarize the responses to these questions.

3.2.1 How would you define success for a fixed-guideway transit project?

Consistent with the participants' varying views on what constitutes a successful project, they offered a diverse and, in some cases, conflicting set of potential success measures. Some concrete assessment factors included ridership, service quality, and manageable costs. Others, less easily measured, included development around transit, improved regional efficiency and mobility, and the creation of a transit-friendly environment.

3.2.1.1 Ridership and Rider Benefits

Several participants suggested potential success measures based on **changes in ridership** on the line, including absolute ridership figures or new transit trips recorded. According to one participant, success is "simply about riders," because "all other goals (such as congestion reduction, air quality improvement, even land use impacts) are premised on providing accessibility and, essentially, on people using the line." The same participant emphasized PMT as the ultimate measure, "better than simply riders, because the element of distance is a valuable measure in terms of mobility accomplished." One participant suggested that ridership figures are important to local decision-makers: "Politicians care about ridership." Other participants emphasized the financial element of transit system operations in the discussion of ridership, suggesting cost per passenger as the more important determinant of project success. Other participants felt that, in addition to increased ridership, an important success measure was an improved trip experience for those already using transit. One participant suggested that a successful project made a transit line "fast, reliable, frequent, and safe," more generally providing "better service for existing trips."

3.2.1.2 Land Use Changes

Participants also emphasized land use changes in response to a transit project. A few felt particularly strongly that it was important for a transit agency to "get a reasonable or expected return on its investment," and that success was all about "what you get in return." For one participant, return was largely expressed in terms of development around transit, whether in the form of new development within a region or more efficient development patterns around stations. An interviewee noted that "it's important to ask whether any development happened. . . . It all comes back to the critical question of land use." Another warned to be "careful how benefits are quantified and how the study/impact areas are bounded. . . . One-hundred units built near a station do not mean that 100 households have been created; they have just been shifted from elsewhere."

More broadly, some participants discussed measuring success through general improvements in efficiency and mobility across the region. One interviewee emphasized that "the conversation about transit success should be more about improving efficiency—this is the best form of economic growth that transportation can provide. By improving efficiency you reduce labor costs by reducing the cost and difficulty of the commute. Improving efficiency is the primary goal."

Another potential measure suggested by one participant was the creation of a transit-friendly environment, which could reflect a project's success through "metrics that reveal an orientation toward transit activity and transit investment." One such metric might be the presence of "a high bike/ped mode share of all trips," which "provides a more comprehensive look—a 24-hour set of outcomes." Other potential figures include the percentage of facilities that are usable by persons with disabilities ("as many ADA-oriented facilities as possible") or the percentage of children and senior citizen users, both reflecting adequate transit "accommodations for those who are not able to or shouldn't drive."

3.2.1.3 Cost-Benefit Analysis

Many participants, especially those representing public transit agencies, saw the need for a quantifiable cost-benefit test to assess the success of a transit project. As one participant put it, "success is somehow quantifiable based on whether benefits exceed costs—essentially a cost-benefit test." A focus group participant noted that when his agency evaluates multiple project proposals, it also "assigns costs to alternatives and trades off the benefits with the costs." The challenge arises from the fact that benefits include not only transportation but also social and environmental factors: "the cost-benefit categories compare apples and oranges." He added that the easiest way to define the "kind of value the project is creating" might be through "land value and density of development," but he stressed that "there could be others."

3.2.1.4 Higher-Resolution Goal Setting

Finally, one theme that occurred in most discussions was that success should also be measured through the achievement of project-specific local goals. As one interviewee put it, a project can be considered successful if it "solves the problem it was supposed to solve."

For some of these success measures, a project's potential success might be apparent by looking at corridor characteristics, but others could require considerable project-specific forecasting and analysis. According to the interviewees, success indicators would need to approach success from multiple scales (regional, system, corridor, local, etc.) and from multiple perspectives (FTA, regional, transit agency, etc.).

3.2.2 How would you assess the success of the FTA New Starts program?

Federal law does not clearly establish goals for the New Starts program. Although the law authorizing the federal funding programs for transit directs FTA to rate projects in terms of cost effectiveness, it says little about how effectiveness is to be measured. Land use and economic development are also called out in the law as rating factors, with little direction on federal goals and objectives.

Participants in the focus group and interviews agreed that it is essential to define what makes a project successful before indicators for predicting success can be identified. One focus group participant emphasized the "need to define what a successful project is, then think about what the warrants are to achieve that." However, participants also tended to agree that the projects funded through the program have had varying goals, and that they serve different markets using different technologies. Some projects are advanced by their local sponsors with the intent of reducing transit travel time, but others are meant to provide accessibility or promote development. As one participant succinctly stated, "Different values lead to different decisions." Without more specific objectives, the success of a project is often measured in terms of whether or not it was completed on time and on budget, or whether or not initial ridership projections were achieved.

Suggesting that a one-size-fits-all approach does not match the diversity of local goals and project types, some participants said that projects with different goals and characteristics should be categorized and evaluated under different criteria. One participant suggested that the evaluation process should "put a project into one of a number of categories" (a typology of projects). One set of success indicators could be used for projects meant to achieve time savings, and another set could be used for projects seeking to improve access or promote economic development.

Other participants noted that federal goals for the New Starts program may differ from local goals for a project. Some participants suggested that there should be one set of indicators that local agencies might use to predict whether a project could be justified in a corridor, and a second set of indicators that FTA might use to determine whether a project is deserving of federal funding. One participant emphasized that there should be room for a locality to say "Yes, it looks like it's a reasonable investment," while FTA employs a separate process for "deciding which projects receive the limited amount of federal funds available."

Some participants also suggested that the indicators might be used by FTA to assess the level of scrutiny a project should receive. If high ridership benefits are obvious according to an indicator-based method, FTA might give a project's demand forecast little review. If ridership benefits are unlikely, however, FTA might use the indicators as the basis for immediately rejecting a project for funding. FTA would then focus its oversight on those projects that are not immediately rejected but that are not obviously likely to achieve high ridership benefits. One participant recalled this policy in practice, where the "level of scrutiny in ridership forecasts on the busy lines was less than the rigorous calculations that were required for the uncertain projects."

At least one participant suggested that federal funding be linked to project outcomes, making local jurisdictions more accountable for a project's success. One participant specifically noted that "things that make a project successful (e.g., design quality, development density, supportive land use policies) have nothing to do with how the project is funded."

3.2.3 Other than the FTA New Starts criteria, what indicators of success have you used or seen used in the planning phase to identify potentially successful fixed-guideway transit projects? What other indicators of success do you think should be used in planning-level evaluations of transit alternatives?

In response to queries on potential indicators of success, participants in the focus group and interviews offered a variety of suggestions, including quality of service (e.g., convenience and reliability), cost savings versus private auto, density surrounding the corridor, supportive local land use policies, the region's demonstrated commitment to transit, and the integration of the new project into the existing system conditions (with respect to proposed technology and impacts on network connectivity).

Many participants expressed the view that the observed quality of service of a transit line could act as a measure of success and that proposed service characteristics could help predict a project's success. Convenience was one central factor mentioned, including proximity of the line to trip origins and destinations, providing people with the "ability to walk to and from stations," as one interviewee put it. In particular, participants stressed the importance of linking people with jobs. One participant noted that office proximity is more important than household proximity when an individual makes the decision to commute by transit. A participant summarized results from the 2005 WMATA Development-Related Ridership Survey, adding that "for workers to commute by transit to suburban offices, offices must be much closer to stations than worker households need to be. . . . People will walk a good distance for access to transit, but not to their final destination." In addition to the presence of jobs in a destination area, participants stressed the importance of having a destination area with a generally vibrant and walkable environment. One interviewee in particular noted the value of "the ability to do things by foot in the area—the availability of options once you're there," adding that "this depends on safety, activity, and general vibrancy near stops." Other essential features of service quality, according to one participant, included "frequent service with a long span of service" and ensured reliability of the proposed service, which would allow individuals to "work [transit] into their lifestyle."

Focus group participants and interviewees strongly emphasized that the success of a transit project is a function of its relative "cost savings versus taking a car," or essentially "how difficult it is to operate an automobile." The cost of automobile use can be measured in monetary terms: one financial cost that participants commonly mentioned was "the price of parking," more specifically, parking management programs that involved the "absence of free/heavily subsidized garages, and the absence of large lots." However, an interviewee pointed out that "a high price of auto[mobile travel] . . . is not always expressed in dollars," and that time costs caused by congestion or road network complexity can be just as important.

Participants also mentioned several land use elements as critical factors in leading to a more successful transit project. One interviewee suggested that an existing opportunity for dedicated right-of-way should be considered, as it could indicate time savings on the line and also reduce the project's costs of construction. Density was also an often-cited element, including "development density" and "density of the street grid" around stations. Participants stressed the importance of local land use policies that support TOD. As one interviewee expressed it, "If you build it, they will come" can apply only if "local land use policies and market demand allow it to happen. Policies can prevent development from occurring around new projects."

The current presence of a successful bus system in the region was also mentioned as an important predictor of the success of a potential rail project. One focus group member felt that "to do rail, a city must show they have an existing commitment to bus." Another supported the sentiment by suggesting that one start by looking at whether "there is a market for bus when considering whether rail makes sense." However, a few members of the focus group countered that current success with bus service is not always a valid indicator, because rail might work where a bus route is not feasible due to "geographic constraints" or "reliability issues" that make a bus service ineffective in the corridor.

An interviewee stressed the importance of examining the existing conditions and capabilities of a line when extension projects are proposed. This interviewee recommended examining the strength of current transit ridership within the corridor, for example, "riders on existing bus routes along the arterial," and proposed that the success of a project hinges on the project sponsor's familiarity with the proposed technology. The interviewee also stressed the importance of "hooking it all together" and "reducing the complication associated with doing something different," adding that "once the central system is established it does not make sense to incorporate different technologies as the system expands."

Finally, participants suggested that the success of a transit project could be predicted through its connection to the rest of the system, including not only new linkages formed but also spillover effects along the line. One participant warned about the importance of modeling the project's "impact on the rest of the system—whether the project relieves or puts pressure on the core and what shifts in inbound and outbound ridership occur." Generally, participants suggested looking for whether a region employed a "sound system/network planning process."

3.2.4 What tools and data are needed to calculate or utilize these indicators?

The research team received no direct recommendations from interviewees for specific tools and data that could potentially be used to calculate relevant indicators and predictors of success, but the participants did discuss on a general level their opinions about how simple or complex the tools should be. One participant suggested that success indicators be "simple and understandable" for "local leadership and public or community stakeholders," and recommended that success indicators be kept from becoming too complicated through "breaking things down into chunks." Another participant disagreed, stating that project analysis is inherently complex and "you cannot simplify and get very accurate answers—there is too much subjectivity." This idea of complexity in the process was echoed by an interviewee's expressed sentiment that "simple sketch tools" cannot replace modeling, because "simple analytics do not make the problems we are trying to solve any simpler."

3.2.5 Do you have any other suggestions with regard to research direction?

Several participants offered additional recommendations on the general direction of the TCRP Project H-42 research. One participant suggested that the study "look at what has happened in the past . . . identifying the corridor characteristics associated with previous New Starts projects as useful points of comparison for new ones." Other participants proposed that the research project might look at changes in travel over the last few decades, and use that knowledge to update the quantitative thresholds presented in *Urban Rail in America* (Pushkarev, Zupan, and Cumella 1982). As one interviewee observed, "The question is more complicated now, with wider ranges of variation in transit performance and cost. It is important to determine what '*x*' level of demand can justify a '*y*' level of investment." This person further suggested that this study's scope remain narrow and concrete, focusing on transportation benefits and avoiding more subjective and political measures like economic development, job creation, or contingency uses. The interviewee bemoaned the fact that "parties today often dismiss the fundamental cost-benefit performance analysis and instead use these other [subjective political] justifications to rationalize the decision to move forward with a transit project."

3.3 Conclusions

Participants saw the primary challenge of measuring the success of transit projects as incorporating different assessment factors into a cost-benefit analysis. They suggested a wide array of potential measures of a project's success, including ridership levels, service improvements, cost control, a general return on investment, improved regional efficiency and mobility, and creation of a transit-friendly environment.

A variety of potentially simple predictors of success also were suggested, including quality of service, cost savings versus the private auto, corridor density, supportive local land use policies, a demonstrated commitment to transit in the region, and the integration of the new project into the existing system conditions.

CHAPTER 4

Conceptual Framework

Numerous possible measures of transit investment success exist. After considering several alternatives, the TCRP Project H-42 team focused on transit ridership at the project and system levels, because these are strong direct measures of the benefits of transit, although they are by no means perfect or appropriate in all cases. This chapter includes a discussion of the different kinds of indicators modeled as predictors of transit ridership for the two types of data: a cross-section of fixed-guideway projects and a time-series of metropolitan-level data on rail and bus passenger-miles traveled (PMT). Summary statistics are provided about the 55 transit investments included in the analysis, as well as the 18 metropolitan areas with fixed-guideway transit investments that occurred from 2002 to 2008, the period of study for which the research team could assemble complete data for statistical analysis. (Notice that the entire MSA data set consisted of 244 metropolitan areas.) The data collection process is described in more detail in Appendix B to this report.

4.1 Defining Transit Project Success

No definition of "success" for a fixed-guideway transit project is universally accepted. Project goals vary by region, by city, and by corridor, and they can be broad and multifaceted. Standards that might be used to classify completed projects as highly successful, moderately successful, or unsuccessful simply do not exist. The literature reviews and focus groups in this project yielded a range of definitions but no definitive metric for measuring success.

A project may be perceived as successful if it is built on time and on budget, or if ridership exceeds expectations. A transit system's success also can be measured through economic cost-benefit comparisons, its impacts on land uses, local measures of equity and environmental effect, or its impacts on congestion and VMT. A person's view of a project's success may also depend on his or her perspective—a transit agency general manager or the agency's board of directors may define success differently than a transit rider, a taxpayer, or a funding partner does. Measuring success is largely driven by the primary goals of the city and the proposed project. In a city like Stockholm, which is committed to be a zero-carbon city by 2050, the ability of a proposal to reduce VMT by automobiles per capita is the primary concern. In other cities, overriding goals might be enhanced mobility or economic productivity. From an economics standpoint, a successful project is one whose benefits exceed its costs.

Table 4.1 compares capital cost per mile by mode for projects in this study. A full accounting of a transit project's direct and indirect costs and benefits is analytically challenging. Many of the benefits and externalities are difficult to quantify and cannot be assigned a dollar value, such as a transit project's contribution to making a city more livable. Another way to measure success might be to assess how fully a completed project meets the goals it was intended to achieve. The goals of fixed-guideway projects are many and varied, however, and they are often difficult to measure. For example, one project goal might be to improve access for poor people, but it is extremely difficult to establish a monetary value for this goal.

Identifying a comprehensive and widely acceptable definition of success proved to be elusive. The researchers therefore focused on measures of success that can be quantified and that generally correspond with a range of project goals: project-level ridership, changes in system-wide transit use, and project-level cost. Though incomplete as a measure of success, the expected ridership on the project and the expected effect on the system's usage as a whole, in combination with the cost of the project, provide valuable information to help establish a corridor's potential for fixed-guideway transit. A simple model of capital cost was added to enable a rudimentary cost-benefit analysis.

The study team used ridership because the number of passengers offers one direct measure of the number of people who benefit. When a new transit project is proposed, one of the first things people want to know is how many people the system

Table 4.1. Capital cost per mile of study set projects by mode.

	HRT	LRT	BRT	Commuter Rail
Cost/mile (2009 $)	$251.2 million	$61.0 million	$49.8 million	$10.5 million

is expected to carry. Increases in system-wide patronage can also serve as a proxy for a project's mobility and accessibility benefits, as well as sustainability benefits such as reductions in automobile use, air pollutant emissions, and energy consumption, to the extent that increased system ridership indicates that more people are choosing to leave their cars at home and take transit instead. These benefits exist only if former motorists switch to transit, and if large shares of future trips by transit would otherwise have been taken by car. Ridership gains of fixed-guideway transit projects could instead come from former bus riders, or from new trips not previously made.

To some degree, ridership can also be viewed as a proxy for potential land use and economic development benefits. The more riders a project attracts, the more likely it is that the project will help stimulate growth. Changes in transit ridership result from, and can be viewed as a measure of, the improved transit speed and reliability produced by a project. Ridership is also a convenient indicator of success because transit ridership data can be both readily collected and statistically correlated with corridor conditions. Thus, the TCRP Project H-42 research identifies the conditions that are likely to lead to increases in transit ridership given investment in a new fixed-guideway transit project. The researchers also consider a project's capital cost in relation to these measures of success.

Recognizing the value of other potential measures of success and understanding the importance of employing a more-refined multiple-indicator approach when different projects are evaluated based on different metrics, the research team chose to address these additional measures and issues through case studies (see Chapter 6). These approaches are particularly relevant in the realm of policy-making. Given data limitations and the highly focused scope of work for TCRP Project H-42, the researchers were unable to address these additional success factors in the quantitative analysis for this study. The principal objective of this study was to create a simple method grounded in empirical analysis, using measures that are distinctive and intuitive. The additional measures add a level of complexity that makes them difficult to implement in practice and therefore incompatible with the project's specific goals.

Multicriteria performance evaluations for urban public transit systems involve multilevel hierarchies and subjective assessments of decision alternatives, expanding on the widely understood simple metrics of system use that are incorporated in the analysis. One example of a multiple-indicator metric was used for a study conducted in Istanbul in 2004 (Gercek et al. 2004). The authors evaluated three alternative rail transit network proposals by using the Analytic Hierarchy Process (AHP), a multicriteria decision support system. The AHP facilitates decision-making by organizing perceptions, experiences, knowledge, and judgments—the forces that influence the decision—into a hierarchical framework with a goal, scenarios, criteria, and alternatives of choice. Research by Yeh, Heng, and Chang implemented a *fuzzy* multicriteria analysis (MA) approach in a case study evaluating the performance of 10 bus companies in Taiwan (Yeh et al. 2000). In this methodology, the subjectivity and imprecision of the evaluation process were modeled as fuzzy numbers by means of linguistic terms.

4.2 Levels of Analysis

When comparing the transit potential of different corridors, or the potential of different alternatives within a corridor, the use of two complementary measures of project ridership is suggested:

- **Project-level ridership** addresses the number of people who use a project on a daily basis, measured as average weekday boardings and alightings at project stations. Project-level ridership includes new riders attracted to transit, such as former automobile drivers who switch to transit or future travelers by transit who would otherwise have used a private car. It also includes existing riders, such as people who previously took the bus but who now ride the new fixed-guideway system and may benefit from faster travel time, improved reliability, or greater comfort.
- **System-level ridership** addresses annual PMT across the entire system, as defined by rail and bus PMT, data that are reported on a yearly basis by transit agencies to FTA, and are collected in the National Transit Database. This metric represents the amount of new transit use that is expected once the project is in service. PMT takes into account the greater regional mobility that may occur when a single fixed-guideway project links riders to a regional system. It captures new riders and the length of their trips, but it does not incorporate existing riders whose trip length on transit does not change, even if these riders benefit from faster travel time. Compared with project-level ridership, the change in system-level PMT offers a better indicator of a project's likely impact on overall highway congestion, emissions, and energy consumption.

Although project-level ridership is a fundamental component of a transit project's success, success should also be considered in the context of the entire regional transit system. Project-level ridership alone fails to account for possible shifts in modes between new transit projects and existing services such as parallel bus lines. System-wide PMT allows examination of changes in transit use across all lines and modes in the system, controlling for any possible shifts in mode and line. A regional approach has been noticeably absent from previous research on travel demand associated with fixed-guideway transit projects.

Project-level and system-level measures are complementary and offer different perspectives on a project's benefits. A project that does well in one dimension may not do well in the other. An urban circulator, for example, may attract a significant number of riders. Given that circulator trips are typically short, however, the project may have little impact on PMT unless it makes longer-distance transit travel more convenient. A CR project, on the other hand, could have a larger impact on PMT even if ridership is not as high, because CR trips tend to be much longer. Neither measure alone tells the full story. Not surprisingly, then, the indicators of project ridership success and PMT success are somewhat different.

A potential disadvantage of using PMT is that it may not be well suited to measuring transit use in larger metropolitan areas that are experiencing rapid suburbanization and seek to reduce vehicle travel distances. In crowded, dense cities, time spent in travel may be a better measure of success than distance traveled. The example of the urban circulator and the CR line is again instructive: the former could strengthen a downtown area, whereas the latter could contribute to decentralization.

The primary levels of the analysis in this study were U.S. Census-defined metropolitan areas and individual transit line projects in the United States. In addition to gathering data at both of these levels, the research team collected spatial information and information at the individual station level, which was aggregated to the project level and metropolitan area for analysis.

4.3 Identifying Indicators of Transit Project Success

A variety of factors can potentially influence the ridership levels of a fixed-guideway transit project. Some factors are attributes of the system itself. Such internal factors include service reliability, fare, frequency, vehicle speed, and service amenities such as comfort. Route alignment and connectivity of the transit network also are important factors that are partially controlled by the transit agency, and improving these elements of the system can potentially increase ridership and contain costs.

Other potentially influential elements are outside a transit agency's control. Such external factors include characteristics of the service population and surrounding metropolitan area. Population growth, improved economic conditions, and certain demographic attributes tend to increase ridership levels. Characteristics of the built environment also can play a significant role. Higher population and employment densities, as well as mixed-use and more walkable neighborhoods, may lead to more transit use. One final potentially significant predictor of transit ridership is the relative cost of the auto. When driving is costly—that is, when congestion levels, parking prices and gas prices are high—people are more likely to choose transit over the auto.

All of these factors are potentially significant indicators of the future success of a transit project. For the analysis used in this study, the researchers grouped them into four distinct categories: system characteristics, service population and metropolitan area characteristics, land use, and relative merit of alternative modes. Each of the categories is composed of a complex set of attributes that change with spatial scale and time, and the study team generated a set of variables that can be used to objectively quantify these attributes.

4.3.1 Project and System Characteristics

Transit use can be related to characteristics of the transit service provided. When an agency improves the quality or expands the coverage of its transit service, ridership tends to increase. Conversely, when an agency increases fares, ridership is expected to drop. However, results vary significantly in studies that examine the price elasticity of transit use, as effects have been shown to differ by geographic location, time of day, and income level. The strength of this relationship between a transit project's service and its ridership levels depends on the metrics used to quantify service.

The simplest measure of a transit system's service is its extent, which can be quantified at the project level as the combined length of the routes. At the system level, the directional route-miles of all fixed-guideway and bus lines can be an indicator of both the physical service area and the number of people being served by the network. Another service characteristic is a project's level of connectivity to other transit networks, possibly measured by the number of bus lines to which it connects. All of these transit system characteristics may increase transit accessibility, which is the primary influence on transit ridership. More connections are likely to be correlated with higher transit use because in these areas more direct travel to many destinations is possible via transit. Some stations or lines are more frequently accessed by car than transit, and in this case service might be measured by the number of park-and-ride spaces provided at the line's stations.

Using service characteristics of a project or system presents a conundrum, because transit service decisions are made not only to increase patronage but also in response to demand.

Overflowing parking lots may be expanded; more bus lines may be added to a busy terminal; and very dense service areas are more likely to have undergrounded rights-of-way for transit. The researchers conducted analysis with and without those characteristics, knowing that including them as predictors of success was problematic but wanting to compare results both ways. The study team was able to predict ridership fairly well without including transit system characteristics, suggesting that these characteristics may change partly in response to demand, either prospectively or over time.

4.3.2 Service Population and Metropolitan Area Characteristics

Transit use might also be associated with characteristics of a project's service population and surrounding metropolitan area. Such factors reflect the influences of sociodemographic and environmental conditions on transit patronage. Resident age could be an important indicator of ridership, as both younger and older people tend to use transit more than people of middle age. Specific age data might include median age, the number of residents over age 65, or the number of residents under age 18. In addition, certain population groups, such as university students, are often associated with higher transit use. Studies have shown that higher transit use is also linked to certain racial or ethnic group status (Taylor et al. 2009) and recent immigrant status (Chatman and Klein 2009). This effect can be isolated by examining concentrations of race, ethnicity, or immigration status.

Other potentially influential characteristics of the metropolitan area are external to policy-makers. For example, weather and climate may affect transit ridership. Harsh environmental conditions might cause people to travel by automobile instead of waiting for transit and walking to connections, or it might lead to increased ridership as people who would normally walk or bike choose to make their trips by transit. The National Climatic Data Center (NCDC), run by the National Oceanic and Atmospheric Administration (NOAA), quantifies weather and climate by providing metropolitan-level estimates for annual precipitation, percent of possible sunlight, average temperature, days with highs above 90°F, days with lows below 32°F, and average snowfall.

Finally, though the study team did not include it in this analysis, it is possible that local crime rates or personal safety concerns on transit or at transit stations could heavily affect its use.

4.3.3 Land Use

Many people have a mental conception of transit-friendly land use, but quantifying it requires more detail than a single number on a range from friendly to unfriendly. The research team considered several aspects of land use and built a set of variables that capture the characteristics that facilitate public transportation.

It is readily observed that many big cities have fixed-guideway transit but many small cities do not. The size of the city has implications for the number of potential users, the number of activities accessible by transit, and amount of capital available for building transit. The size of the city could be quantified in many ways, including the population, the area, the GDP, and the number of jobs.

Residential and employment density was considered by examining catchment areas around each of the stations. By analyzing the number of jobs, the number of residents, and the interaction between job and resident figures in the catchments, relationships between urban densities and transit use can be identified. Density of workers in different industries, and residents of different types of housing or different income levels, is also potentially relevant. In TCRP Project H-42, such measures were found to be highly predictive of transit use.

The idea of density is further explored through accessibility measures. Since the connection between density and transit use might be more specifically based on access to activities, gravity-based accessibility measures might be a more helpful way of describing the intensity of land use. (A gravity model predicts the number of trips from an originating zone to destination zones as a function of the attractive power of destination zones and the distance to each of them from the originating zone.)

Because transit is often accessed by foot or bike, the walkability of the area around transit stations might be an important indicator of transit use. Although this characteristic can be nuanced, the researchers quantified walkability using the Street Smart Walk Score algorithm. This metric takes into account the accessibility of various amenities including retail, institutions, and dining. Additionally, the algorithm factors in the density of intersections and block lengths. Walk Scores are calculated on a range of 0 to 100, and higher walk scores might be expected to influence transit use by making the walk to and from transit stops more interesting and useful.

In some cases, transit use may be influenced by the prevalence of a specific industry. Using the North American Industry Classification System, the study team generated indicators of 20 industries using the number of jobs in each station catchment from the LEHD data. This allowed the models to distinguish between a dense commercial district and a dense industrial district, for example. Cases were found of differential effects on ridership or PMT by industry, as is discussed in Chapter 6.

Land use also affects transit use through the presence of specific facilities and institutions. During the case studies, transit agencies reported that universities, stadiums, hospitals, museums, airports, and hotels can be important trip generators. These land uses can be more difficult to quantify without local knowledge, but it is possible to substitute relevant jobs using industry data categories (e.g., healthcare industry workers as a proxy for hospitals).

4.3.4 Competition from Other Modes

The service provided by the transit network should be considered relative to the attractiveness of alternative modes. In particular, attributes that characterize the speed and convenience of driving—factors generally out of the control of a transit agency—may influence transit use.

Transit use might be expected to increase when the cost of driving is high. This characteristic of a system can be quantified through gas prices and parking prices. Parking prices in the downtown area and parking prices in the catchments might have independent effects on transit use, depending on the type of trips that are dominant on a transit route.

The level of investment in driving infrastructure might also determine use of public transit. One way of quantifying this is through the number of highway lane-miles, and average daily traffic per lane-mile.

4.4 Observation Set

Between 1974 and 2008 32 metropolitan regions had fixed-guideway transit and 126 fixed-guideway transit projects were completed in the United States (Appendix C). Ideally, the TCRP Project H-42 research would incorporate information on all of these projects and metropolitan regions, but the set of observations that were modeled is limited to the projects for which the team could secure data on ridership and its indicators. For example, the researchers' set of system-level observations was restricted by the availability of LEHD employment data, which was used to construct measures of employment near proposed stations. The data that were available from 2004 to 2008 do not cover some areas of the United States with significant transit investments, notably Washington, D.C.; Charlotte, North Carolina; and Boston. The best-fit models in this study are therefore based on a subset of recently completed transit projects.

4.4.1 Metropolitan Areas of Study

The PMT model includes data from 244 MSAs, 18 of which had a fixed-guideway transit investment occur during the study's 7-year data set (2002–2008) (Table 4.2). Because transit service density and the sheer size of the New York City metropolitan area make it an outlier, the research team excluded the region in most of the analysis.

The 18 regions varied in population between 1.1 and 12.8 million people in 2008. The largest metropolitan area studied was the Los Angeles–Long Beach–Santa Ana, CA, region; the smallest was the Salt Lake City, UT, region. The combined 2008 population of this subset of 18 metropolitan areas in the data set totaled 75.6 million people, representing one-quarter of the total U.S. population. Table 4.3 provides a detailed descriptive summary of the 18 metropolitan areas. Figure 4.1 shows PMT per capita by transit for those metropolitan areas in 2008.

Table 4.2. Metropolitan areas included in analysis.

Atlanta–Sandy Springs–Marietta, GA
Baltimore–Towson, MD
Chicago–Naperville–Joliet, IL–IN–WI
Cleveland–Elyria–Mentor, OH
Dallas–Fort Worth–Arlington, TX
Denver–Aurora, CO
Los Angeles–Long Beach–Santa Ana, CA
Miami–Fort Lauderdale–Miami Beach, FL
Minneapolis–St. Paul–Bloomington, MN–WI
Philadelphia–Camden–Wilmington, PA–NJ–DE–MD
Pittsburgh, PA
Portland–Vancouver–Beaverton, OR–WA
Sacramento–Arden-Arcade–Roseville, CA
St. Louis, MO–IL
Salt Lake City, UT
San Diego–Carlsbad–San Marcos, CA
San Francisco–Oakland–Fremont, CA
San Jose–Sunnyvale–Santa Clara, CA

Among the 18 metropolitan areas with a fixed-guideway transit investment during the 2002 to 2008 period, the highest intensity of transit ridership is in the San Francisco–Oakland–Fremont, CA, metropolitan area, based on per capita fixed-guideway transit PMT in 2008. This metropolitan area is the seventh largest of those modeled, with 4.3 million residents in 2008.

4.4.2 Fixed-Guideway Transit Projects of Study

The ridership models include 55 fixed-guideway transit projects in 21 U.S. metropolitan areas (Table 4.4). The data set includes 13 HRT projects, 36 LRT projects, three CR projects, and three fixed-route BRT projects.

Because of the small number of CR projects in the data set, the researchers do not recommend the use of this model with proposed CR investments. Likewise, data was not available for streetcar or urban circulator projects—which may require entirely different indicators of success—so this model should not be applied to such investments, and no projects of that mode are in the data set. Although there is also good reason to use caution when using the model for BRT projects, better estimates from similar methods are not currently possible

Table 4.3. Descriptive summary of metropolitan areas included in the analysis, 2002–2008.

Descriptor	Mean	SD	Min	Max	n
Annual passenger-miles (thousands)[a]	961,443	1,064,339	142,510	4,154,660	124
Operating cost per thousand passenger-miles (millions, $2009)	$713	$253	$364	$1,636	124
Population within 1/2 mile of stations	401,263	581,464	37,019	2,218,951	124
Annual passenger-miles per person residing within 1/2 mile of stations	3,941	2,670	628	11,973	124
Population of metropolitan area (thousands)	4,107	2,919	1,002	12,768	124
Annual passenger-miles per person residing in metropolitan area	206	122	74	609	124
Percent of metropolitan area population within 1/2 mile of stations	8%	7%	1%	26%	124
Population per total land area within 1/2 mile of stations[b]	23	21	7	87	124
Jobs within 1/2 mile of stations	387,648	385,696	99,085	1,673,264	124
Annual passenger-miles per job within 1/2 mile of stations	2,332	878	582	4,675	124
Labor force of metropolitan area (thousands)	2,112	1,462	536	6,548	124
Annual passenger-miles per job in metropolitan area	396	233	147	1,156	124
Percent of metropolitan area jobs within 1/2 mile of stations	18%	9%	7%	35%	124
Jobs per total land area within 1/2 mile of stations[a]	28	13	9	65	124
Retail, entertainment, and food jobs within 1/2 mile of stations	61,110	58,983	14,549	249,071	124
Higher-wage jobs within 1/2 mile of stations	182,314	184,598	28,216	884,079	124
Population under 18 within 1/2 mile of stations	31,060	37,272	3,873	132,413	124
Directional route-miles of system	4,282	2,797	1,471	14,214	124
Average walk score of stations	68	6	58	84	124
Real GDP (millions, $2005)	$208,921	$151,659	$47,847	$695,513	124
Per capita income	$40,615	$6,597	$29,892	$62,427	124
Average daily traffic per highway-lane	16,274	3,073	7,377	20,425	124
Congestion index	6,955,203	16,200,000	66,095	71,500,000	124
Average gas price by county	$2	$1	$1	$4	124

[a] Passenger-miles include rail and bus services.

[b] Differs from Pushkarev and Zupan, who used residential land area.

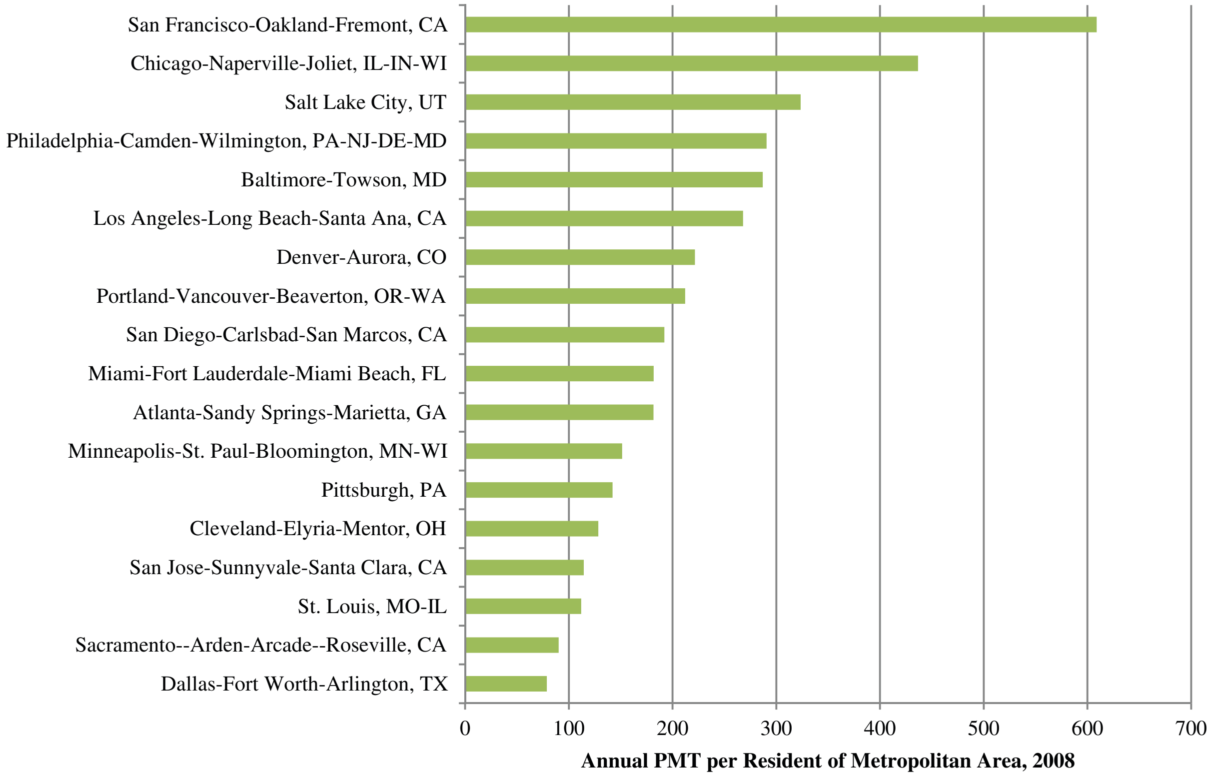


Figure 4.1. 2008 annual fixed-guideway transit passenger-miles per person, by metropolitan area with fixed-guideway transit included in analysis.

Table 4.4. Fixed-guideway transit projects included in analysis.

State	City	Project Name	Mode
AZ	Phoenix	Metro Light Rail	LRT
CA	Los Angeles	Long Beach Blue Line	LRT
		Red Line Segments 1,2,3	HRT
		Green Line	LRT
		Pasadena Gold Line	LRT
		Orange Line	BRT
CA	Sacramento	Sacramento Stage I	LRT
		Mather Field Road Extension	LRT
		South Phase 1	LRT
		Sacramento Folsom Corridor	LRT
CA	San Diego	Blue Line	LRT
		Orange Line	LRT
		Mission Valley East	LRT
CA	San Francisco	Initial BART	HRT
		BART SFO Extension	HRT
CA	San Jose	San Jose North Corridor	LRT
		Tasman West	LRT
		VTA Tasman East and Capitol Segments	LRT
		VTA Vasona Segment	LRT
CO	Denver	Central Corridor	LRT
		Denver Southwest Corridor	LRT
		Denver Southeast (T-REX)	LRT
FL	Miami	Metrorail	HRT
		South Florida Tri-Rail Upgrades	CR

(continued on next page)

Table 4.4. (Continued).

State	City	Project Name	Mode
GA	Atlanta	North/South Line	HRT
		North Line Dunwoody Extension	HRT
IL	Chicago	O'Hare Extension (Blue Line)	HRT
		Orange Line	HRT
		Metra North Central and SW Corridors	CR
		Douglas Branch	HRT
MD	Baltimore	Baltimore Metro	HRT
		Central Line	LRT
		Three extensions	LRT
MN	Minneapolis	Hiawatha Corridor	LRT
NJ	Jersey City[a]	Hudson-Bergen MOS 1 and 2	LRT
NJ	Newark[a]	Newark Elizabeth MOS-1	LRT
NJ	Trenton[a]	Southern NJ LRT System	LRT
NY	Buffalo	Buffalo Metro Rail	LRT
OH	Cleveland	Cleveland Healthline	BRT
OR	Eugene	Eugene EmX	BRT
OR	Portland	Portland MAX Segment I	LRT
		Portland Westside/Hillsboro MAX	LRT
		Portland Airport MAX	LRT
		Portland Interstate MAX LRT	LRT
PA	Philadelphia	SEPTA Frankford Rehabilitation	HRT
TX	Dallas	S&W Oak Cliff and Park Lane	LRT
		North Central	LRT
UT	Salt Lake City	North South Corridor	LRT
		University and Medical Center Extension	LRT
WA	Seattle	Seattle Central Link Light Rail Project	LRT

[a] Jersey City and Newark, New Jersey, belong to New York City's metropolitan area. Trenton, New Jersey, is part of the Philadelphia metropolitan area.

because this study includes almost all possible fixed-guideway BRT projects currently operating in the United States.

Appendix F provides a summary of the projects included in the ridership models for TCRP Project H-42, and Appendix C provides information for 71 other projects completed in the past 40 years that the researchers did not include because of age or because data were missing.

Figure 4.2 shows the 55 projects within their respective transit networks and metropolitan areas across the United States.

The 55 transit projects included in the ridership model opened as early as 1974 and as recently as 2008. The projects range in size from 1 to 72 route-miles in length and from 2 to 33 stations. The longest projects are typically CR lines, whereas the systems with the most stations are often a city's first investment in a particular transit mode. Such projects were termed *initial*, and the database includes two initial HRT projects, 11 initial LRT projects, and one initial BRT project, for a total of 14 "initial" projects.

In aggregate, the projects represent 849 bidirectional route-miles of fixed-guideway (approximately 88 below grade and 130 elevated track) with 774 stations and 151,564 transit agency-owned parking stalls. The total cost of constructing the projects in 2009 dollars was $54.4 billion. Table 4.5 provides a more detailed descriptive summary of the 55 transit projects.

Figure 4.3 shows the distribution of average weekday ridership by transit project, and Figure 4.4 shows the distribution of average weekday ridership per guideway-mile by transit project.

The research team deliberately did not establish a typology of indicators according to fixed-guideway transit type (e.g., initial versus expansion project), transit mode (e.g., LRT, HRT, CR, BRT) or by urban setting (e.g., based on surrounding densities or whether location is a CBD, central city, inner suburb, or outer suburb). The approach was instead to run analyses that included appropriate measures to render variables representing type and mode statistically insignificant, given that such measures are imprecise. Other indicators were sufficient to predict ridership according to the statistical tests used, enabling the method to avoid relying on somewhat arbitrary definitions of HRT, LRT, and BRT—categories that have large overlaps in service quality and capital cost. Although the researchers did not model differences in indicator effects among metropolitan areas of different sizes, measures of city size were tested extensively. (Note: for the rudimentary capital cost model appearing in the spreadsheet only, mode is included to help estimate capital cost.)

Figure 4.2. Fixed-guideway transit projects included in analysis.

Table 4.5. Descriptive summary of fixed-guideway transit projects included in analysis.

Descriptor	Mean	SD	Min.	Max.	n
Average weekday ridership	28,470	41,092	1,065	284,162	55
Total capital cost (millions, $2009)	$950	$1,137	$26	$6,960	55
Route-miles	15	15	1	72	55
Percent at grade	69%	35%	0%	100%	51
Percent below grade	15%	27%	0%	100%	51
Percent elevated	16%	27%	0%	100%	51
Number of stations in alignment	13	8	2	33	55
Opening year	1998	8	1974	2008	55
Age of project	10	8	0	34	55
Frequency of trains in peak AM hour	13	6	4	26	55
Number of bus lines that connect to stations	54	59	0	339	55
Transit-owned parking stalls per station	3,087	4,563	0	29,778	51
Jobs within 1/2 mile of stations	70,355	63,719	4,819	311,300	55
Population within 1/2 mile of stations	55,754	53,159	1,709	269,182	55
Population of metropolitan area (thousands)	5,424	4,657	348	18,969	55
Average daily parking rate within 1/2 mile of stations	$10	$5	$2	$26	44
Average daily parking rate in the CBD	$15	$8	$4	$38	55
Average county gas price	$3	$0	$3	$4	55
Capital cost per thousand riders (millions, $2009)	$50	$45	$4	$211	55
Capital cost per route mile (millions, $2009)	$93	$124	$4	$755	55

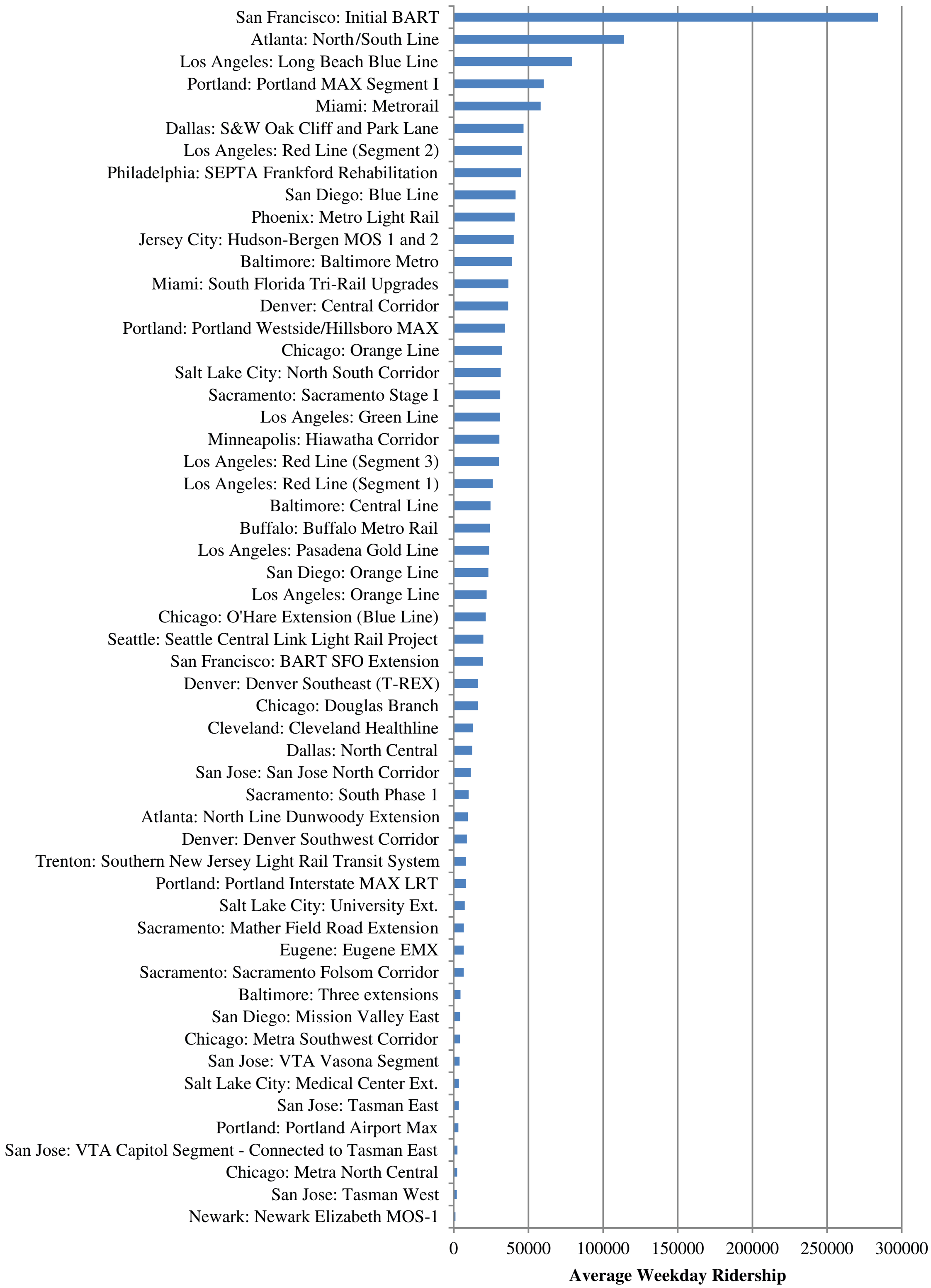


Figure 4.3. Average weekday ridership, by fixed-guideway transit project included in analysis.

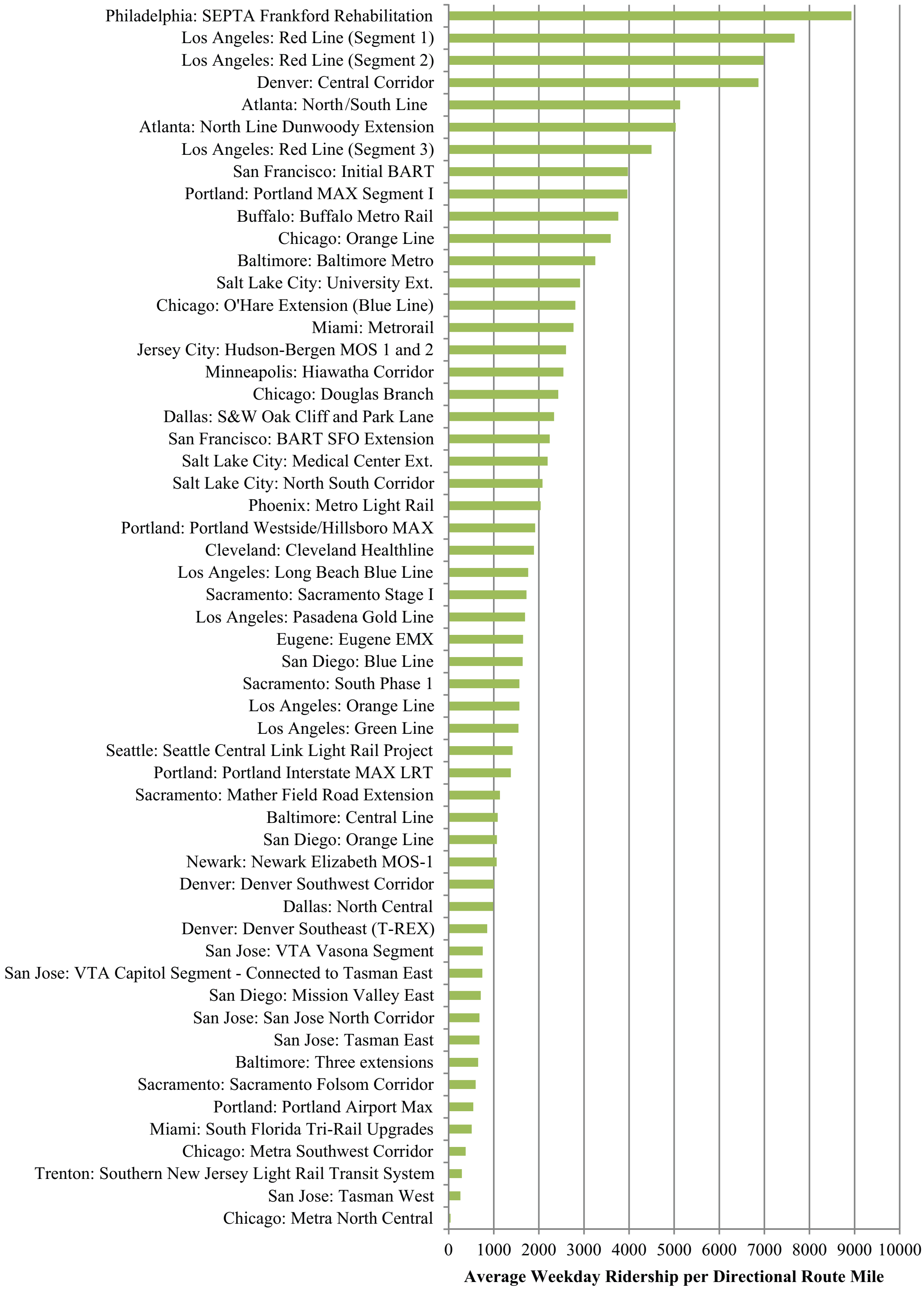


Figure 4.4. Average weekday ridership per directional route mile.

CHAPTER 5

Quantitative Analysis Methods and Findings

The project team tested more than 140 different factors that might be expected to influence project-level ridership or system-level PMT on transit. Multiple regression analyses were conducted using the projects and cities for which the researchers had complete data. The model-building process proceeded down multiple parallel tracks, while always being constrained by having a relatively small number of observations available. The first step was to specify models based on utility theory, focusing on the relative costs of transit and automobile use as reflected in the number of near-station households and workers, parking costs, congestion, and transit connectivity, along with built-environment measures and neighborhood sociodemographic attributes. Because of the small data set and the problem of correlated variables, the research team also tested several stepwise approaches to model-building.

Several important variables reflecting transit agency decisions—such as the number of bus lines serving fixed-guideway transit stations, parking availability, and the percentage of the track at grade—are highly correlated with rail use, but are problematic as predictors, because they both reflect and generate demand. Therefore, this report presents results with and without these highly correlated service variables and discusses the differences.

For both project-level ridership and system-level PMT, the research team built parsimonious regression models (the simplest plausible models with relatively few predictive indicators) that reflected a physical explanation of the factors that drive transit use, such as access to stations, origins and destinations of different types on the transit network, the costs of driving, and the size of the metropolitan area. Generally, the starting point was a complete model reflecting a utility theory of transit use, to the extent possible with aggregate data. The researchers then began to pare down the model, rejecting variables that the analysis showed to be insignificant predictors of ridership. This approach was complemented by building a model based on the significance of a larger set of variables. Here the variables that were considered to be most important (based on theory and their significance) were tested first. New variables were incrementally added and retained if they were significant and improved the goodness of fit. The results of this approach were used to inform the set of variables in the complete theoretical model. The model-building process used in this study was iterative and exhaustive.

The combination of population and employment near stations with parking costs in the downtown area was highly correlated with project ridership. System-level PMT was correlated with the population of the metropolitan area; the number of higher-wage jobs and leisure (retail, entertainment, and food) jobs within ½ mile of stations in the metropolitan area; and the interaction of road congestion, population, and employment near stations. Transit travel speed and frequency were not significant predictors of project ridership when controlling for other factors. These are endogenous and likely are determined by transit managers in response to anticipated or actual demand, so this result is less surprising than it might at first seem.

Several other factors have been thought by transit managers to affect transit use, or have been shown to be correlated with transit patronage in previous research. These factors include mixed-use development near stations, walkability (as measured using walk scores), whether the project serves the downtown area, key trip generators such as stadiums or universities, and the weather in the area. In some cases, such as local intersection density, the researchers were unable to acquire a direct measure of these factors within the budget and timeframe of TCRP Project H-42. In the remaining cases, however, the researchers tested the measures and found that including them did not improve the performance of the models (see Chapters 4 and 5).

Table 5.1 provides summary statistics for the indicators of greatest statistical significance in explaining project ridership and system-wide PMT on transit. A full list of the indicators considered in the research and their contributions as

Table 5.1. Summary statistics for model variables.

Variable Name	Description	Obs[a]	Mean	Median
	Project Ridership Model			
Jobs near stations	Employment within ½ mile of project stations	55	70,355	46,107
Population near stations	Population within ½ mile of project stations	55	55,754	42,224
Transit utility	(Jobs × population × parking rate)/10^6	55	113,077	30,695
CBD parking rate	Daily parking rate in the CBD	55	15	14
Project age	Age of project	55	10	7
Ridership		55	28,470	21,350
Predicted Ridership		55	28,470	19,344
	Metropolitan Area PMT Model			
Jobs near stations	Jobs within ½ mile of fixed-guideway stations in metropolitan area	141[b]	250,112	187,042
Population near stations	Population within ½ mile of fixed-guideway stations in metropolitan area	141[b]	239,984	112,926
Leisure jobs near stations	Retail, entertainment, and food jobs within ½ mile of fixed-guideway stations in metropolitan area	141[b]	38,611	26,380
High-wage jobs near stations	Jobs with salaries exceeding $3,333/month within ½ mile of fixed-guideway stations in metropolitan area	141[b]	118,844	84,359
Congestion index[c]	Total VMT divided by number of freeway lane-miles in MSA (FHWA)	1,641	10,275	10,339
MSA jobs	Overall employment in MSA (LEHD)	1,888	211,323	86,621
MSA population	Overall population of MSA (BEA)	1,888	706,284	289,937
MSA leisure jobs	Retail, entertainment, and food jobs in MSA (LEHD)	1,888	44,533	18,973
MSA high-wage jobs	Jobs with salaries exceeding $3,333/month in MSA (LEHD)	1,888	72,267	26,222
PMT		1,888	84,309	6,775

[a] The ridership model has a single observation for each investment, whereas the PMT model records an observation for each year in each MSA.

[b] Catchment variables are summarized only over MSA-years in which catchment population was positive (i.e., those in which fixed-guideway transit was operating).

[c] Variable does not vary by year—multiple observations have repeated values

predictors of success can be found in Appendix E. For values of significant indicators for each of the 55 projects in the ridership model, see Appendix F.

Many of these indicators of project ridership and system-level PMT are outside the control of local transit agencies or local governments; however, jobs and people within ½ mile of stations could be affected by public policy. In the longer term, transportation and land use planning decisions are likely to affect congestion and the monetary price of travel, including parking costs. Nevertheless, it is primarily the station-area-specific data that are relevant to comparing different corridors and station locations in terms of their potential for success.

The daily parking rate indicator deserves special mention. Although the price of parking was found to correlate with ridership, the price of parking may actually be a reflection of a variety of conditions that are positive for transit ridership, such as density and transit-supportive public policies. Most importantly, however, it reflects the relative cost of rail transit's chief competitor, the private automobile. When automobile travel is relatively costly and there are many near-station jobs and residents, the project can be expected to have higher ridership.

As in previous research, the study team for TCRP Project H-42 found employment and population densities to be highly predictive of a proposed transit project's success, but the interaction of residents and jobs near stations was found to be particularly important in conjunction with high parking costs. This measure captures the exponentially increasing value of a well-connected network of origins and destinations.

5.1 Project-Level Models

The research team's initial statistical model of project-level ridership was designed to capture the following concepts associated with high transit use:

- A large number of workers, shoppers, and residents have good access to stations.
- The relative time costs of driving versus transit are high.
- The project is connected to a larger network serving activity centers and other residents.
- Jobs and housing are balanced over the project and/or system.

Ridership is reported in different ways by different agencies. For this project the researchers used average weekday ridership, measured as the average of non-summer weekday boardings and alightings on project stations. Multivariate regression models were constructed using data from existing BRT, LRT, and HRT projects in the United States. The regressions extracted potential indicators from the database of 600 independent variables discussed in Chapter 5. The richness of the data set emphasizes the importance of finding a parsimonious model, as including all of the presumptively relevant indicators is simply not possible. From the original group, the study team sought independent variables and interactions between independent variables that were most effective at predicting ridership. For those variables that describe characteristics of the station catchments, consistent catchment sizes within the sets of employment and household variables were preferred in order to improve usability, based on focus group feedback and case studies. The researchers opted to use a ½-mile catchment after determining there was little loss of precision from specifying different catchment sizes and that the ½-mile catchment tended to perform as well or better than the ¼-mile or 1-mile catchments for various variables specified on a station-area basis.

5.1.1 Findings

The first of the final models expresses ridership as a function of jobs and population around the stations, parking rates in the CBD, the percent of the alignment at grade, the number of park-and-ride spaces, and the age of the project (Table 5.2). Specifically, the ridership is predicted by Equation 1:

$$R = 0.12[P\_Jobs] + 0.04[P\_Pop] - 393.64[P_{Rate}] + 0.05[R_{Int}] - 9{,}971.61[\%_{Grade}] + 3.38[P\,\&\,R] + 707.94[Age] + 8{,}235.44 \quad (1)$$

Although this is the best-fit model mathematically, it includes variables that may be endogenous. (See Section 5.1.3 for more on endogenous variables.) A more theoretically defensible model omits the number of park-and-ride spaces, expressing ridership in terms of jobs and population around the stations, percent at grade, parking rates in the CBD, and the age of the project, as shown in Equation 2:

$$R = 0.16[P\_Jobs] - 0.01[P_{Pop}] - 491.9[P_{Rate}] + 0.08[R_{Int}] + 3{,}294.39[D_{Grade}] - 17{,}846[\%_{Grade}] + 913.39[Age] + 4{,}431.84 \quad (2)$$

A comparison of predicted and actual ridership for the model including park-and-ride spaces is shown in Figure 5.1 and for the model omitting park-and-ride spaces in Figure 5.2. Notice that the scatter for the latter is a bit larger than for the model including park-and-ride spaces, but not dramatically so.

Table 5.3 shows five project-level models, as follows:

1. The final endogenous model;
2. The final defensible model, which is the model used in the spreadsheet tool;
3. Model C, illustrating the impact of including endogenous variables for level of service and the number of bus connections available at stations, and showing that these variables are not statistically significant;

Table 5.2. Summary of variables in final ridership models.

Variable Name	Abbreviation	Definition
Catchment jobs	P_Jobs	Jobs within 1/2 mile of project stations
Catchment population	P_Pop	Pop. within 1/2 mile of project stations
CBD parking rate	P_Rate	Daily parking rate in CBD
Ridership model interaction term	R_Int	(I_Jobs × I_Pop × P_Rate)/(1 million)
Percent at grade	%_Grade	Percent of alignment at grade
Missing at-grade values dummy	D_Grade	1 if %_Grade info missing; 0 if not
Number of park-and-ride spaces	P&R	Number of park-and-ride spaces
Project age	Age	Age of the project

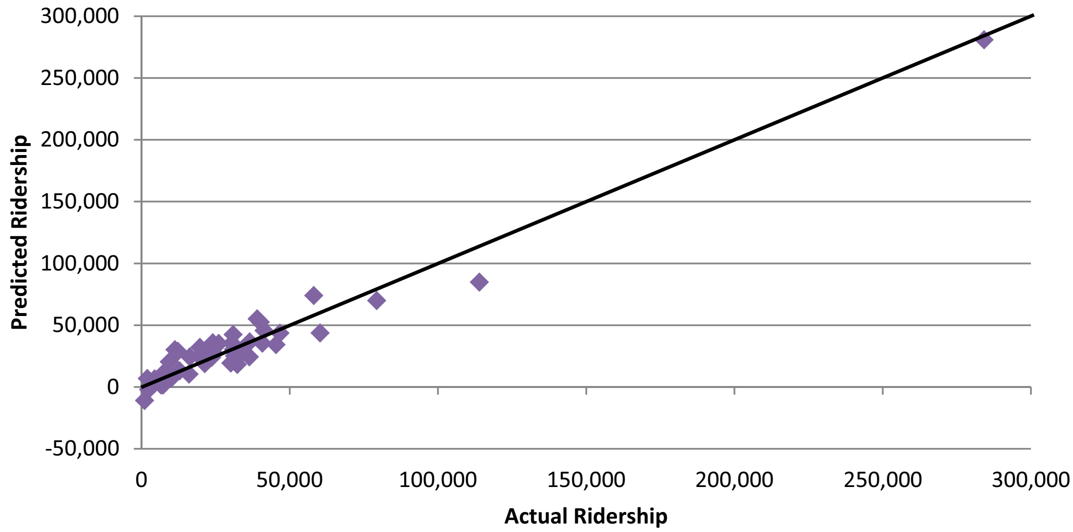


Figure 5.1. Predicted versus actual ridership for the endogenous model.

4. Model D, including indicator variables for HRT and BRT modes. Notice that neither coefficient is statistically significant; and
5. Model E, showing the simplest model expressing weekday ridership in terms of near-station jobs and population. This model has the largest sample and both variables are significant, but the fit is relatively poor.

As shown in Table 5.3, it is the interaction between jobs, population, and downtown parking cost that best predicts ridership. Jobs and residents near stations are not statistically significant on their own in the best model (Table 5.3, Column 2—Final Models, Defensible).

The effect of the CBD parking rate illustrates the interaction between driving costs and transit convenience. When downtown parking rates are high and the project serves many jobs and residents, ridership tends to strongly increase. This interaction term contributes more than any other term to the fit of the ridership model. At first glance, the sign on the parking rate coefficient might seem counterintuitive. However, the influence of parking cost also gets picked up through its association with job and population densities in the interaction term. The combination of concentrated housing and employment with parking charges boosts transit ridership more than downtown parking rates alone. The net effect of parking rates on transit ridership is positive because the effects of the interaction term eclipse the effects of the CBD parking rate. Finally, as the equations indicate, transit ridership tends to rise as projects mature, and a project that is entirely at grade has fewer riders than does a subway or elevated rail line.

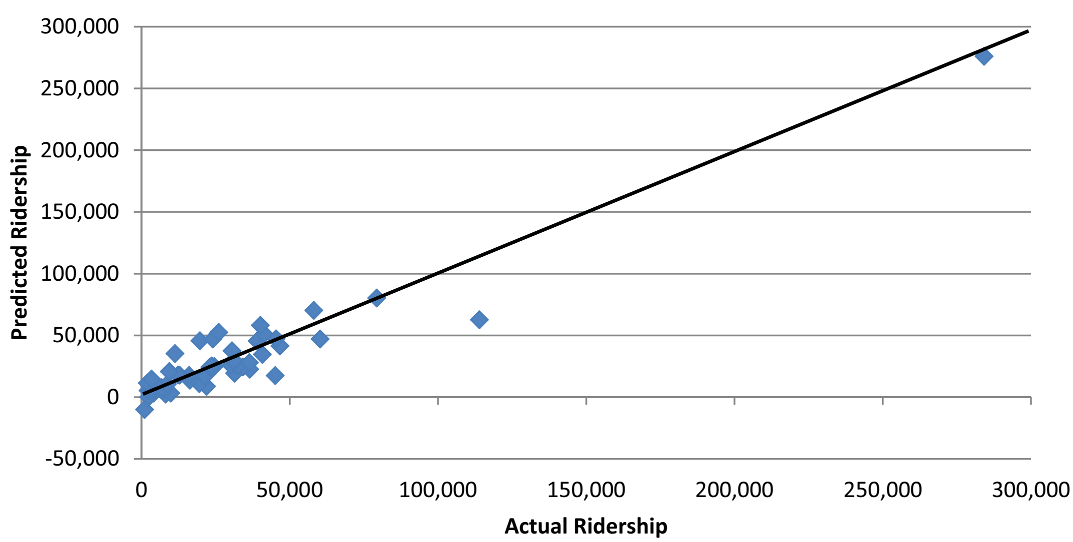


Figure 5.2. Predicted versus actual ridership for the defensible model.

Table 5.3. Summary of project-level ridership models.

Variable Name	Final Models		Rejected Models		
	Endogenous	*Defensible*	*Model C*	*Model D*	*Model E*
Catchment jobs	0.117**	0.155	0.0646	0.122**	0.324**
Catchment population	0.0384	-0.0140	0.00103	0.0441	0.309*
CBD parking rate	-393.6	-491.9*	-354.2	-462.7	
Ridership interaction term	0.0455**	0.0773***	0.0441*	0.0470**	
Percent at grade	-9,971.6*	-17,846.2*	-10929.1*	-3028.4	
Missing at-grade dummy		3,294.39			
Park-and-ride spaces	3.383**		3.170*	3.139**	
Age of project	707.9**	1,040.3**	574.3*	659.0*	
Number of bus lines			100.4		
Level of service			340.2		
HRT dummy variable				7,757.3	
BRT dummy variable				880.2	
CONSTANT	8,235.4	20,672.69**	5,917	2,854	-11,258.3
Number of observations	50	55	50	50	56
Adjusted R^2	**0.939**	**0.894**	**0.942**	**0.939**	**0.656**

* p < 0.05, ** p < 0.01, *** p < 0.001

5.1.2 Comparing Variable Impacts

In understanding the contribution of different variables to the explanatory power of the model, one useful method is to compare the beta weights, which normalize the variable coefficients from the model by the standard deviation of the variable (these are sometimes also referred to as standardized regression coefficients). These are unitless coefficients between 0 and 1, reflecting the relative predictive power of variables in the model. Beta values for the defensible model are shown in Figure 5.3.

Notice that the interaction term has the largest magnitude coefficient relative to the range of the variable. Catchment jobs, population, and CBD parking rate are more influential in combination than they are individually.

Another illustration of the relative influences of the variables is a partial R^2 analysis. The partial R^2 represents the percentage of the variation in ridership that is explained by each variable. As shown in Figure 5.4, the interaction term by itself explains about 62 percent of variation; jobs within ½ mile of stations, another 20 percent; and variations in percent at grade, an additional 16 percent.

5.1.3 Endogenous Variables

Some variables that are intuitively associated with high ridership both cause and are caused by transit use. Sometimes these endogenous variables represent attributes that could be retrospectively adjusted to accommodate high transit use. For example, a transit agency might increase the number of park-and-ride spaces, the frequency of service, or the number of bus connections if demand exceeds the planned capacity. Other variables are prospectively adjusted because

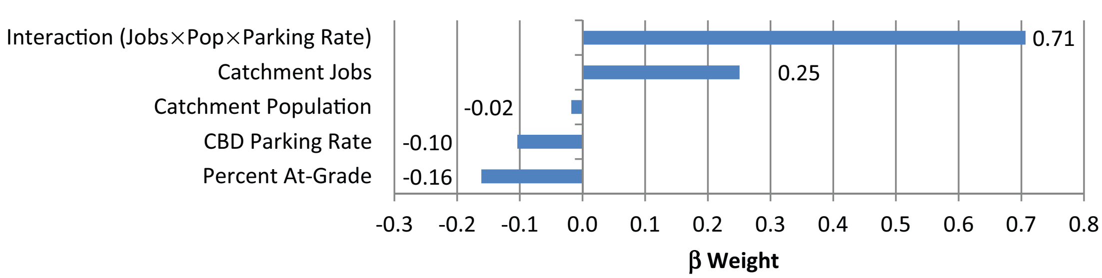


Figure 5.3. Beta weights for defensible ridership model.

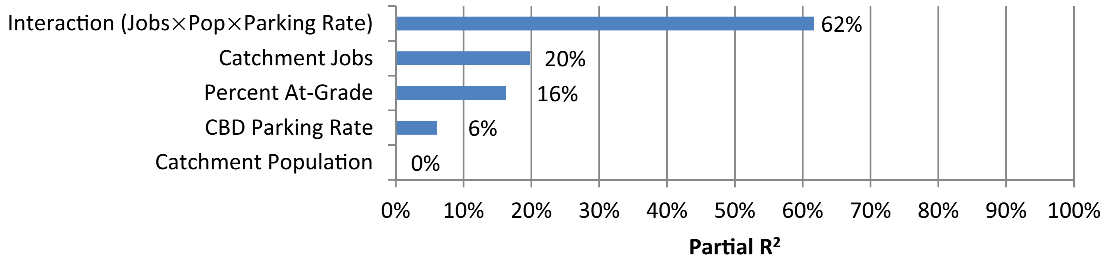


Figure 5.4. Partial R^2 values for defensible ridership model.

there is reason to believe the project will have high ridership. Examples of these variables include percent of the alignment that is at grade, or the design speed of the system, in which added construction or capital expense is acceptable because of high anticipated use. Although there is no doubt that transit ridership increases in response to more frequent and faster service, determining the exogenous component of demand associated with parking, bus service, and other service measures is a difficult task. It can only be presumed that transit agencies make the best possible decisions about service factors and, therefore, that the effects of such variables reflect judgments about existing levels of demand (or likely future levels of demand) rather than actually causing ridership. Also notable, based on discussions from the case studies, is that including parking spaces and bus connections might be confusing from the user's perspective. It would be incorrect in many cases to infer that building more parking spaces without otherwise changing the project would increase ridership. As a compromise, the researchers did include one endogenous measure—the percent of the project at grade—in the project-level ridership model. This measure can only be prospectively adjusted, but it may be highly correlated with other service characteristics such as travel frequency, speed, and reliability.

One indicator, project age, exhibits some endogeneity that has a minor impact on the predictive power of the model. The age of the project is a useful predictor of use with older projects experiencing higher ridership. This variable captures three phenomena: maturation, prioritized selection, and attrition. The most straightforward interpretation of project age is that the transit project will mature as travelers adjust their behavior and land use responds. Additionally, cities tend to prioritize projects with high expected ridership, so older projects also tend to be those with high demand. The age of the project may also affect estimates because unsuccessful projects may be discontinued and are therefore absent from the sample. Including age is less problematic than including other endogenous variables because it is not possible for an agency to increase the age of the project in the same way that it could add a park-and-ride lot or make service more frequent.

5.2 System-Level Models

Another measure of the success of a transit project is its impact on the entire metropolitan-wide transit system. The research team's second set of analyses examined incremental changes in annual system-wide PMT on rail and bus. This measure is intended to capture the impact of the project without double-counting usage that may have shifted from other transit routes. The early PMT models for this study included only MSAs with fixed-guideway transit, for a total of 18 metropolitan areas after attrition due to missing data. The researchers ultimately estimated a more comprehensive model that included 244 MSAs with available data.

The two final models (described in Section 5.2.2) predict negative increments 50% and 80% of the time, respectively, when used to retroactively project PMT for the completed investments in the project-level database. This surprising finding is discussed in more detail in Section 5.3 It should be noted that falling PMT over multiple years is not uncommon, regardless of whether any investments in transit were made. Of all city-years in the data set, 59% show stagnant or dropping PMT. Furthermore, flat or falling PMT is more common in city-years with fixed-guideway transit in place (79/122, or 65% of city-years in the data set show less than 5% growth).

5.2.1 Method of Analysis

The goal of this method is to identify indicators of transit use at the metropolitan level. By comparing predictions for the current state of the system and the system after a transit project, the overall impact of the project can be estimated. Specifically, incremental changes in the annual metropolitan PMT due to individual fixed-guideway transit projects are identified.

The researchers used a panel data set composed of 244 cities observed over 7 years (2002–2008). One technique for addressing panel data is a fixed-effects model, which calculates a unique constant baseline PMT value for each metropolitan area to capture metropolitan-level differences. The fixed-effect technique is useful for making predictions for metropolitan areas included in the analysis, but it is somewhat less reliable in terms of its ability to make predictions for metropolitan areas that were not included. Also, as the number of metropolitan areas in the sample grows, fixed-effects models become less efficient. Alternatively, random-effects models fit a distribution of variation between cities rather than estimating a specific value for each one, based on characteristics of the cities such as their total population or their climate. Statistically speaking, a random-effects model is a more efficient technique for a panel of many metropolitan areas, because the metropolitan-level characteristics can be described by a small set of variables (as compared to the fixed-effect models that require one variable for each metropolitan area).

There is an important distinction in the interpretation of the estimated coefficients for random-effects and fixed-effects models. In random-effects models, the coefficients represent a combination of between- and within-city effects, whereas the coefficients from the fixed-effects model describe only the average of the within-city effect of the variables. For both approaches, the researchers assume that the omitted variables accounted for in the city-level effect are stable over the period of the project.

The composition of the final system-wide PMT model was selected from a set of 93 variables and interactions (see Appendix E). The researchers selected ½-mile catchments around fixed-guideway stations in the metropolitan area to be consistent with the project-level model.

Both fixed- and random-effects regressions were estimated. A Hausman test indicated that a random-effects approach was superior for the final models. Figure 5.5 shows the actual PMT observed in the 244 modeled MSAs (not increments) compared to the value predicted by the final MSA-level model. For reference, the figure includes a black line representing a perfect prediction.

5.2.2 Findings

The final model expresses system-wide annual PMT in terms of the metropolitan area's population, congestion level, and information about the ½-mile radius catchment areas around all rail stations in the region, including population; jobs; the number of jobs associated with food, shopping or entertainment; and the number of high-wage jobs. The values for the catchment measures change in any year after a new project comes into service, so the data represent both within-city and across-city variation. Table 5.4 presents a summary of the variables used in this study's final PMT models.

The final catchment-level model is specified as shown in Equation 3:

$$\begin{aligned}\mathrm{PMT_{Catch}} = & -2.54\,Jobs_{Catch} - 0.223\,Pop_{Catch} + 8.44\,LeisJobs_{Catch} \\ & + 3.28\,HWJobs_{Catch} - 1.01\,Cong + 0.0610\,Int_{PMT} \\ & - 0.0147\,Pop_{MSA(BEA)} - 18{,}977 \qquad (3)\end{aligned}$$

The final MSA-level model was not used in the spreadsheet tool. This model includes MSA-wide employment and population data derived from the same LEHD source as the catchment area data. These additional variables were included to control for how metropolitan-level characteristics affect system-wide transit use. Including these terms resulted in the specification shown in Equation 4:

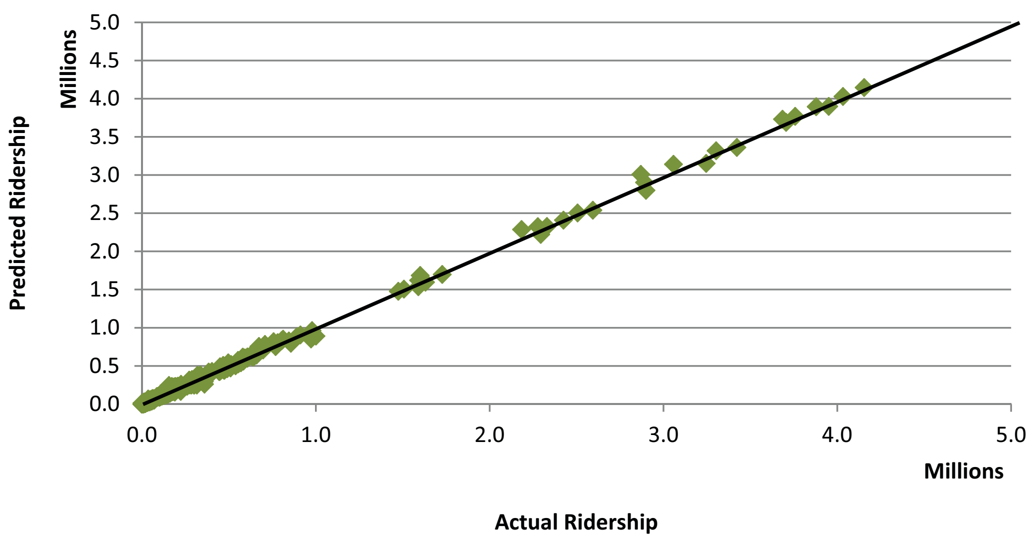


Figure 5.5. Predicted versus actual PMT for the best-fit model.

Table 5.4. Summary of variables in final PMT model.

Variable Name	Abbreviation	Definition
Jobs near stations[a]	$Jobs_{Catch}$	Jobs within 1/2 mile of system stations
Population near stations[a]	Pop_{Catch}	Pop. within 1/2 mile of system stations
Leisure jobs near stations[a]	$LeisJobs_{Catch}$	Number of retail, food, accommodation, entertainment, arts and sports jobs within 1/2 mile of system stations
High-wage jobs near stations[a]	$HWJobs_{Catch}$	Number of jobs earning more than $3,333 per month within 1/2 mile of system stations
FHWA congestion index	Cong	Avg. weekday VMT/freeway lane-mile in metropolitan area
PMT interaction term	Int_{PMT}	(S_Jobs × S_Pop × Cong)/(1 billion)
MSA jobs	$Jobs_{MSA}$	Total MSA employment
MSA high-wage jobs	$HWJobs_{MSA}$	Number of jobs earning more than $3,333 per month in MSA
MSA leisure jobs	$LeisJobs_{MSA}$	Number of retail, food, accommodation, entertainment, arts and sports jobs in MSA
MSA population	Pop_{MSA}	Population of MSA (2000 Census)

[a] Measured within 1/2 mile of all fixed-guideway rail stations in the region, excluding commuter rail stations.

$$\begin{aligned}\mathrm{PMT_{MSA}} = & -2.21 - 0.661 + 7.41\,LeisJobs_{Catch} + 3.16\,HWJobs_{Catch} \\ & -1.12\,Cong + 0.479 - 0.332\,\mathrm{Jobs_{MSA}} \\ & + 0.486\,\mathrm{HWJobs_{MSA}} + 0.189\,\mathrm{LeisJobs_{MSA}} \\ & + 0.273\,\mathrm{Pop_{MSA(Census)}} - 64{,}450.4 \qquad (4)\end{aligned}$$

As expected, population and jobs in the station catchments remain important indicators of system-wide PMT. The story is complex, however: population and jobs near stations, when interacted with metropolitan congestion, yield positive PMT gains. In addition, both higher-wage and leisure jobs are associated with higher system-wide PMT. Leisure jobs—those held by workers in retail, food, accommodation, entertainment, arts, and sports—may represent workers who commute on fixed-guideway transit, but the measure may also capture the impact of activity centers and dense, transit-friendly destinations often found in large cities that are not readily measured with variables such as mixed-use entropy indexes and walk scores, neither of which were statistically significant in our testing. Near fixed-guideway stations, high-wage jobs may cause a system-wide boost in PMT if those workers are less likely to use bus services but are willing to patronize new fixed-guideway service. The size of the region (expressed as the population) and the FHWA congestion index alone are not statistically significant, but they are included in the model to control interacting variables.

Table 5.5 displays three models—two final specifications and one alternative. The first model, referred to as the catchment-level model, contains employment data only from within ½ mile of fixed-guideway stations in the MSA. This model is applied in the spreadsheet tool. The second model adds a set of metropolitan area variables for employment from the LEHD. The third model is the same as the MSA-level model except that, instead of using the BEA count of MSA population, it uses less recent but more easily obtainable MSA data from the 2000 U.S. Census.

The census MSA population and congestion index variables are the only ones that do not vary by year. Given that the metropolitan data set is built in MSA-years, these variables will have many repeated values across observations, whereas other variables will have a unique value for every data point.

Just as for the ridership model, beta values (normalized coefficients) were calculated for the variables in the two final PMT models. The strongest station-based influences on passenger-miles of transit usage were the number of high-wage jobs and the number of leisure jobs near stations (Figure 5.6).

Metropolitan-level measures such as the overall MSA population employment and jobs by type also exert large influences on PMT. The impact of population is intuitive, as the largest urban areas would be expected to have the busiest transit systems. Interestingly, both catchment and MSA employment show the same trend: leisure and high-wage jobs both have a strong positive impact on PMT, whereas other types of employment have a negative influence when controlling for population growth, high-wage jobs, and leisure jobs.

Table 5.5. Metropolitan-level PMT models.

Variable Name	Final		Census
	Catchment-Level	*MSA-Level*	*MSA Variables*
Catchment jobs	-2.542***	-2.608***	-2.212***
Catchment population	-0.223	-0.202	-0.661***
Catchment leisure jobs	8.441***	8.299***	7.412***
Catchment high-wage jobs	3.279***	3.464***	3.157***
FHWA congestion index	-1.088	-1.282*	-1.123*
PMT interaction term	0.061***	0.056***	0.048***
MSA jobs		0.120*	-0.322***
MSA high-wage jobs		-0.076	0.486***
MSA leisure jobs		0.355	0.189
MSA population (U.S. Census)			0.273***
MSA population (BEA)	0.147***	0.115***	
Constant	-18,977.0	-29,783.5*	-64,450.4
# of observations	1,641	1,641	1,641
Cluster-specific variance	145,053.9***	141,380.8***	147,803.0***
Other variance	14,624.4***	14,531.2***	13,129.8***
BIC score	37,789.2	37,781.0	37,519.3

*p < 0.05, ***p < 0.001, BIC = Bayesian information criterion.

Before settling on the final models, many alternative approaches were tested. The inclusion of low-wage jobs was tested because low-wage workers are generally more likely to use transit. Unexpectedly, low-wage employment—tested only for catchments, not for the full MSA—was found to have a significant negative effect on PMT, though the model fit was not much improved. This result may be because low-wage employment indicates declining economic fortunes more than the presence of potential transit riders. Another possible reason for the result is that high-wage employment may better reflect *added* transit ridership than low-wage employment when new fixed-guideway transit lines come online. Although workers making a lower wage are more likely to ride transit, it may also be likely that they already do so. As has been discussed, higher-income workers are less likely to choose to ride a city bus, but may find train or BRT service more appealing. Therefore, fixed-guideway alignments serving higher-income workers might be more likely to add PMT to the system.

The study team also tested whether the number of units of rental housing and/or the number of office jobs near stations was associated with PMT, but the results did not improve the model.

Alternative measures of the utility of driving were tested, including the number of freeway and arterial lane-miles, lane-miles of each type per square mile, per capita length of freeways and arterials, and the year-to-year change in these values, gas

Figure 5.6. Beta values for final PMT model (MSA level).

prices, parking costs, and congestion measures. Testing these variables in the final model demonstrated that the researchers' congestion score (based on FHWA data on freeway use per lane-mile) was the most significant measure of automobile utility.

The research team used lagged variables to test the significance of the relationship between changes in a given year and the resulting impact in subsequent years. Instead of using inputs such as population, employment, ridership, and so forth for the year when PMT is measured, the study team tested values lagged by 1, 2, or 3 years to see whether there was evidence of the investment maturing and ridership stabilizing. The results did not change very much, likely because a longer lag (e.g., 10 years) may be the likely period over which ridership effects are felt. Testing lags longer than 3 years are not possible with existing data.

5.3 Estimating Uncertainty in Model Outputs

The model outputs are based on a fit to data that shows natural variation, or scatter. Even if the measurements are assumed to be free of error and the functional form to be correct, uncertainty remains associated with the fit. The uncertainty in the estimated coefficients is summarized in the variance-covariance matrix. For both the project-level ridership models and the metropolitan-level PMT models, the variance-covariance matrix generated during the modeling process is used to allow the user to estimate the error in predicted transit use for the proposed project. Uncertainty in the incremental PMT estimates is about 20 percent on average, with smaller projects typically having less certainty as a percentage of the estimate.

Because the negative increments were a constant throughout multiple tests of the model's robustness and several alternative data sets, the researchers concluded that they are legitimate findings. Possible explanations include diversion of service and increasing efficiency.

5.3.1 Diversion of Service

It is possible that agencies may pay for rail investments in part by diverting resources from existing services, or that they respond to new rail lines by downgrading or closing parallel bus routes. The resulting drop in PMT might overwhelm the added miles from the rail investment. To test this, the research team observed the changes in bus and rail seats provided per capita over the MSAs in the sample set (from the National Transportation Database, or NTD). MSAs with increasing rail seats between 2002 and 2007 showed a decrease in the number of bus seats, whereas MSAs with no increase in rail seats showed an increase in the number of bus seats; however, these changes were on average so small as to be negligible.

If it is assumed that increasing metropolitan population and an improving economy over those 5 years should have naturally resulted in increased bus service, bus service might hypothetically be allowed to stagnate when investments in rail were made. The data do not, however, strongly support the diversion of service hypothesis.

5.3.2 Increasing Efficiency

Although data were not available to test this hypothesis, it is possible that rail investments decrease the miles traveled on transit for some passengers, resulting in a negative overall increment. Rail lines can sometimes provide more direct routes than bus service. Furthermore, whereas a bus rider might be willing to make multiple transfers to board and alight close to the individual's origin and destination, fixed-guideway systems encourage using alternate modes (driving, walking, or bicycling) to access stations farther from home. Both of these effects may decrease overall PMT. On the other hand, rail lines also allow passengers to travel farther than bus in a given time, so that might imply that travel distances would actually get longer with increased mobility.

The estimates of incremental PMT for each project in the study's database were calculated as the difference between the model predictions for the entire metropolitan area with and without the project. The incremental difference is sometimes on the same order of magnitude as the error in the estimate of overall PMT. Some small negative increments are, in fact, within the margin of error for the model, implying that the project has no statistically significant effect on system-wide PMT. The spreadsheet tool reflects this by reassigning small negative increments of PMT to zero. The same issue applies to small positive increments as well, although these values are not reassigned in the spreadsheet tool.

5.4 Input from Focus Groups: Phase 2

Development of a spreadsheet tool to make it possible for transit agencies or other interested parties to estimate ridership on proposed fixed-guideway transit projects and the projects' impacts on system-wide PMT was an element of TCRP Project H-42. The spreadsheet tool provides a simple way to apply the indicator-based models to compare corridors, alignments, and modes in terms of these success measures.

During the second round of focus groups and interviews, participants were shown an initial mock-up of the spreadsheet tool and invited to comment on its utility for local planning. Many participants said that the tool would be useful for an initial evaluation of potential transit projects, helping prioritize alternatives, providing a means for scenario testing, and demonstrating to the community the implications of different options. Comments were offered suggesting additional capabilities that would make the tool more useful, including improved visualization of the tool's outputs in the form of charts and tables. Overall, participants expressed no significant concerns about the difficulty of generating the input data for the tool, apart from the time required. Many participants requested that the handbook provide clear and detailed information about the underlying mechanisms of the spreadsheet tool to give them more confidence in the validity of its results and to better explain the tool's outcomes to interested parties. More information about the second round of focus groups and interviews appears in Appendix H.

In Phase 2, the research team made efforts to broaden the outreach to include MPOs and both large and small transit agencies. One focus group was held during APTA's June 2012 Rail Conference in Dallas, which tends to attract transit agency professionals. As with the first focus group, participants were selected from among the conference attendees based on their knowledge of transit project evaluation and their leadership roles within APTA. To broaden the participation, representatives of the local MPO also were invited. Participants included:

- Doug Allen, deputy general manager for planning and development, Capital Metro, Austin, Texas, and vice chair of APTA's policy and planning committee
- Matt Sibul, director of planning for the Utah Transit Authority, Salt Lake City, Utah
- Barb Weigle, planner with Dallas Area Rapid Transit, Dallas, Texas
- Kay Shelton, planner with Dallas Area Rapid Transit, Dallas, Texas
- Chad Edwards, planner with North Central Texas Council of Governments, Dallas, Texas
- Hua Yang, planner with North Central Texas Council of Governments, Dallas, Texas
- Cheryl King, planning director for the Metropolitan Atlanta Rapid Transit Authority, Atlanta, Georgia
- Kim Slaughter, planning director for Houston Metro, Houston, Texas

Two smaller focus group discussions were subsequently held to solicit broader input. The first was held on June 13 at the Houston-Galveston Area Council (HGAC), the MPO serving the Houston, Texas, region. Participants included Ashby Johnson, deputy director of planning, and four members of the HGAC planning staff. The second small focus group was held July 18 at the MTC, the MPO serving the San Francisco Bay area. Participants included David Ory, head of the MTC's systems analysis group; Carolyn Clevenger, a senior planner with the MTC; and Dave Vauten, an MTC staff planner.

Telephone interviews were also conducted with three individuals who expressed interest during the mid-year meeting of TRB's Metropolitan Policy, Planning and Processes Committee (ADA20): Mary Archer, Marin County (California) Transit; Elizabeth Schuh, Chicago Metropolitan Agency for Planning; and Tom Schwetz, Lane County (Oregon) Transit.

The focus groups and the telephone interviews started with a PowerPoint presentation through which the research team summarized the research goals, introduced the analytical approach, and presented a preliminary mock-up of the spreadsheet tool's input and output screens. In the focus groups, participants were particularly interested in seeing how their projects compared with others in the database.

Participants in the APTA rail focus group were generally more interested in the policy/planning implications of the findings than in potential applications of the model. For instance, in an initial version of the model, they wanted to know why the radius for calculating station-area density would differ for residential and employment development. At that time the best predictors were ½ mile for population near stations and ¼ mile for employment. One participant noted that his agency had considered locating a station near an office campus but did not do so because the campus density was not "transit oriented." Knowing the importance of jobs within a quarter-mile of stations, he said that they might have fought harder to put the station close to the corporate campus, or to have planned for branch lines serving that center and other nearby job centers. Participants also showed interest in the mode-neutral nature of the model, while noting that FTA now allows agencies to factor in the added appeal of rail.

Participants in one of the focus groups said that the traditional approach to New Starts planning emphasized finding solutions to a current or future transportation problem. One participant wondered if a focus on project-level ridership signaled a movement away from problem-solving. This participant pointed out that the tool does not tell the user whether or not a specific problem has been solved, nor does it address whether conditions for existing riders have been improved. The participant also noted that his agency has used land use density thresholds as a success indicator for proposed rail stations, giving them a lever for influencing projects before they receive formal submissions for consideration.

A participant in another focus group also questioned whether the spreadsheet tool implied that projects with a lower cost per rider were by definition more successful. This participant gave an example of a project that is considered to be a local success, despite being at the high end of the cost per rider range, because fare revenues from that project exceed operating costs. Although cost per rider might be useful as part of a multicriteria project evaluation considering return on investment and other measures, some might consider a focus on cost per rider alone to be incendiary. The participant suggested that the handbook explain how the user should interpret and use this information as part of a multicriteria project evaluation.

This suggestion was echoed by one of the telephone interviewees, who pointed out that cost per rider needed to be considered in context, such as the cost of other alternatives. This interviewee stated that a variety of factors enter into local decisions on a transit project—impacts on business, property values, parking, vegetation, traffic volumes, emissions, jobs—and suggested that the researchers consider how to estimate some of these other factors based on ridership results, or at least point users to other sources they might use to estimate a fuller array of factors.

Participants in the APTA rail focus group also suggested other variables that might be considered in the regression analyses:

- Regional and/or corridor characteristics
  - Number of CBDs
  - Quality of pedestrian access to stations
- Characteristics of the project
  - Extension or new line
  - Does project provide a one-seat ride to the CBD, or is transfer required?
- Special events
  - Seats at sports venues within ¼ mile of stations, number of events, attendance
  - Convention center size
  - Hotel rooms within ¼ mile
- Key trip generators
  - Hospital beds in catchment area
  - Commuting students in catchment area
- Weather
  - Days of sunshine
  - Inches of precipitation, snow

Focus group attendees added that the tool should consider the walkability of pedestrian access to stations, not merely the distance. They also recommended that the research team try to expand the tool to include CR. An interviewee suggested that the research team consider an operations and maintenance cost output as well as capital cost.

5.5 Response to Practitioner Input

Many additional variables, including walkability, entropy indexes, and specific industry types, were tested and created in response to input from focus group participants and case study interviewees. None of these additional measures improved the models significantly, but a few of the factors are discussed in more detail in this section.

5.5.1 CBD Employment

Earlier work identified jobs in the CBD as an important indicator of transit use. This analysis uses jobs located within ½ mile of stations to predict transit use at both the project and the metropolitan level. To test whether CBD jobs have a distinct and separate impact on ridership and PMT, the researchers defined CBD jobs in three ways. First, the researchers nominated one station in each metropolitan area as the central station and counted the number of jobs within ½ mile of stations that are themselves within ½ mile or less of that central station. The second definition expanded the size of the CBD to include all stations within 1 mile of transit distance to the central station. The third definition used catchment jobs for stations that fall inside the CBD as defined by the U.S. Census Bureau in 1982.

As Table 5.6 shows, only one of the CBD catchment variables—residents near stations within ½ mile of the central station—was significant in the project-level ridership model. It shows a counterintuitive negative contribution. The model's overall goodness of fit does not change significantly, so the research team retained the more parsimonious model without CBD measures.

At the metropolitan level, the CBD catchment variables likewise do not improve the model. As shown in Table 5.7, only the third definition improves the fit significantly, but the CBD variables are still statistically insignificant. Model D shows a model in which only CBD station areas are counted, and the fit is distinctly worse.

This result does not necessarily indicate that CBD employment is irrelevant as an influence on ridership and PMT. Rather, it indicates that the inclusion of jobs located near stations allows for the greater job density of the CBD to be incorporated in the model, because the CBD contains stations. CBD employment is not independently a significant influence on ridership or PMT.

5.5.2 Exclusion of Renovation Projects

Of the 72 projects used in the study set, six involved rehabilitating existing stations, five of which were included in the estimation data set. Three of these projects were in Chicago (Metra North Central, Metra Southwest Corridor, and CTA Douglas Branch); one was in Miami (South Florida Tri-Rail Upgrades); and one was in Philadelphia (SEPTA Frankford Rehabilitation). The Tri-Rail and Frankford Projects were classified as enhancement projects in the study's data set, indicating that they consisted solely of the improvement of existing infrastructure. An additional project in Chicago—the Metra UP West, was excluded from the final data set because of incomplete data.

To test the impact that including these projects had on the ridership models, the researchers compared the final

Table 5.6. Comparison of project-level models that include CBD catchment variables.

Variable Name	Final Model	CBD Test Models		
	Defensible	*½-mile*	*1-mile*	*Census-Defined*
Catchment jobs	0.155	0.280*	0.307**	0.308*
Catchment population	-0.014	-0.0888	-0.0795	-0.0585
CBD parking rate	-491.9	-387.8	-386.7	-247.6
Ridership interaction term	0.0785***	0.0815***	0.0752***	0.0654***
Percent at grade	-17,846.2*	-92.7	-516.2	-1,111.5
Missing at-grade dummy	3,294.9	-20,899.9***	-21,115.9**	-19,099.8**
Project age	913.4*	968.8**	953.3**	742.7*
½-mile CBD jobs		-0.0532		
½-mile CBD population		-1.664*		
1-mile CBD jobs			-0.126	
1-mile CBD population			-0.795	
Census-defined CBD jobs				-0.0932
Census-defined CBD population				-0.89
CONSTANT	20,672.7**	21,763.0**	21,278.0**	17,896.9*
# of observations	55	55	55	55
Adjusted R^2	**0.894**	**0.911**	**0.906**	**0.902**

*p < 0.05, **p < 0.01, ***p < 0.001

Table 5.7. Comparison of metropolitan-level models with CBD catchment variables.

Variable Name	Final Model	CBD Test Models			
	Defensible	*½-mile*	*1-mile*	*Census-Defined 1*	*Census-Defined 2*
CSA population	0.0161	0.0202	0.0188	-0.0143	-0.0228
Catchment jobs	-2.742***	-3.017***	-2.836***	-3.500***	
Catchment population	-1.305**	-1.201**	-1.067*	-0.938*	
Catchment leisure jobs	8.816***	9.505***	8.927***	8.655***	3.031
Catchment high-wage jobs	4.486***	4.442***	4.415***	4.524***	3.559***
Congestion index	-5.001	-3.478	-4.502	-11.42	0.733
PMT interaction term	0.0633***	0.0691***	0.0552**	0.0748***	-0.0231
½-mile CBD jobs		0.441			
½-mile CBD population		35.58			
1-mile CBD jobs			0.492		
1-mile CBD population			-10.41		
Census-defined CBD jobs				0.753	-0.976
Census-defined CBD population				-3.186	-12.02
Constant	798,410.7**	375,261	909,602.0**	1,099,246.7***	714,128.9*
# of observations	124	124	124	110	110
Adjusted R^2	0.714	0.717	0.711	0.752	0.633

*p < 0.05, **p < 0.01, ***p < 0.001

Table 5.8. Comparison of project-level models with rehabilitation and enhancement project adjustments.

Variable Name	Final Model	Renovation Test Models		
	Defensible	*Rehab. Stations Dummy*	*Enhancement Dummy*	*Rehab. Projects Removed*
Catchment jobs	0.155	0.163*	0.165*	0.167*
Catchment population	-0.014	-0.0475	-0.0424	-0.0504
CBD parking rate	-491.9	-594.0*	-386.5	-479.9
Ridership interaction term	0.0785***	0.0818***	0.0794***	0.0808***
Percent at grade	-17,846.2*	-14,536.9*	-14,548.6*	-13,646.1*
Missing at-grade dummy	3,294.9	-9,217.7	-2,549.8	-7,367.6**
Project age	913.4*	1,040.1**	1,038.9**	1,065.5**
Rehab. stations dummy		19,567.2		
Enhancement dummy			27,200.9***	
CONSTANT	20,672.7**	18,794.0**	15,755.9*	16159.9*
# of observations	55	55	55	50
Adjusted R^2	0.894	0.901	0.907	0.908

*p < 0.05, **p < 0.01, ***p < 0.001

defensible model with three test alternatives (see Table 5.8) as follows:

1. Adding a dummy variable for projects including station rehabilitations (the column marked *Rehab. Stations Dummy*).
2. Adding a dummy variable for projects classified as enhancements (the column marked *Enhancement Dummy*).
3. Removing rehabilitation and renovation projects from the estimation data set (the column marked *Rehab. Projects Removed*).

Job diversity and the importance of retail jobs were suggested as important indicators of transit use during conversations with several regional planners in the case study phase. The modeling process in TCRP Project H-42 used retail jobs as one component of the leisure-based jobs category when predicting PMT. To measure job diversity, the researchers created a success metric that is designed to measure the balance of jobs that are associated with non-work activities. As shown in Table 5.9, three groups of activities were created, each of which is associated with a set of codes developed for the North American Industry Classification System (NAICS).

The researchers used an entropy index (Cervero & Kockelman 1997) to estimate the balance within the subset of jobs listed in Table 5.9. The entropy index can be expressed as follows:

$$E = -\sum \frac{P_A \times \ln P_A}{\ln 3} + \frac{P_B \times \ln P_B}{\ln 3} + \frac{P_I \times \ln P_I}{\ln 3} \tag{5}$$

P_A is the fraction of jobs in the catchment that belong in group A, P_B is the fraction jobs in the catchment that belong in group B, and P_I is the fraction jobs in the catchment that belong in group I. Perfect balance between the three groups would yield an entropy index of 1. This was done at the project and metropolitan levels. In both cases, the job diversity measure did not improve the goodness of fit; thus, it was not included in the final models.

The job diversity index is also a means of addressing a set of variables considered to be important by practitioners. Some agencies stated that they found the presence of dry cleaners,

Table 5.9. Definition of groupings for non-work employment analysis.

Label	Activities	Codes
A	Shopping, beauty salons, mechanics, laundry, religious activities, restaurants, and banks	NAICS codes 44/45, 81, 72, 52
B	Real estate, lawyers, accountants, notaries, arts, entertainment, recreation	NAICS codes 53, 54, 71
I	Schools, doctors, dentists and hospitals, public services	NAICS codes 61, 62, 92

NAICS = North American Industry Classification System.

drug stores, flower shops, and other specific retail services to be important. In TCRP Project H-42 the data were not detailed enough to examine each of these niches individually; however, the larger industry categories into which they fall were each tested, and each was found not to be statistically significant.

Certain institutions and facilities are also considered to be important indicators of transit use. Specifically mentioned in focus groups and case studies were schools (quantified by number of students or desks), hospitals (quantified by number of hospital beds), and stadiums (quantified by number of seats). Although the presence of one of these institutions may have a significant impact on ridership, the researchers were unable to gather reliable data across the panel, and therefore these indicators were not tested.

Weather and climate were suggested at a case study visit and subsequently included. The researchers tested various metrics from the NCDC, including number of days with high or low temperatures, percent of possible sunlight, and average temperature, precipitation, and snowfall. When controlling for other factors, these weather characteristics were not significant predictors of transit use at the project or metropolitan level.

5.6 Summary of Results and Comparison with Previous Studies

The analysis in this study used aggregate demand models to investigate the impact of numerous indicators on ridership and PMT for the largest possible set of fixed-guideway projects, incorporating cross-sectional and time-series data. Other indicator-based research has similarly attempted to predict the success of transit lines using causal models that incorporate numerous characteristics of the system itself and surrounding conditions. The work for this project examines almost all of the same indicators as those other causal studies, and includes some that others ignore. This study also tested system-wide impacts of fixed-guideway investments, something which the team's review of prior research suggested has not been done systematically before.

Similar to the original work of Pushkarev and Zupan as well as subsequent studies, the researchers for this study found that population density and employment density were highly predictive of transit ridership; unlike those studies, however, the researchers found that the combination of jobs, residents, and high parking cost or high road congestion is much more influential than any of those indicators on their own. Additional indicators that this study shares with other recent research include income measures, measures of network configuration, service frequency, local bus connections, and park-and-ride spaces.

The research team found some often-cited predictors of success to be insignificant when controlling for other factors. Insignificant factors include population characteristics such as education level, immigrant status, renter status, and car ownership; service characteristics such as fare, frequency, revenue vehicle-miles, and speed; average station distance to the CBD; transit network service coverage; weather measures; and fuel price. The study described in this report does not investigate other cited indicators (e.g., trip destination type) or street network design characteristics (e.g., intersection and street density and percent of intersections that are 4-way intersections, an indicator of both density and connectivity). Although this study differentiates by mode and finds that mode-specific dummy variables are not significant, the project-level data set is too small to enable a test of how the influence of indicators like jobs and residents near stations may vary by mode (HRT, LRT, and BRT).

Conversely, one element that is incorporated into the model presented in *TCRP Report 167* but often is excluded from other studies is the relative costs of transit versus private automobile—namely congestion measures and parking prices and availability. This study finds that high congestion is a significant indicator of transit use in conjunction with concentrations of jobs and residents near stations, but not by itself.

CHAPTER 6

Case Studies: Overview

The research team conducted case studies of transit projects in six metropolitan areas, reviewing public reports and other materials, conducting site visits, and interviewing more than 50 transit planners, MPO officials, and consultants who had worked on the projects. The cases were used to help the researchers understand how transit planning decisions had been made and the nature of any indicator-based evaluations that had occurred. This included determining what measures of transit project success were considered by planners and how those success measures might have predicted the future performance of a project. The study team also discussed TCRP Project H-42's proposed indicator-based method to understand how it might be used by planners, and what improvements would be helpful. This section summarizes the findings from the case studies. Detailed write-ups are available in Appendix I.

The study team focused on HRT, LRT, and BRT projects because the project's data set has few commuter rail (CR) examples and no streetcar examples. For three of the case study sites, the researchers analyzed the planning and performance of CR projects in the same region, drawing conclusions about the indicator-based method that may not apply to the HRT, LRT, and BRT cases.

The cases were as follows:

- Lynx South Line (Charlotte, North Carolina)
- North Central DART Extension (Dallas, Texas)
- Emerald Express BRT line (Eugene, Oregon)
- Interstate MAX (Portland, Oregon)
- University and Medical Center Extensions (Salt Lake City, Utah)
- Metro Branch Avenue Extension (Washington, D.C.)

The research team sought out diverse cases in order to identify differences between projects and to better understand the potential implementation of the proposed indicator-based method across different project types (see Case Study Diversity). The team also ensured that it had access to project planning documentation and that planners were available for interviews. Finally, the researchers looked for outlier cases, such as Portland's Interstate MAX and the Branch Avenue Extension of WMATA's Green Line. Interstate MAX was a below-average project, based on net cost per passenger-mile ratios (Guerra and Cervero 2011), in a region lauded for its high-quality transit planning. By contrast, the Green Line was one of the most cost-effective projects (Guerra and Cervero 2011).

Case Study Diversity

Modal: One HRT project, four LRT projects, and one BRT project (with three CR lines in the same metropolitan areas also discussed).
Geographic: Two Pacific, one Mountain West, one Sunbelt, and two East Coast.
Metropolitan area size: Ranging from 350,000 to 6 million residents.
Project context: Two cases were the first fixed-guideway projects in a region and four cases were system expansion projects.
Transit funding: Four projects received federal New Starts funding, and five received some form of direct federal support. No two projects had the same mix of project funding sources.
Stakeholders: Three of the projects passed through multiple jurisdictions. Plans for two of the projects crossed state lines.

The research team visited the case study projects, met with transit agency and MPO staff, and reviewed documents archived by the project sponsors. Transit project consultants were also interviewed. During the site visit in Washington, D.C., 2 days were spent at FTA reviewing document archives and speaking with staff.

Although case study settings and case study projects varied considerably, very similar indicator-based planning practices emerged across all the cases. Qualitative indicators and measures of success were often given more credence in decision-making than quantitative indicators and technically derived measures. Because the indicator-based method developed as part of this project focused on ridership and PMT and did not include other success measures, many interviewees believed the use of the quantitative method would be limited, and that changes and additions would be necessary for the tool to be more useful.

6.1 Settings

Differences in case study settings may have contributed to the different ways projects were evaluated and planning decisions were made. One element that differentiates these case studies is distinct cultural and physical transit orientation. The Dallas project, Washington, D.C., project, and the southern portion of the Charlotte project were planned in settings that were auto-oriented at the time, which contributed to their auto-oriented features. Eugene, Portland, and Salt Lake City were built, at least partly, in arterial medians close to the cores of urban areas. These settings influenced the planning philosophies that guided the projects. Whereas planners in Washington, D.C., and Dallas, Texas, tended to consider potential patrons of their rail system extensions to be park-and-ride users or bus riders, planners in Charlotte, North Carolina, and Eugene, Oregon, thought of their patrons as arriving by a mix of modes. In Portland, Oregon, planners suggested that the average rider they planned for was a pedestrian (Interviewee AA, in-person conversation, 8/7/12).

Macro regional factors also play a role in how transit projects perform. For instance, the Dallas North Central Line failed to achieve ridership projections, whereas the Washington, D.C., Branch Avenue Extension met projections. The Dallas and Washington, D.C., regions have similar total population and employment, but Washington, D.C., now has four times the transit route-miles and four times the number of people living near its rail system stations. Parking rates in the CBD, an indicator of supply-and-demand dynamics, are three times as high in D.C. as in Dallas—in fact Dallas has one of the lowest average CBD parking rates of any major city. These factors may help explain the fivefold difference in regional transit ridership between the two locations.

In spite of differences in the settings of these case studies, their transit planning processes were similar. Several factors that could be expected to produce different approaches among the case studies did not seem to play a role, including the mix of transit modes and the size of the metropolitan area. Federal environmental policy and funding requirements may have led to a consistent transit planning process, as well as the use of consulting firms. If stakeholder agencies lacked fixed-guideway planning capacity, as was the case in Charlotte where no light rail previously existed, consulting firms were engaged to lead the planning. Even in locations where fixed-guideway projects had previously been developed, consultants were consistently retained to aid with planning.

6.2 Project Attributes

Differing project characteristics may have contributed to the ways they were evaluated and how planning decisions were made. The interviews conducted in TCRP Project H-42 suggest that transit planners carry out system planning and project planning differently—primarily varying the prioritization of the decision criteria they consider—depending on those characteristics. Motivations for transit projects and typologies of transit facilities varied greatly. For example, some projects were motivated largely by a desire to support changes to the regional urban form and land use patterns (Charlotte, Eugene, and Portland), but others were motivated by automobile traffic mitigation or mobility concerns (Washington, D.C.; Dallas; and Salt Lake City). This led planners to use different prioritization of success measures when considering modes, alternatives, station locations, and other project attributes. At the same time, some of the cases were primarily envisioned as walk-up services (Portland, Eugene, and Salt Lake City), whereas others were envisioned as park-and-ride facilities early in the planning process (Washington, D.C., and Dallas). Again, the expected role of the project informed the prioritization of various measures of success and, therefore, success criteria used by planners during the planning process.

Variance in planning philosophies and characterizations of projects might be partly attributable to the timing of the planning processes. Most of the case study projects were added to regional plans during the 1980s, and planning was carried out in the 1990s and 2000s. These more recent planning processes strongly considered land use impacts, economic development at each station, and other current-day concerns. However, the case studied in Washington, D.C., although opened in 2001, was actually planned in the 1950s when priorities focused on decongesting central cities and facilitating travel between rapidly expanding suburbs and the CBD. Transit planning has changed over time, based on changing values and advances in the state of the art.

Different priority was given to success metrics depending on project differences, but the researchers were struck by how similar the success metrics, evaluation techniques, and planning processes actually were across projects that varied by size, mode, and other features. All of the cases used very similar indicator-based methods to develop early transit plans and to quickly assess the potential for various proposals to be successful. Additionally, qualitative indicators and measures were often given more credence in decision-making than quantitative indicators and technically derived measures. Some of these similarities may be explained by the same nationwide factors that were enumerated in the prior section, including adherence to federal policies by national consulting firms.

6.3 Indicator-Based Planning Methods

The case study research suggests that TCRP Project H-42's indicator-based method will be situated within an already-robust set of indicator-based transit planning methodologies. Several transportation planning agencies noted that their regions have recently employed robust indicator-based transit project prioritization methodologies (Interviewee AB, in-person conversation, 8/7/12; Interviewee AC, in-person conversation, 8/20/12). During the planning of every case study project, various kinds of indicator-based methods—some heuristic, some empirical—were used to propose transit alignments, compare and contrast project alternatives, and justify the selection of a particular proposal, and typically included goals in addition to ridership and capital cost.

Multiple interviewees stated that transit planning is an art and a political process, not a science (Interviewee AD, telephone conversation, 8/24/12; Interviewee AA, in-person conversation, 8/7/12). Project stakeholders invariably discussed the need to balance multiple objectives beyond ridership and capital cost as they planned transit projects. Notably, the goals associated with implementing the six case study transit projects were consistent across all the projects, although they were prioritized differently. Those goals are listed in Table 6.1.

The transit planning literature often focuses on predicting project success based on specific technical planning approaches and sophisticated planning tools, such as four-step transportation models; however, the research team identified nearly 20 different simple criteria being used by planners to predict whether a transit project would be successful according to one or more of the goals enumerated above. These criteria can be described as rule-of-thumb procedures for predicting project success and making determinations about route options or alternative station locations (Table 6.2).

Considering that most technical approaches—even the proposed indicator-based method—require users to describe a transit project before an evaluation can be made, it is obvious that less-technical methods were employed to develop the test cases. Across every case study, transit planning decisions seemed to rely more on the rules of thumb than on the outputs of the technical evaluations.

Though not technically complex, the rule-of-thumb methods helped transit planners address the immense complexity of designing and building a transit project. The case studies illustrate several balancing acts among various interest groups, among conflicting objectives, and between technical analysis and heuristic evaluations.

Table 6.1. Project goals discussed by project stakeholders.

Measure of Project Success	Example Metrics Evaluated Before Operations	Abbreviation
Ridership	Modeled riders per day, riders per day per station, and riders per mile	R
Sustainability	Modeled mode shift (i.e., choice ridership), VMT, air quality (particulate matter)	S
Real estate impacts	Projects proposed during transit planning, billions of dollars in private real estate investment since stations were announced	RE
Economic development	Qualitatively assessed through anecdotes, case studies, and business community's advocacy (*also see* real estate impacts)	ED
Consolidated bus operations	Modeled operating costs	BUS
Congestion relief	Modeled hours of congestion on parallel roadways	C
Project completion	Passed local, regional, and state votes; completed federal process steps; won funding; set project delivery date; opened for revenue service	PC
Dependent riders	Non-auto households in proposed station areas, low-income households in proposed station areas	DR

All goals were observed in each case study.

Table 6.2. Criteria discussed by project stakeholders.

Criterion (Rule-of-Thumb)	Measure of Project Success	Charlotte	Dallas	Eugene	Portland	Salt Lake City	D.C./MD
Provide fixed-guideway transit where bus ridership is already high	R / BUS		X	X	X	X	X
Select high-visibility corridors where patrons will feel safe	R				X		
Connect CBD with suburban park and rides near a congested belt loop	R / S / C / BUS	X	X				X
Minimize stations to maximize speed	R / S / C	X		X			
Minimize grade crossings and in-street operations to maximize speed	R / S / C	X	X	X	X		X
Provide fixed-guideway transit in corridors where parallel highway infrastructure is heavily congested	R / S / C	X	X		X		
Connect multiple employment centers	R / S / C		X	X		X	X
Connect major regional destinations	R / ED			X	X	X	
Place alignment in close proximity to commercial property	R / ED				X	X	
Place stations in busy locations where "eyes on the street" provide a sense of safety	R				X		
Provide transit in high-demand travel corridors where alternate capacity is prohibitively expensive	ED	X	X		X	X	
Maximize the number of stations	ED, RE	X		X	X		X
Place alignment along corridors with ample development potential to facilitate urban growth as described by local land use plans or regional plans	RE	X		X	X	X	
Provide fixed-guideway transit in corridors where inexpensive right-of-way can be easily accessed	PC	X	X	X	X	X	X
Maximize distance between alignment and single family neighborhoods; minimize taking of residential property	PC	X		X	X		X
Identify corridors that can help garner local political support for further transit system investment	PC	X		X			X
Select corridors that garner congressional support	PC	X			X		X
Locate stations in low-income areas or in communities of color	DR / PC / ED			X	X		X
Provide service that has average travel speeds greater than existing bus routes	R / BUS	X	X			X	X
Provide substantial bus layover facilities at stations	BUS		X			X	X

6.4 Potential Usefulness of the TCRP Project H-42 Method

The study team demonstrated the preliminary spreadsheet tool and discussed how interviewees might employ it. One objective of TCRP Project H-42 is to "identify conditions and characteristics that are necessary to support alternate fixed-guideway transit system investments." As noted in the prior section, the case studies suggest that transit planners balance numerous objectives for which certain "conditions and characteristics" are relevant to some planners but uncorrelated with or counterproductive to others. Although ridership was universally regarded as a measure of transit project success, it was one of many success measures under consideration. In Portland, transit planners implemented a project to satisfy other objectives of the transit agency, local governments, community members, and other stakeholders, despite the fact that according to several quantitative measures of success the project was expected to have low ridership and be less successful (Interviewee AA, in-person conversation, 8/7/12). In Charlotte, planners found that the Bush Administration's singular focus on cost effectiveness based on cost per hour of travel-time savings led them to make cost-saving changes to their project that ultimately produced a short-sighted investment (Interviewee AD, telephone conversation, 8/24/12). Although fully aware that their long-range planning models predicted that future light rail extensions would require service on the line to use longer trains, Charlotte reduced the capital cost of their initial light rail facility by limiting station platform sizes to those required to accommodate initial ridership demand. Subsequently, when extending the rail line, they were forced to disrupt operations to lengthen the platforms on the existing segment.

Project-level and system-level patronage were seen as distinct by some interviewees. Interviewees in Salt Lake City stated that some of their latest projects have not achieved the ridership they anticipated, but system-wide ridership gains have resulted from operational changes on the trunk line services that were enabled by those projects (Interviewee AE, in-person conversation, 8/20/12).

Interviewees in Dallas were interested not in the total number of riders on the line but in attracting incremental choice riders to the facility to relieve traffic congestion on a parallel highway (Interviewee AF, in-person conversation, 8/13/12). This observation suggests that, at a minimum, this study's project-level ridership model should be used in combination with its system-wide PMT model. Given the lack of a "choice rider" output variable, however, Dallas may not have used the spreadsheet tool had it existed when they were planning their project.

Although cost considerations were foremost—given that a project could not be built if it exceeded the limits of local funding and federal matching capacities—local planners seldom considered cost per rider as a success measure. Several interviewees said that they would be more likely to use a rider per mile metric, saying they saw it as a more intuitive metric for transit agency board members and the public (Interviewee AG, in-person conversation, 8/30/12; Interviewee AF, in-person conversation, 8/13/12; Interviewee AH, in-person conversation, 6/5/12).

Most of the interviewees reported that they considered development density and the connection of activity centers when designing a project. Charlotte transit staffers were staunch promoters of downtown job growth and real estate development to help justify their investment in light rail rather than enhanced bus services (Interviewee AD, telephone conversation, 8/24/12). Portland regional planners first argued against Westside Express Service, the region's commuter rail (CR) facility, because of the low densities along the line (Interviewee AI, in-person conversation, 8/7/12). However, land use density thresholds had little explicit influence on transit technology choices. In most instances, the mode of transit was dictated by the system that was being extended or by the funding sources available to the sponsoring agency. Eugene's transit agency was one exception, using density thresholds to argue for the less expensive BRT mode rather than light rail.

Even though interviewees felt that the model provided excellent predictions of ridership on past projects, they worried that its method lacked face validity and that it would be susceptible to criticism. For example, planners in several cities focused on travel-time competitiveness as a predictor of ridership. They felt that any model that did not include a proxy of such a measure would be considered faulty by constituents who had become accustomed to both a four-step regional model that directly considered travel times and a federal project evaluation process that for many years had focused on travel-time savings (Interviewee AG, in-person conversation, 8/30/12). Some interviewees expressed discomfort with sharing TCRP Project H-42 model outputs that are based on regressions of national data points and stated that they would likely rely instead on locally calibrated regional models (Interviewee AF, in-person conversation, 8/13/12; Interviewee AL, in-person conversation, 8/7/12). In one instance, modelers felt the lack of mode specification was problematic because their local research found significant differences in perceived wait times for various transit modes (Interviewee AM, in-person conversation, 8/7/12). Other modelers suggested that they would likely use the model and share the results with other staff and with board members as supplemental evidence if the results corroborated their opinions and the regional model (Interviewee AG, in-person conversation, 8/30/12).

Stakeholders also noted that the tool and the existing regional models suffered similar issues related to their granularity. For example, one interviewee noted that the method did not address local street grids, station-area aesthetics, and other factors that were considered influential in transit planning decision-making (Interviewee AK, in-person conversation, 8/30/12). Planners tend to rely on rules of thumb for these matters, even when there are conflicting views. For example, Charlotte transit planners argued that the line should limit the number of at-grade roadway crossings (calling them *conflict points*) because they would slow operations and detract from the appeal of the service. Simultaneously, Charlotte land use planners prioritized keeping the rail alignment at grade and maximizing the density of local roadways near stations to promote connectivity and attractive urban form. They believed this would allow more people to physically reach the stations and would overcome any psychological impediment to service access that might be caused by grade separation (Interviewee AN, in-person conversation, 8/30/12).

Some interviewees suggested that the method would be a helpful tool for specific circumstances when expected ridership was considered in a non-technical manner. For example, one interviewee thought the model might be usable to quickly compare potential projects within a regional system plan to produce an initial prioritization of projects for review by elected officials (Interviewee AP, in-person conversation, 8/13/12). This interviewee saw this use of the model as a low-risk situation, because elected officials typically ignored staff's technical prioritizations unless they supported their position. In half of the case study cities, transit planners thought the tool could be given to citizens and local officials who were demanding obviously infeasible rail projects, providing those constituents with clear evidence of the shortcomings of such projects without requiring more complex (and costly) regional modeling exercises (Interviewee AQ, in-person conversation, 8/08/12; Interviewee AM, in-person conversation, 8/7/12; Interviewee AC, in-person conversation, 8/20/12).

In every case study city, interviewees thought the tool could be helpful for reducing certain workloads. They proposed using the model to narrow the number of project alternatives before they handed proposals to their regional transportation modelers for more robust analyses. Several interviewees suggested that they might be able to intuit results after just a few applications and would no longer rely on the tool.

Regardless of the usefulness of the method, interviewees agreed that their agency would use any tool that was officially sanctioned by FTA to be used in the New Starts evaluation process (Interviewee AA, in-person conversation, 8/7/12). Given a choice between an FTA-approved spreadsheet tool and an FTA-approved regional model, one planner stated that their agency would likely use whichever model gave them the answer that would win funding (Interviewee AM, in-person conversation, 8/7/12).

6.5 Synopses

The Charlotte Lynx South Line case study highlighted the interplay between transportation-related rules of thumb and politically driven strategic thinking, both of which shape transit project planning. The case study suggests that transit project planners consider a wide array of success indicators to predict performance across several measures. Those measures may be more related to indirect transit outcomes, such as land use impacts, than to direct measures of success, such as ridership. This case study suggests that transit planning is a complex art that uses both qualitative indicators and quantitative forecasts to balance various expectations for a single fixed-guideway transit project.

The Dallas North Central Corridor case study provided insights on transit planning in a highway-oriented metropolitan area. Many of the transit project success factors and attendant indicators considered in Dallas related to highway issues, such as capacity, demand, and expansion costs. This led to the prioritization of project elements that would attract choice riders, thereby helping mitigate highway congestion. Although other evaluation criteria and success measures were considered, the project's overpasses, direct routing, and park-and-ride facilities reflected these highway-oriented concerns. Though the project has underperformed in terms of ridership projections, it is considered a success based on many other qualitative measures. For example, the presence of rail transit is considered a regional economic benefit and a competitive advantage in the global marketplace. It would seem that, in the eyes of many Dallas stakeholders, the most important measure of success for the North Central Corridor extension—and any other DART light rail projects—is that any rail transit was built in unabashedly automobile-centric Dallas, Texas.

The Eugene EmX BRT case suggests that planners of rail and bus fixed-guideway projects may consider the same measures of success. The researchers found that BRT planning leveraged many of the same indicator-based methods that were observed in HRT and LRT case studies. As with the other cases, qualitative measures and indicators were often more important in defining transit plans than quantitative considerations such as ridership. As the initial fixed-guideway investment in a region, the Eugene case shares some features with the Charlotte South Line. The EmX alignment was selected among several other viable segments in the system plan because, given its potential to succeed across various measures, it offered the greatest potential to garner political support for additional fixed-guideway investments.

The Interstate MAX project in Portland offered an opportunity to investigate a transit project for which project success was redefined under changing planning conditions. A major portion of the Interstate MAX project that was ultimately constructed was projected to be more expensive, slower, have lower ridership, and have more nuisance impacts on the neighborhood than alternatives. However, the qualitative notion of transit-driven community development swayed decision-makers. The project is widely believed to be successful because it has provided several years of travel benefits for citizens, generated significant community development benefits for the neighborhoods it currently serves, and preserved opportunities to expand the project north and south as originally envisioned.

The Salt Lake City University and Medical Center Extension case is one in which both system planning and project design were informed by rules of thumb that related to ridership and several other measures of success. Much of the planning for the region's rail system related to highway capacity constraints, and this project provided a cross-town rail transit connection between major destinations in a corridor that lacked highway links. Relative to other cases, the planning and development of the line was fast-tracked so that operations could commence in time for the 2002 Winter Olympics. Although planning focused on one set of criteria, the projects have proven to be successful across multiple measures of success, suggesting that some indicators may effectively address multiple considerations simultaneously.

Finally, the Washington, D.C., Branch Avenue Extension case provided an opportunity to review documents detailing 20 years of debate over the route and station locations for a project. Planners of the Green Line had to repeatedly prove their case for the line to Congress, to WMATA's member jurisdictions, and to various groups that advocated for alternative alignments or to stop construction altogether. In the end, the line met ridership projections while providing high-quality transit service to one of the most economically depressed parts of the Washington, D.C., metropolitan area. It was service to a particular location—a station area upheld as an archetypal transit-dependent community—that justified the overall project and the relatively higher cost and less efficient operations of the chosen alternative. The case highlights the diversity of success measures that can be considered for a single project and how local priorities shaped the definition and interpretation of success measures.

Detailed case study write-ups are provided in Appendix I. The write-ups explain how six distinct transit projects fit into their respective regions' transit systems and describe the planning processes that led to the ultimate project being chosen from the alternatives proposed during the planning process. They also demonstrate how largely heuristic indicator-based methods have been used to predict the success of transit projects. Regional descriptions of each case study area appear at the end of Appendix I.

CHAPTER 7

Spreadsheet Tool: Technical Notes

The research team combined the results of the modeling process with feedback from practitioners to create a spreadsheet tool that can be used to predict the transit use impacts of proposed fixed-guideway projects. To build the tool, the researchers selected spreadsheet-friendly versions of the project- and metropolitan-level models, incorporating recommendations from case study participants and the report's review panel. Selection criteria were that the model must be usefully predictive, the model variables must be easily interpretable, and the data collection process for the model inputs must not be too onerous. A user guide for the spreadsheet tool is provided as Chapter 3 in the handbook. The material in this chapter provides additional background.

The spreadsheet tool serves as an implementation of the models. Its outputs are produced by substituting data on a proposed fixed-guideway transit project into the model equations discussed in Sections 5.2 and 5.3. Users enter data of the same form as the variables comprising the spreadsheet's underlying models. Where possible, the spreadsheet contains pre-entered data, such as the population of the metropolitan area, so the user can select from a dropdown list.

Each input is automatically normalized or otherwise manipulated as necessary, then multiplied by the model coefficient. For the project-level model, ridership is simply a sum of the inputs multiplied by their coefficients. At the metropolitan level, incremental PMT is given by subtracting an estimate of PMT on the committed network from PMT on the committed network plus the proposed project. For this calculation, the spreadsheet calculates the model outputs once by multiplying the coefficients by the data describing the committed network and again by multiplying the coefficients by the sum of the connected network and the proposed project.

Users can navigate through the spreadsheet tool with various buttons. From the inputs page, a button brings the user to the outputs page where a table shows the transit use characteristics of the proposed project. In addition to common metrics of success such as ridership, cost per mile, and incremental PMT, several charts plot the proposed project in the context of other projects. The comparisons were taken from the researchers' full database of projects, although not all of the charts portray all of the projects. Some attributes of the comparison projects are reported statistics (such as weekday ridership) whereas others (incremental PMT) have been calculated using the model in the spreadsheet.

After examining the predicted transit use, users of the spreadsheet tool can navigate back to the inputs page to adjust the inputs, experimenting with different alignments or growth scenarios.

The navigational buttons initiate Microsoft Visual Basic macros which, in addition to navigating between tabs in the spreadsheet, provide the user with visual assistance such as ranking the proposed project in order with the comparison projects, changing the color of the project to make it more visible, or selecting a subset of projects from the database to provide more relevant comparisons. Enabling macros (a setting on the user's Excel interface) is essential for getting the most valuable results from the tool.

CHAPTER 8

Conclusion

The evaluation method proposed in *TCRP Report 167* is not meant to replace existing processes of planning fixed-guideway transit systems, but rather to provide additional information that is consistent for all regions in the United States. The indicators of success presented in this report are only the beginning. If a corridor or project is shown to have good potential for attracting ridership commensurate with its cost, it may be appropriate to conduct more detailed corridor-level planning studies of transit needs and alternative solutions. These studies would typically include the use of travel-demand forecasting models, conceptual engineering, environmental studies, and stakeholder involvement.

8.1 Implementation

The implementation of the research recognizes the issues that need to be addressed during the adoption process and the overall concept of research product implementation. The three products of this research are this final research report (presented as Volume 2 in *TCRP Report 167*), the handbook (presented as Volume 1 in *TCRP Report 167*), and the spreadsheet tool (which may be downloaded by accessing the report's web page at www.trb.org). The research report documents the literature review, the analysis of potential success factors, the spreadsheet tool, and the case studies. The handbook provides a user-friendly guide to the indicator-based approach in general and to the use of the spreadsheet tool.

Publication of *TCRP Report 167* electronically through the TCRP website will provide ready access to all of these materials for researchers who are interested in how this analysis adds to the understanding of transit success factors. The research results may also be of use to FTA as it develops guidance on its New Starts/Small Starts criteria and potential warrants for evaluating new projects.

The handbook will be of interest to transit planning professionals at transit agencies, MPOs, local jurisdictions, state DOTs, consulting firms, and others interested in conducting a preliminary assessment of a project's potential. Users will need to access both the handbook and the spreadsheet tool.

Successful implementation of this research faces two potential impediments. The first potential impediment is best described as the "black box" nature of the spreadsheet tool. Without an understanding of how the tool works, users may lack confidence in its ability to provide reliable results, and thus may be reluctant to use it. Practitioners are most comfortable with the tools they know and trust. The second potential impediment is the limitations of the database that underlies the spreadsheet tool. Projects completed since 2008 are not included, and over time the tool may be perceived as more and more dated. In addition, the database used in this research has few CR and BRT projects, and no streetcars or other urban circulator projects. Users who are interested in exploring the potential of these modes may decide to look elsewhere. That said, further research could be undertaken to keep the database up to date, include additional transit technologies, and modify the spreadsheet tool.

As this project was being completed, FTA reported that it was developing its own simplified techniques for predicting the benefits of a fixed-guideway system (see *Federal Register* Vol. 78, Number 6, January 9, 2013), and FTA has since released a report. Given that the ridership projections developed using the FTA-sanctioned methodology will be more readily accepted for funding purposes, practitioners may choose to rely on that methodology rather than the tool developed in this research; however, practitioners may also find it useful to use both methods and compare the results.

References

Aizenman, N. A Lot Riding on New Stations; Area Residents Hope Metro Brings Growth, Not Crime and Noise. *Washington Post*, Jan. 13, 2001.

Allison, P. D. *Missing Data.* Sage Productions, Thousand Oaks, CA, pp. 9–11.

American Public Transportation Association. *2012 Public Transportation Fact Book, Appendix A: Historical Tables.* Washington, D.C., 2012.

Amodei, R., and D. Schneck. *Fixed Guideway Capital Costs: Heavy Rail and Busway HOV Lane.* Federal Transit Administration, Springfield, VA, 1994.

Baird, J. TRAX Debuts Extension to the U. Medical Center, *Salt Lake Tribune*, Sept. 28, 2003.

Banister, D., and J. Berechman. *Transport Investment and Economic Development.* University College London Press, 2000.

Barnes, G. The Importance of Trip Destination in Determining Transit Share. *Journal of Public Transportation*, Vol. 8, No. 2, 2005.

Baum-Snow, N., and M. E. Kahn. The Effects of New Public Projects to Expand Urban Rail Transit. *Journal of Public Economics*, Vol. 77, No. 2, 2000, pp. 241–263. doi:10.1016/S0047-2727(99)00085-7.

Baum-Snow, N., and M. E. Kahn. Effects of Urban Rail Transit Expansions: Evidence from Sixteen Cities, 1970–2000. *Brookings-Wharton Papers on Urban Affairs*, 2005, pp. 147–206.

Bay Area Rapid Transit. BART Reports. Available at: http://www.bart.gov/about/reports/index.aspx (accessed March 2011).

Bell, R. Metro Celebrates Breaking Ground For Final Leg in PG. *Washington Times*, Sept. 24, 1995.

Bertaud, A., and H. W. Richardson. Transit and Density: Atlanta, the United States and Western Europe. *Urban Sprawl in Western Europe and the United States.* Ashgate Publishing, Ltd., 2004, Chapter 17.

Boarnet, M., and R. Crane. LA Story: A Reality Check for Transit-Based Housing. *Journal of the American Planning Association*, Vol. 63, No. 2, 1997, pp. 189–204.

Boarnet, M., and R. Crane. Public Finance and Transit-Oriented Planning: New Evidence from Southern California. *Journal of Planning Education and Research*, Vol. 17, No. 3, 1998, p. 206.

Boarnet, M., and R. Crane. The Influence of Land Use on Travel Behavior: Specification and Estimation Strategies. *Transportation Research Part A: Policy and Practice*, Vol. 35 No. 9, 2001, pp. 823–845. doi:10.1016/S0965-8564(00)00019-7.

Booz Allen Hamilton. Light Rail Transit Capital Cost Study Update Final Report, submitted to Federal Transit Administration, Washington, D.C., 2003.

Booz Allen Hamilton. *TCRP Web-Only Document 31: Managing Capital Costs of Major Federally Funded Public Transportation Projects: Contractor's Final Report*, Transportation Research Board of the National Academies, Washington, D.C., 2005. Available at: http://www.trb.org/Publications/Public/Blurbs/Managing_Capital_Costs_of_Major_Federally_Funded_P_158051.aspx.

Bowman, J. L., and M. E. Ben-Akiva. Activity-Based Disaggregate Travel Demand Model System with Activity Schedules. *Transportation Research Part A: Policy and Practice*, Vol. 35, No. 1, 2001, pp. 1–28. doi:10.1016/S0965-8564(99)00043-9.

Brown, J., and G. Thompson. *The Relationship between Transit Ridership and Urban Decentralisation: Insights from Atlanta.* Urban Studies, Vol. 45, Nos. 5&6 (May 2008), pp. 1119–1139.

Brown, J., and G. Thompson. Should Transit Serve the CBD or a Diverse Array of Destinations? A Case Study Comparison of Two Transit Systems. *Journal of Public Transportation*, Vol. 15, No. 1, 2012.

Cairns, S., J. Greig, and M. Wachs. *Environmental Justice & Transportation: A Citizen's Handbook.* Institute of Transportation Studies, University of California, Berkeley, CA, 2013.

Central Lane Metropolitan Planning Organization. Regional Transportation Plan, Lane Council of Governments, 2001.

Cervero, R. Transit Pricing Research. *Transportation*, Vol. 17, No. 2, 1990a, pp. 117–139. doi:10.1007/BF02125332.

Cervero, R. *The Transit Metropolis: A Global Inquiry*, 1st ed., Island Press, 1998.

Cervero, R. Alternative Approaches to Modeling the Travel-Demand Impacts of Smart Growth. *Journal of the American Planning Association*, Vol. 72, No. 3, 2006, pp. 285–295.

Cervero, R. Transit-Oriented Development's Ridership Bonus: A Product of Self-Selection and Public Policies. *Environment and Planning, A.* Vol. 39, No. 9, 2007, pp. 2068–2085.

Cervero, R., G. B. Arrington, J. Smith-Heimer, R. Dunphy, et al. *TCRP Report 102: Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects.* Transportation Research Board of the National Academies, Washington, D.C., 2004.

Cervero, R., and E. Guerra. To T or Not to T: A Ballpark Assessment of the Costs and Benefits of Urban Rail Transportation. *Public Works Management & Policy*, 2011.

Cervero, R., and C. D. Kang. 2011. "Bus Rapid Transit Impacts on Land Uses and Land Values in Seoul, Korea." *Transport Policy*, 18 (1), pp. 102–116.

Cervero, R., and K. Kockelman. Travel Demand and the 3 Ds: Density, Diversity, and Design. *Transportation Research Part D: Transport and Environment, Vol. 2, No. 3*, 1997, pp. 199–219. doi:10.1016/S1361-9209(97)00009-6.

Cervero, R., and J. Landis. Development Impacts of Urban Transport: A US Perspective. *Transport and Urban Development*, 1995, pp. 136–156.

Cervero, R., and J. Landis. Twenty Years of the Bay Area Rapid Transit System: Land Use and Development Impacts. *Transportation Research Part A: Policy and Practice*, Vol. 31, No. 4, 1997, pp. 309–333. doi:10.1016/S0965-8564(96)00027-4.

Cervero, R. and J. Murakami. Effects of Built Environments on Vehicle Miles Traveled: Evidence from 370 U.S. Urbanized Areas. *Environment and Planning, A*, Vol. 42, No. 2, 2010, pp. 400–418.

Charlotte Area Transit System. South Corridor Light Rail Project: Before and After Report, 2012.

Chatman, D. Deconstructing Development Density: Quality, Quantity and Price Effects on Household Non-Work Travel. *Transportation Research, Part A*, Vol. 42, No. 7, 2008, pp. 1008–1030.

Chatman, D., and N. Klein. Immigrants and Travel Demand in the United States: Implications for Transportation Policy and Future Research. *Public Works Management Policy*, Vol. 13, No. 4, 2009, pp. 312–327. doi:10.1177/1087724X09334633.

Chatman, D., et al. *TCRP Web-Only Document 56: Methodology for Determining the Economic Development Impacts of Transit Projects.* Transportation Research Board of the National Academies, Washington, D.C., 2012.

City of Portland, Bureau of Technology Services. 2011. *Corporate GIS.* Available at: http://www.portlandonline.com/bts/index.cfm?c=25779 (accessed March 2011).

City of Portland Office of Transportation. 2001. Interstate Corridor Community Involvement.

Clower, T., B. Weinstein, and M. Seman. *Assessment of the Potential Fiscal Impacts of Existing and Proposed Transit-Oriented Development in the Dallas Area Rapid Transit Service Area.* Center for Economic Development and Research University of North Texas, Denton, TX, 2007.

Cook, E. A. Landscape Structure Indices for Assessing Urban Ecological Networks. *Landscape and Urban Planning*, Vol. 58, 2002, pp. 269–280.

Crane, R. On Form versus Function: Will the New Urbanism Reduce Traffic, or Increase It? *Journal of Planning Education and Research*, Vol. 15, No. 2, 1996, pp. 117–126. doi:10.1177/0739456X9601500204.

Daganzo, C. F. Structure of Competitive Transit Networks. *Transportation Research Part B*, Vol. 44, No. 4, 2010, pp. 434–446.

Dallas Area Rapid Transit Authority. 1991. Briefing on Second AA/DEIS Corridor Selection.

Dallas Area Rapid Transit Authority. 2006. North Central LRT Extension: Before and After Study.

Dallas Area Rapid Transit Authority. 2012. DART Reference Book—April 2012.

Data Quick. *DataQuick Database.* Available at: http://www.dataquick.com/products/database/ (accessed March 2011).

Davidson, L. New Airport TRAX Line is in Final Push Toward Completion. *Salt Lake Tribune*, May 1, 2012.

Deakin, E., C. Farrell, J. Mason, and J. Thomas. 2002 Policies and Practices for Cost-Effective Transit Investments: Recent Experiences in the United States. *Transportation Research Record: Journal of the Transportation Research Board, 1799*(-1),1-9. doi: 10.3141/1799-01.

De Neufville, R. *Applied Systems Analysis: Engineering Planning and Technology Management*, McGraw-Hill Companies, 1990.

Evans, J. E. *TCRP Report 95: Road Value Pricing: Traveler Response to Transportation System Changes, Chapter 9: Transit Scheduling and Frequency.* Transportation Research Board of the National Academies, Washington, D.C., 2004.

Ewing, R., and R. Cervero. Travel and the Built Environment—A Meta-Analysis. *Journal of the American Planning Association*, Vol. 76, No. 3, 2010, p. 265. doi:10.1080/01944361003766766.

Feaver, D. Prince George's County Council Chooses Rosecroft Metro Line. *Washington Post*, May 10, 1978.

Feaver, D. B. What Ever Happened to the Green Line? *Washington Post*, Oct. 14, 1980.

Federal Highway Administration. Highway Statistics Series. Available at: http://www.fhwa.dot.gov/policyinformation/statistics.cfm.

Federal Highway Administration. *Traffic Congestion and Reliability: Linking Solutions to Problems.* http://ops.fhwa.dot.gov/congestion_report_04/appendix_C.htm

Federal Transit Administration. New Starts Ratings: North Central Corridor, 1996.

Federal Transit Administration. New Starts Ratings: Dallas, Texas/North Central Corridor, 1998.

Federal Transit Administration. *Annual Report on New Starts*, 2000.

Federal Transit Administration. *Annual Report on New Starts*, 2002.

Federal Transit Administration *New Starts Funding Allocation: South Corridor LRT Charlotte, North Carolina*, FTA NSFA, 2005.

Federal Transit Administration *South Corridor LRT Charlotte, North Carolina*, FTA SCLRT, 2005.

Federal Transit Administration. *New Starts Before and After Study Report*, 2007.

Federal Transit Administration. *The Predicted and Actual Impacts of New Starts Projects—2007*, 2008.

Federal Transit Administration. *The EmX Franklin Corridor—BRT Project Evaluation*, 2009.

Federal Transit Administration and Charlotte Area Transit System. *Draft Environmental Impact Statement: South Corridor Light Rail Project—Charlotte-Mecklenburg County Light Rail System*, 2002.

Federal Transit Administration and Charlotte Area Transit System. *Final Environmental Impact Statement: South Corridor Light Rail Project—Charlotte-Mecklenburg County Light Rail System*, 2003.

First American CoreLogic. *RealQuest Professional.* Available at: http://pro.realquest.com/home/ (accessed March 2011).

Florida Department of Transportation, Transportation Statistics Office. *TranStat.* Available at: http://www.dot.state.fl.us/planning/statistics/ (accessed March 2011).

Flyvbjerg, B. Cost Overruns and Demand Shortfalls in Urban Rail and Other Infrastructure. *Transportation Planning and Technology*, Vol. 30, No. 1, 2007, pp. 9–30.

Flyvbjerg, B., M. K. Skamris Holm, and S. L. Buhl. Underestimating Costs in Public Works Projects: Error or Lie? *Journal of the American Planning Association*, Vol. 68, No. 3, 2002, pp. 279–295.

Flyvbjerg, B., N. Bruzelius, and W. Rothengatter. *Megaprojects and Risk: An Anatomy of Ambition.* Cambridge University Press, 2003.

Forman, R. T. and M. Godron. *Landscape Ecology.* Wiley, New York, 1986, pp. 417–419.

Frank, L., M. Bradley, S. Kavage, J. Chapman, and T. K. Lawton. Urban Form, Travel Time, and Cost Relationships with Tour Complexity and Mode Choice. *Transportation*, Vol. 35, No. 1, 2008, pp. 37–54. doi:10.1007/s11116-007-9136-6.

Garrett, M., and B. Taylor. Reconsidering Social Equity in Public Transit. *Berkeley Planning Journal*, Vol. 13, 1999, pp. 6–27.

Gercek, H., B. Karpak, and T. Kilincaslan. *A Multiple Criteria Approach for the Evaluation of the Rail Transit Networks in Istanbul.* Transportation: Planning, Policy, Research, Practice, Vol. 31, Issue 2, 2004, pp. 203–228.

Glaeser, E. L., M. E. Kahn, and J. Rappaport. Why Do the Poor Live in Cities? The Role of Public Transportation. *Journal of Urban Economics*, Vol. 63, No. 1, 2008, pp. 1–24. doi:10.1016/j.jue.2006.12.004.

Gomez-Ibanez, J. A. Big-City Transit Ridership, Deficits, and Politics: Avoiding Reality in Boston. *Journal of the American Planning Association*, Vol. 62 No. 1, 1996, p. 30. doi:10.1080/01944369608975669.

Guerra, E. Valuing Rail Transit: Comparing Capital and Operating Costs to Consumer Benefits. *Transportation Research Record: Journal of the Transportation Research Board, No. 2219*, Transportation Research Board of the National Academies, Washington, D.C., 2011.

Guerra, E., and R. Cervero. *Cost of a Ride: The Effects of Densities on Fixed-Guideway Transit Ridership and Capital Costs.* University of California Transportation Center Research Report, University of California, Berkeley, 2010.

Guerra, E. and R. Cervero. Cost of a Ride. *Journal of the American Planning Association*, Vol. 77, No. 3, 2011, pp. 267–290.

Hagget, P., Cliff, A. D., and Fry, A. *Locational Analysis in Human Geography*, 2d Ed. Wiley, New York, 1977, p. 454.

Harford, J. D. Congestion, Pollution, and Benefit-to-Cost Ratios of US Public Transit Systems. *Transportation Research Part D: Transport and Environment*, Vol. 11, No. 1, 2006, pp. 45–58. doi:10.1016/j.trd.2005.09.001.

Harmatuck, D. Light Rail Cost Functions and Technical Inefficiency. *Transportation Research Record: Journal of the Transportation Research Board*, *No. 2042*. Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 58–70. doi:10.3141/2042-07.

Hess, P. M. Measures of Connectivity. *Places*, Vol. 11, No. 2, 1997, pp. 58–65.

Hess, D. B., and T. M. Almeida. Impact of Proximity to Light Rail Rapid Transit on Station-Area Property Values in Buffalo, New York. *Urban Studies*, Vol. 44, No. 5-6 (May 1, 2007), pp. 1041–1068. doi:10.1080/00420980701256005.

Holmgren, J. Meta-Analysis of Public Transport Demand. *Transportation Research Part A: Policy and Practice*, Vol. 41, No. 10, 2007, pp. 1021–1035. doi:10.1016/j.tra.2007.06.003.

Kain, J. Choosing the Wrong Technology: Or, How to Spend Billions and Reduce Transit Use. *Journal of Advanced Transportation*, Vol. 21, No. 3, 1988, pp. 197–213. doi:10.1002/atr.5670210303.

Keeler, T., and K. Small, Associates. *The Full Costs of Urban Transport, Part III: Automobile Costs and Final Intermodal Comparisons.* Monograph. University of California, Berkeley: Institute of Urban and Regional Development, 1975.

Kittelson & Associates Inc., KFH Group, Inc., Parsons Brinckerhoff, Inc., and K. Hunter-Zaworski. *TCRP Report 100:Transit Capacity and Quality of Service Manual—2d Ed.: Part 3 Quality of Service Contents.* Transportation Research Board of the National Academies, Washington, D.C., 2003. Available at: http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp100/part%203.pdf.

Kohn, H. *Factors Affecting Urban Transit Ridership.* Statistics Canada, 1999.

Kuby, M., A. Barranda, and C. Upchurch. Factors Influencing Light-Rail Station Boardings in the United States. *Transportation Research Part A*, Vol. 38, 2004, pp. 223–247.

Lane Transit District. EmX promotional brochure, date unknown.

Layton, L. "Green Line Riders Are Feeling Crunched." *Washington Post*, Jan. 19, 2001.

Layton, L. Metro Seeks To Unclog Green Line. *Washington Post*, Jan. 25, 2001.

Lee, D. B. Requiem for Large-Scale Models. *Journal of the American Institute of Planners*, Vol. 39, 1973, pp. 163–178.

Levinson, D. M., and A. Kumar. Density and the Journey to Work. *Growth & Change*, Vol. 28, No. 2, 1997, p. 147.

Lewis-Workman, S., and D. Brod. Measuring the Neighborhood Benefits of Rail Transit Accessibility. *Transportation Research Record: Journal of the Transportation Research Board*, *No. 1576*, Transportation Research Board of the National Academies, Washington D.C., 1997, pp. 147–153.

Lewis-Workman, S., B. White, S. McVey, and F. Spielberg. The Predicted and Actual Impacts of New Starts Projects—Capital Costs and Ridership. Technical Report, Federal Transit Administration and Vanasse Hangen Brustlin, Inc., 2008.

Litman, T. Evaluating Public Transit Benefits and Costs. *Victoria Transport Policy Institute*, 2006.

Liu, Z. *Determinants of Public Transit Ridership: Analysis of Post World War II Trends and Evaluation of Alternative Networks.* Harvard University, Cambridge, MA, 1993.

Lowe, J. C. and S. Moryadas. *The Geography of Movement.* Houghton Mifflin, Boston, MA, 1975, p. 442.

Massachusetts Bay Transportation Authority. Information at: http://www.mbta.com/ (accessed March 2011).

Maze, T. H. and O. Smadi. GASB Statement 34: The On-ramp to Transportation Asset Management, or a Detour Leading Business as Usual? *Transportation Quarterly*, Vol. 57, No. 4, 2003, pp. 23–29.

McCollum, B. E., and R. H. Pratt. *TCRP Report 95: Traveler Response to Transportation System Changes. Chapter 12—Transit Pricing and Fares.* Transportation Research Board of the National Academies, Washington, D.C., 2004.

McMillen, D. P., and J. McDonald. Reaction of House Prices to a New Rapid Transit Line: Chicago's Midway Line, 1983–1999. *Real Estate Economics*, Vol. 32, No. 3, 2004, pp. 463–486. doi:10.1111/j.1080-8620.2004.00099.x.

Meyer, J., J. Kain, and H. Wohl. *The Urban Transportation Problem.* Harvard University Press, Cambridge, MA, 1965.

Metropolitan Transportation Commission. Resolution 3434, as revised 4/26/06. (MTC Res3434), 2006.

Miller, J. and W. Ibbs. Toward a New Paradigm: Simultaneous Use of Multiple Project Delivery Methods. *Journal of Management in Engineering*, May/June 2000, pp. 58–66.

Mohring, H. Land Values and the Measurement of Highway Benefits. *The Journal of Political Economy*, Vol. 69, No. 3, 1961, pp. 236–249.

Mohring, H. Optimization and Scale Economies in Urban Bus Transportation. *The American Economic Review*, Vol. 62, No. 4, September 1972, pp. 591–604.

Moilanen, A. and M. Nieminen. Simple Connectivity Measures in Spatial Ecology. *Ecology*, Vol. 83, 2002, pp. 1131–1145.

Musgrave, R. A. *The Theory of Public Finance: A Study in Public Economy*, 1959.

Nelson, A. C. Transit Stations and Commercial Property Values: A Case Study with Policy and Land-Use Implications. *Journal of Public Transportation*, Vol. 2, No. 3, 1999, pp. 77–93.

Neumann, L. and M. Markow. Performance-based Planning and Asset Management. *Public Works Management and Policy*, Vol. 8, No. 3, 2004, pp. 156–161.

Newman, P., and J. Kenworthy. Urban Design to Reduce Automobile Dependence. *Opolis*, Vol. 2, No. 1, 2006, pp. 35–52.

North Central Texas Council of Governments Transportation Department. *Rail Station Access: Bicycle and Pedestrian Needs Assessment*, 2011. Available at: http://www.nctcog.org/trans/sustdev/bikeped/access_to_rail/atrgis.asp (accessed March 2011).

O'Toole, R. Defining Success: The Case Against Rail Transit. *Policy Analysis*, No. 663, 2010. Available at: http://www.cato.org/pub_display.php?pub_id=11608.

Okun, A. *Equality and Efficiency, the Big Tradeoff.* Brookings Institution Press, 1975.

Parry, I. W. H., and K. Small. Should Urban Transit Subsidies Be Reduced? *American Economic Review*, Vol. 99, 2009, pp. 700–724. doi:10.1257/aer.99.3.700.

Parsons Brinckerhoff Quade & Douglas, Inc. I-15/State Street Corridor Study—Transit, Salt Lake County, Utah: Final Environmental Impact Statement. Federal Transit Administration and Utah Transit Authority, 1994.

Parsons Transportation Group. University-Downtown-Airport Major Investment Study: Draft Environmental Impact Statement. Wasatch Front Regional Council, July 1997.

Parsons Transportation Group. Airport to University West-East Light Rail Project: Final Environmental Impact Statement. Utah Transit Authority, 1999.

Peat, Marwick, Mitchell, & Co. Metrorail Alternatives Analysis: F Route. Metropolitan Washington Council of Governments, 1977.

Pendall, R., R. Puentes, and J. Martin. From Traditional to Reformed: A Review of the Land Use Regulations in the Nation's 50 largest Metropolitan Areas. Brookings, 2006. Retrieved from http://www.brookings.edu/research/reports/2006/08/metropolitanpolicy-pendall.

Pickrell, D. *Urban Rail in America: A Review of Procedures and Recommendations from the Regional Plan Association Study.* Transportation Systems Center, U.S. Department of Transportation, Cambridge, MA, 1985.

Pickrell, D. *Urban Rail Transit Projects: Forecast Versus Actual Ridership and Costs.* Urban Mass Transportation Administration, Washington, D.C., 1990.

Pickrell, D. A Desire Named Streetcar: Fantasy and Fact in Rail Transit Planning. *Journal of the American Planning Association*, Vol. 58, No. 2, 1992, pp. 158–176.

Pickrell, D. Transportation and Land Use. *Transportation Economics and Policy Handbook*, 1999.

Project Management Group (PMG). South/North Transit Corridor Study—Briefing Document: Tier I Technical Summary Report, 1994.

Project Management Group. South/North Transit Corridor Study—Briefing Document: Design Option Narrowing, 1995.

Project Management Group. South/North Transit Corridor Study—Design Option Narrowing Final Report, 1996.

Portland Metro. Segments and Design Options, 1995.

Portland Metro. South/North Corridor Project: Draft Environmental Impact Statement, 1998.

Portland Metro. Regional High Capacity Transit System Plan 2035: Public Involvement Outreach Summary and Attachments. Retrieved from http://library.oregonmetro.gov/files/hct_pi_outreach_summaryno_attachments.pdf

Pushkarev, B., and J. Zupan. *Public Transportation and Land Use Policy.* Indiana University Press, Bloomington, IN, 1977.

Pushkarev, B., J. Zupan, and R. S. Cumella. *Urban Rail in America: An Exploration of Criteria for Fixed Guideway Transit.* Indiana University Press, Bloomington, IN, 1982.

Randall, T. A., and B. W. Baetz. *Evaluating Pedestrian Connectivity for Suburban Sustainability. Journal of Urban Planning and Development*, Vol. 127, No. 1, 2001, pp. 1–15.

Rodrigue, J., C. Comtois, and B. Slack. *Geography of Transportation Systems*, 2d Ed. Routledge, New York, 2009.

San Francisco Bay Area Metropolitan Transportation Commission. *GIS Data: Category 2.* Available at: http://www.mtc.ca.gov/maps_and_data/GIS/data.htm (accessed March 2011).

Schrag, Z. M. The Great Society Subway: A History of the Washington Metro. The Johns Hopkins University Press, 2006.

Shapiro, M. Group Seeks to Delay Rosecroft Line. *Washington Post*, Feb. 27, 1980.

Small, K. *Urban Transportation Economics.* Hardwood Academic Publishers, Chur, Switzerland, 1992.

Small, K. Project Evaluation, Chapter 5. *Essays in Transportation Economics and Policy: A Handbook in Honor of John R.* Brookings Institution Press, Washington, D.C., 1999, pp. 137–177.

Small, K. and E. Verhoef. *The Economics of Urban Transportation.* Taylor & Francis Group, 2007.

Spanberg, E. Charlotte Wins $580M from Feds for Light-rail Extension, *Charlotte Business Journal*, Oct. 16, 2012.

Stokes, R. J., J. MacDonald, and G. Ridgeway. Estimating the Effects of Light Rail Transit on Health Care Costs. *Health & Place*, Vol. 14, No. 1, 2008, pp. 45–58. doi:10.1016/j.healthplace.2007.04.002.

Sugihara, G. and R. M. May. Applications of Fractals in Ecology. *Trends in Ecology and Evolution*, Vol. 5, No. 3, 1990, pp. 79–86.

Taaffe, E. J., H. L. Gauthier, and M. E. O'Kelly. *Geography of Transportation, 2d Ed.* Prentice-Hall, New Jersey, 1996.

Taylor, B. D. The Geography of Urban Transportation Finance. *The Geography of Urban Transportation*, 3d. Ed., eds. Susan Hanson and Genevieve Giuliano, New York: The Guilford Press, 2004, pp. 294–331.

Taylor, B., E. J. Kim, and J. E. Gahbauer. The Thin Red Line: A Case Study of Political Influence on Transportation Planning Practice. *Journal of Planning Education and Research*, Vol. 29, No. 2, 2009, pp. 173–193. doi:10.1177/0739456X09344718.

Taylor, B., D. Miller, H. Iseki, and C. Fink. Nature and/or Nurture? Analyzing the Determinants of Transit Ridership across US Urbanized Areas. *Transportation Research Part A: Policy and Practice*, Vol. 43, No. 1, 2009, pp. 60–77. doi:10.1016/j.tra.2008.06.007.

Theobaldi, D. M., K. Ramseyii, and J. Thomasii. A National Dataset for Characterizing Location Sustainability and Urban Form. Draft Technical Report, February 2011.

Thompson, G., and J. Brown. Explaining Variation in Transit Ridership in U.S. Metropolitan Areas Between 1990 and 2000: Multivariate Analysis. *Transportation Research Record: Journal of the Transportation Research Board*, *No. 1986.* Transportation Research Board of the National Academies, Washington, D.C., 2006, pp. 172–181. doi:10.3141/1986-23.

Thompson, G., and J. Brown. Evaluation of Land Use and Transportation Strategies to Increase Suburban Transit Ridership in the Short Term. The Public Transit Office, Florida Department of Transportation, 2010.

Thompson, G., and J. Brown. Making a Successful LRT-Based Regional Transit System: Lessons from Five New Start Cities. *Journal of Public Transportation*, Vol. 15, No. 2, 2012.

Thompson, G., J. Brown, T. Bhattacharya, and M. Jaroszynski. Understanding Transit Ridership Demand for a Multi-Destination, Multimodal Transit Network in an American Metropolitan Area: Lessons for Increasing Choice Ridership While Maintaining Transit Dependent Ridership. Mineta Transportation Institute, Report 11-06, January 2012.

Tischendorf, L., and L. Fahrig. How Should We Measure Landscape Connectivity? *Landscape Ecology*, Vol. 15, 2000, pp. 633–641.

Tomer, A. *Where the Jobs Are: Employer Access to Labor by Transit.* Metropolitan Infrastructure Initiative Series and Metropolitan Opportunity Series. Brookings Institution, Washington, D.C., July 2012.

Tomer, A, E. Kneebone, R. Puentes and A. Berube. *Missed Opportunity: Transit and Jobs in Metropolitan America.* Metropolitan Infrastructure Initiative Series and Metropolitan Opportunity Series, Brookings Institution, Washington, D.C., May 2011.

Transportation Institute. *Annual Urban Mobility Report.* Available at: http://mobility.tamu.edu/ums/.

Urban Mass Transportation Administration (UMTA). *Dallas North Central Subarea Transit Alternatives Analysis: Draft Environmental Impact Statement*, 1982.

U.S. Census Bureau. Decennial Census 2000 Summary File 1 and 3.

U.S. Census Bureau. American Community Survey, 1-Year Estimates, 2005–2009.

U.S. Department of Transportation. Final Environmental Impact Statement: Metropolitan Washington Regional Rapid Rail Transit System, 1975.

U.S. Department of Transportation. *Bicycle and Pedestrian Data: Sources, Needs, & Gaps.* BTS00-02. Bureau of Transportation Statistics, Washington, D.C., 2000.

U.S. Department of Transportation. Table 1-70: Travel Time Index in the National Transportation Statistics. Bureau of Transportation Statistics, Washington, D.C., 2000. Available at: http://www.bts.gov/publications/national_transportation_statistics/html/table_01_70.html.

U.S. Department of Transportation and Washington Metropolitan Area Transit Authority (WMATA). Draft EIS: Washington Metrorail System, Branch/Rosecroft (F) Route. Urban Mass Transportation Administration and WMATA, Washington, D.C., 1979.

U.S. General Accounting Office. Bus Rapid Transit Shows Promise. *Report to Congressional Requesters, U.S. General Accounting Office*, 2001. Available at: http://www.gao.gov/new.items/d01984.pdf.

Utah Transit Authority. 2005. Weber County to Salt Lake City Commuter Rail Project: FEIS.

Voith, R. Changing Capitalization of CBD-Oriented Transportation Systems: Evidence from Philadelphia, 1970–1988. *Journal of Urban Economics* Vol. 33, No. 3, May 1993, pp. 361–376. doi:10.1006/juec.1993.1021.

Waddell, P. *Forecasting Land Use Activities (1): The Evolving State of the Practice.* U.S. Department of Transportation Travel Model Improvement Program (TMIP) website. Available at: http://tmip.fhwa.dot.gov/webinars/flua1 (accessed March 2011).

Walk Score. *Transit Score Methodology*. Available at: http://www.walkscore.com/transit-score-methodology.shtml (accessed December 2012).

Wallace, D. A., I. McHarg, W. H. Roberts, and T. A. Todd. Preliminary Evaluation Report: Branch (F) Route. The Washington Metropolitan Area Transit Authority (WMATA), 1976.

Washington State Department of Transportation. *Congestion Report*, 2011. Available at: http://www.wsdot.wa.gov/Accountability/Congestion/ (accessed March 2011).

Washington Metropolitan Area Transit Authority (WMATA). F Route Comparative Alignment Study, 1984.

Washington Metropolitan Area Transit Authority (WMATA). Summary: Final EIS and Section 4(f) Statement, Washington Regional Rapid Rail Transit System, Outer Branch Avenue Segment, 1993.

Washington Metropolitan Area Transit Authority (WMATA). Development-Related Ridership Survey, 2005.

Washington Metropolitan Area Transit Authority (WMATA). Draft Supplemental Environmental Impact Statement—Washington Regional Rapid Rail Transit System—Green Line (F) Route Outer Branch Avenue Segment, Sections F-6 through F-11, 1992.

Weinberger, R. Light Rail Proximity: Benefit or Detriment in the Case of Santa Clara County, California? *Transportation Research Record: Journal of the Transportation Research Board, No. 1747*, January 1, 2001, pp. 104–113. doi:10.3141/1747-13.

Winston, C., and V. Maheshri. On the Social Desirability of Urban Rail Transit Systems. *Journal of Urban Economics* Vol. 62, No. 2, 2007, pp. 362–382. doi:10.1016/j.jue.2006.07.002.

Yeh, C. H., H. Deng, and Y. H. Chang. Fuzzy Multicriteria Analysis for Performance Evaluation of Bus Companies. *European Journal of Operational Research*, Vol. 126, Issue 3, 2000, pp. 459–473.

Yin, R. K. *Case Study Research: Design and Methods*, 4th ed. Sage Publications, Inc., 2008.

Zillow, Inc. *Zillow.com.* Available at: http://www.zillow.com/ (accessed March 2011).

Zupan, J., and Cervero, R. *Transit and Urban Form. Vol. 1, Part 2: Commuter and Light Rail Transit Corridors: The Land Use Connection.* Washington D.C.: National Academies Press, 1996.

APPENDICES

Appendices A–J and Related Material

Appendices A–J were prepared in conjunction with the final report.

The TCRP Project H-42 Draft Spreadsheet Tool: Estimated Ridership and Cost of Fixed-Guideway Transit Projects provides the analytical model in Excel format. The spreadsheet tool is not published herein, but is available separately for download from the report web page at www.trb.org by searching for "TCRP Report 167".

CONTENTS

APPENDIX A: Data Source Review

A.1 Data

The measures and predictors of transit success addressed in the literature cover a range of transportation issues. Using these measures to evaluate transit systems requires a variety of quantitative datasets covering regions where fixed-guideway transit projects are proposed and delivered. Nonetheless, there is little study that systematically and comprehensively links the measures and predictors of transit success to the many secondary data sources. This lack of integration among various national, regional, and local data sources, in addition to the lack of quantitative data on unconventional transit technologies and policies, prevents federal, state, metropolitan, and local decision makers from incorporating more innovative measures and predictors of transit success into their project evaluation practices. This section thus attempts to match the measures and predictors of transit success that are described in the literature review with readily available data sources in the United States and to identify some measures and predictors that are not sufficiently available in existing U.S. nationwide databases.

There are certain challenges to developing one comprehensive database for measures and predictors of transit success. Foremost are inconsistencies across different data sources and the general lack of information on newer transit technologies and policies. A variety of readily available databases on transportation, land use, economic elements, and social characteristics are managed by several public, private, non-profit, and academic entities for different purposes. This review lays out the similarities and differences in how these nationwide data sources define significant variables (e.g., transit capital, operation, maintenance, disposal, or life cycle costs and transit agency or private household expenditures), measure the scope of analysis (e.g., state, transit agency, metropolitan area, census tract, census block or household), measure survey periods (e.g., short-, mid- or long-term), and the frequency at which information is updated (e.g., decennially, annually, quarterly, or monthly). In addition, many of the readily available nationwide databases on fixed-guideway transit systems in the United States do not yet satisfactorily cover contemporary transportation attributes, such as geographic scope/network, intermodal features, bus rapid transit (BRT) systems, parking, and urban design characteristics, across national, regional, local, and human scales. To fill the knowledge gaps, some local data sources and alternative analysis approaches are listed to complement each of these under-documented transportation attributes.

One of the most difficult practices for transportation researchers and decision makers is to conceptualize in a logical order all of the various datasets and their broad ranges of measures and predictors of transit success. To aid in this process, this review re-organizes the secondary data sources and discusses the challenges to computing measures and predictors of transit success. The review breaks down the measures and predictors into four categories: (i) internal (cost and system/finance data); (ii) extensive (social, geographic/network and intermodal data); (iii) unconventional (BRT, parking and urban design data); and (iv) external (urban development data such as residential and business location, property transaction, land use integration, and urban simulation). A summary table of the key data sources reviewed in this section is attached in Appendix J.

A.2 Internal Attributes

Fixed-guideway transit projects have long been evaluated primarily by the cost-performance data managed and reported by traditional operators. Computations of such internal performance measures and predictors call for appropriate datasets on transit costs, supplies and demands, and funding sources.

A.2.1 Cost Data

The costs associated with fixed-guideway transit systems can be differentiated among those held by internal, extensive, and external stakeholders. Internal cost components, which are reported by large fixed-guideway transit agencies, are relatively clear to identify and address both measures and predictors of transit success. On the other hand, extensive and external cost components, which are covered by small transit operators, individual households, specific organizations, or local jurisdictions, are generally challenging to define as measures of transit success in a broader social context. Here we discuss the availability and limitations of datasets that describe internal cost components. These can be subdivided into transit expenditures of capital, operations, maintenance and disposal for the short-term phases and the long-term life cycle of a fixed-guideway transit project.

A number of readily available nationwide data sources cover U.S. transit agencies' capital and operation expenditures for short-term phases. At the aggregate agency or metropolitan level of analysis, the *National Transit Database* (NTD) and the *APTA Public Transportation Factbook* (PTFB) both offer summary-level information on annual transit agency expenses since 1996 and 2003, respectively. Both of these sources provide statistics that allow data on transit agency internal expenditure to be normalized by transit facility and service factors, including rail track miles, number of vehicles, service hours, total passengers, or service areas. Since annual data on transit fare prices or farebox revenues are also included in the NTD/PTFB tables, the magnitude of cross-subsidies can be roughly estimated as the net difference between annual-based transit fare revenues and total transit expenditures at the aggregate transit agency and metropolitan-area levels.

While there is much information on capital and operating costs at the aggregate level, the need for disaggregate cost data rapidly increases as transportation researchers and transit managers recognize the essential roles that space, direction, and time play in determining transit agencies' expenditures. This effect can be attributed to the phenomenon of peaking, which Taylor (2004) identifies in his following conclusions: (i) providing both demand-driven and policy-driven network patterns tends to be expensive (spatial peaking); (ii) the marginal costs of adding transit services in peak directions to/from downtown and other employment centers tend to be high (directional peaking); and (iii) the marginal costs between morning, midday, evening, and midnight hours on weekdays and weekends are different (temporal peaking). Despite the fact that space, direction and time characteristics significantly determine the internal performance of transit systems and transit finance programs, the lack of nationwide databases on disaggregate expenditures impedes the use of more accurate internal measures and predictors of success in transit costs.

The long-term maintenance, disposal, and life cycle costs of a fixed-guideway transit project have historically been overlooked and are rarely reported by traditional public transit agencies. The documentation of these non-traditional cost accounts or "asset management records" has recently become more crucial, however, as public-private partnerships are increasingly utilized to deliver mega-infrastructure projects and avoid cost overrun problems in the United States (Maze and Smadi 2003; Neumann and Markow 2004; Miller and Ibbs 2000; Flyvbjerg 2007; Flyvbjerg et al. 2003). One important piece of information related to these lifetime cost accounts is social and business discount rates. These data, which can be found in sources like the Board of the Governor of the Federal Reserve System's *Statistics & Historical Data on Interest Rates* (1954), provide information on the long-term measures and predictors of transit success in internal costs.

A.2.2 System and Financial Data

By and large, transportation professionals and public decision makers in the United States consider success based on the internal measures of transit system performance and financial program performance (Taylor 2004). To measure transit system performance, the internal costs paid by transit agencies are normalized by transit service supply and passenger demand variables. Using finance programs to measure transit success requires information on the internal structures of transit revenues and cross-subsidies from several public funding resources (e.g., fuel taxes, sales taxes, property taxes, land and air-right sales, toll revenues, and obligation bonds). The data necessary for both of these performance measures are discussed in this section.

Transit service supply, which is used to measure transit system performance, can be characterized in a number of ways, such as facility and vehicle counts; travel times and speeds; service capacity, frequency and hours; reliability and comfort; fare policies and technologies; network patterns; and market coverage (*TCRP Report 100*: Kittelson & Associates Inc. et al. 2003). However, many of these service attributes are hard to quantify in a comparative and in-depth way due largely to the paucity of nationwide disaggregate datasets. Two of the most common national databases on transit supply attributes, both tracked at the aggregate agency and metropolitan levels, are the APTA *Public Transportation Factbook* (PTFB) and the *National Transit Database* (NTD). These sources include information on vehicle availability, track and service lengths, transit vehicle speeds, fares, and service areas. Disaggregate datasets on service supply attributes (by space, direction, and time) can be extracted from online information systems, annual operation reports, and internal survey documents provided by individual transit agencies, but the service attributes and periods covered are often inconsistent across different transit agencies. The Massachusetts Bay Transportation Authority (MBTA) and Bay Area Rapid Transit (BART) are two examples of transit agencies that make extensive information available, including data on service reliability, passenger environment indicators, train cleanliness, customer complaints, crime, etc.

The PTFB and NTD tables contain only aggregate data on passenger demand characteristics (e.g., unlinked passenger trips, trip lengths, and passenger miles traveled), whereas disaggregate ridership patterns at corridor and station levels must be obtained from the individual agency reports published annually or monthly. Because of this discontinuity among national and local data sources, it is difficult to compile and compare peaking transit demands by zone, direction, and time, which critically influence the internal structures of marginal expenditures, fare revenues, and cross-subsidies.

To study the internal structures of fare revenues and cross-subsidies, the NTD table contains many transit finance variables: public funds used to pay back interest and principal on bonds and loans; capital program funds; carryover amount to next year; state and local government contributed services; passenger fares earned by mode and type of service; gasoline tax amount and percentage; the general revenues of the government entity; revenues earned from high occupancy toll lanes; investment revenue and non-transportation funds; park-and-ride parking revenue; and income, property, and sales tax amounts and percentages. These fare revenue and cross-subsidy attributes are very important for decision makers to understand because public funding resources not only help reduce the financial deficits of transit agencies but also extensively redistribute the internal costs of fixed-guideway transit systems between internal transit users and extensive social stakeholders based on the benefit principle and the ability-to-pay principle (Taylor 2004; Musgrave 1959).

A.3 Extensive Attributes

The internal measures and predictors of fixed-guideway transit success suggested in the literature are usually associated with equity concerns, urban geographic patterns, or regional network performances. Accounting for such extensive attributes, existing databases on social, geographic information system/network, and intermodal characteristics need to be well understood.

A.3.1 Socioeconomic Data

In practice, public funding decisions are guided not only by the internal measures and predictors of success in transit systems and finance programs, but also by the extensive debates over four types of social equity: individual equity, environmental equity (or justice), group equity, and geographic equity (Taylor 2004; Cairns et al. 2013). As reviewed, fixed-guideway transit projects are likely to redistribute both user benefits and social costs among different individuals and groups in certain jurisdictions and geographies. Therefore, there is a growing need for the organization and integration of nationwide secondary data on the measures of transit success through social welfare attributes: (i) transportation and housing affordability; (ii) public health and safety; (iii) socioeconomic diversity; and (iv) geographic accessibility.

According to classic theories, fixed-guideway transit investments change individual and household transportation and housing affordability in regional and local spaces. Individual and household information on transportation and housing costs, representing measures of transit success in affordability, can be gained from several U.S. government surveys and data packages: *Decennial Population and Housing Census*; *American Community Survey* (ACS); *Census Transportation Planning Package* (CTPP); *National Household Travel Survey* (NHTS) and *Nationwide Personal Transportation Survey* (NPTS); and *American Housing Survey* (AHS). These nationwide data sources complement one another with a range of datasets about personal earnings, household incomes and expenditures, housing prices and rents, transportation expenditures and commuting times for different years at several geographic levels. Some nationwide private data services, such as *ESRI Updated Demographics* and *GeoLytics 2001-2008 Demographic Data*, cover similar household income, housing expenditure and commuting cost variables to fill the gaps in the above public databases. While most of the housing variables in these public and private data sources are neither temporally nor geographically standardized, the U.S. *House Price Index* (HPI) data, with a special focus on housing affordability, are annually and regionally comparable over the last few decades at the census region, state, and metropolitan statistical area (MSA) levels. The Center for Neighborhood Technology (CNT)'s *Housing +Transportation (H+T) Affordability Index* website further provides a nationwide interactive map with computed 2000 and 2008 affordability variables (such as transportation and housing costs standardized by income, gasoline and housing expenditures, transit service indices, travel times, and household incomes) at the region, county, city, and census block group levels.

Another social welfare measure of success is a fixed-guideway project's ability to decrease the negative effects on public health and safety of an auto-dependent society. In the United States, various databases on public health and safety are organized by the Centers for Disease Control and Prevention (CDC) at the national or regional aggregate level. The CDC's *Behavioral Risk Factor Surveillance System* (BRFSS) began an annual survey in 1984 to assess health-related risk factors by calculating health condition, physical behavior, and social status variables of selected metropolitan/micropolitan areas (SMART). The *National Health Interview Survey* (NHIS) is another aggregate data source provided by the CDC's National Center for Health Statistics (NCHS) since 1963, covering injury and poison condition variables by family, household, person, and age categories. In addition, the CDC maintains the *National Vital Statistics System* (NVSS) that annually reports all deaths by cause (e.g., motor vehicle) and circumstance (including fall and collision with motor vehicle, animal, bicycle, pedestrian, or fixed object), as well as the *National Hospital Ambulatory Medical Care Survey* (NHAMCS) that contains a sample of injuries by cause. The National Highway Traffic Safety Administration (NHTSA) also manages the *Fatality Analysis Reporting System* (FARS), which contains data on more than 100 accident, vehicle, and person variables since 1975, and the *National Automotive Sampling System: General Estimates System* (NASS GES), which covers a nationally representative sample of police-reported motor vehicle accidents of all types since 1988. The social costs mentioned above are unevenly reduced or redistributed by fixed-guideway transit projects among a variety of socioeconomic groups and local jurisdictions along regional transportation networks. Unfortunately, these referenced nationwide secondary databases on public health and safety are not directly linked to other databases on transit systems, socioeconomic characteristics, and micro-geographic boundaries, making it difficult to evaluate fixed-guideway projects on the basis of success with regard to environmental justice.

Socioeconomic diversity across the United States can be measured by a variety of characteristics in readily available government sources, as well as in customizable private data services, for different survey periods. However, the unit of analysis used to measure socioeconomic diversity must be carefully chosen from among various options, such as income, age, gender, educational status, race/ethnicity, religion, occupation, and place of residence. These groups share the user benefits and social costs of fixed-guideway transit projects within a certain jurisdictional/geographic boundary. None of the nationwide databases reviewed in this report calculates any socioeconomic mixture indices at a given jurisdictional level. In recent databases (e.g., *National Dataset for Location Sustainability and Urban Form*), socioeconomic variables are instead associated with transit network, regional employment, and local service accessibility on multiple geographic information system (GIS) tabulations.

A.3.2 GIS and Networking Data

Geographic information systems have grown to play an important role in transit research. This is because transit systems operate in various economic and social geographies, and their performance is strongly related to spatial characteristics. GIS software uniquely enables the analysis of the spatial relationships that occur between transit facilities and their surrounding communities. Many popular indicators of successful fixed-guideway transit can be derived from manipulation of GIS shapefile data sets. Most prominently for transit analysis, GIS can be used to estimate the amount of population or employment that is located within a radius or street network "access shed" of a transit facility. It can also be used to measure accessibility to jobs, retail, and other destinations by different modes.

Although GIS systems enable a broad array of spatial data processing and analysis techniques, it is important to note that products derived through GIS applications are only as useful as the input data and the theoretical approach to understanding spatial relationships. In particular, GIS representations of population or employment are spatial averages of survey, forecast, or estimate data. Not only is the accuracy of the data often questionable, but it often represents finite discrete attributes in a spatially flattened context. Population or other land use characteristics can be spatially clustered or broadly dispersed within a geographic unit of analysis, but GIS techniques are insensitive to these distinctions. The geometry of transportation analysis zones (TAZ)—a common unit of analysis in regional transportation models—is particularly insensitive to the pedestrian scale features of a neighborhood that could facilitate pedestrian activity and transit use or render it infeasible.

GIS shapefiles are produced both by public governments or agencies and by private parties. Many useful shapefile datasets can be downloaded for free from state or regional geographic data clearinghouses. Possibly the most commonly used shapefiles are the U.S. Census TIGER/Line shapefiles. These shapefiles, available for download from the U.S. Census Bureau's website, feature political boundaries, census tabulation boundaries, and basic street networks. Numerous private street network datasets are available, but they are usually expensive.

Fixed-guideway transit shapefiles are available as part of the *National Transportation Atlas Database* (NTAD). NTAD shapefiles can be downloaded for free from the Internet and feature various transportation-related shapefiles on a nationwide basis, but not all transit systems are included in NTAD. Many metropolitan planning organizations (MPOs), DOTs, and transit agencies provide more complete transit network shapefiles, possibly including bus route information. Another option for geographically representing transit station locations is the manipulation of *General Transit Feed Specification* (GTFS) data feeds. The GTFS format was developed by Google for transit agencies to make route and schedule information publicly available on Google Maps. The text-based GTFS format is now becoming a standard data format for expressing transit service information. Available GTFS data differ by transit agency, but they typically include latitude and longitude location fields that can be used to geocode station locations in GIS applications. Schedule and route information in GTFS format can also be used to obtain data on transit service characteristics. Another useful resource for publicly available geospatial data is a national GIS portal supported by the Geospatial One-Stop E-Government initiative: www.geodata.gov.

The characteristics of, and differences between, various transit networks are of unique interest. As transit networks expand, the expanded accessibility offered by a system as a whole is expected to improve the desirability of all stations and thus increase ridership across existing stations. Despite the significance of network characteristics, methods of directly measuring such characteristics are not widespread. This section presents some tools and challenges related to preparing data to represent network characteristics of fixed-guideway transit systems.

Several issues that complicate transit network characteristics measurement are immediately apparent. First, the format in which most fixed-guideway transit system geospatial information is made publicly available is not conducive to easy network analysis. This would require a complete and integrated set of route and station GIS shapefiles. In practice, when shapefiles of transit networks are readily available, stations are not usually placed as nodes at link vertexes and links often do not relate to connections between nodes. GIS data for fixed-guideway transit systems vary in format, but often they do not include a unique feature for each link between two stations. Often, a single polyline represents an entire transit corridor, or multiple polyline features start and end at curves and other geographic features not related to station location. As a result, some amount of manual editing and data manipulation is often necessary before network analysis can be conducted with GIS shapefiles.

There are different possible measures of network size or density. The simplest is to count the total number of stations or route-miles. This method represents network size but does not give any indication of a network's connectivity or accessibility between origins and destinations. Link-to-node ratios relate system-wide station counts to interconnectivity between stations. This is a measure of network density. The rationale for this measure is that good connectivity can be defined as routes offering more linkages between any given fixed number of stations. But it does not distinguish some systems that vary greatly in connectivity; for example, the link-to-node ratio of a single-line system might differ only slightly from a multi-route system that converges on a multiple-line transfer hub in the central business district. Due to GIS issues discussed above, link-to-node ratios are often easiest to calculate by hand through observation of a transit route map.

Another option for quantifying network scale and scope is measuring the population, employment, and activity center characteristics of places that can be accessed by the transit system. At a system-wide level this can be done using GIS to create service area zones around stations and then calculating the population and other features of the areas within the service area. Service area populations can be calculated by associating census or third-party data with Census TIGER/Line shapefiles, as discussed in the GIS section above. For localized transit demand modeling, a similar approach can be performed for each station where land uses at other stations that are accessible by the fixed-guideway transit are calculated for each individual station. Numerous other methods are available for analyzing network characteristics of transit systems, but many in reality only apply to networks that provide coverage across broad service areas. Daganzo (2010) introduced methodologies for determining ideal network layout based on population, travel demand, and service area geography conditions. Under Daganzo's framework, transit systems can form radial networks, grid networks, or a hybrid central grid and radial periphery system. The underlying characteristics of a region can be analyzed to determine which system type would optimally serve a specific service region. In short, the best network is the one that best matches the distribution origins and destinations in a given city.

A.3.3 Intermodal Characteristic Data

Fixed-guideway transit lines are often a part of wider national, state, regional, and local networks consisting of other transportation modes. This implies that the congestion levels, market shares, nodal facilities, and feeder services for a given fixed-guideway service not only influence that service's internal measures of success, but they also change the extensive measures of success for other modes throughout the network. Such intermodal characteristics need to be systematically and comprehensively analyzed as measures and predictors of transit success by federal, state, regional, and local transportation decision makers. To facilitate this process, we organize a number of nationwide databases into the following four categories: (i) urban mobility on regional roadway systems; (ii) modal competitiveness in national, state, regional and local transportation markets; (iii) intermodal connectivity among regional airport, waterway, and fixed-guideway transit systems; and (iv) local access availability around urban transit centers and along suburban transit corridors.

Urban mobility on regional roadway systems is annually reported by the Texas Transportation Institute (TTI) and Federal Highway Administration (FHWA). The TTI's *Urban Mobility Report* (UMR) provides aggregate estimates of several traffic mobility and congestion variables (e.g., daily vehicle miles traveled, annual travel delay, travel time index, and overall congestion cost) for approximately 100 select urban areas. For some urban areas, however, UMR data is inconsistent with secondary data from state DOTs and metropolitan planning organizations. The other annual resource on urban mobility, the FHWA's *Highway Statistics*, covers a larger number of urbanized areas (more than 400 in 2009) and includes aggregate estimates of daily vehicle-miles traveled by hierarchical roadway systems (including Interstate, other freeway, and expressway, other principal arterial, minor arterial, and collector). One disadvantage of this database is that, due in large part to changes in the definition of U.S. urbanized areas, the *Highway Statistics*' panel data on aggregate estimates of daily vehicle-miles traveled are inconsistent from 1992 through 2009. In order to thoroughly investigate urban mobility characteristics at local roadway network and corridor levels, transportation analysts and decision makers need to rely on state-based or metropolitan organization-based disaggregate data sources (e.g., the California DOT's *PeMS*, the Florida DOT's *TranStat*, and the Washington DOT's *Congestion Report*).

Modal shares for commute trips are covered by the U.S. decennial census and the annual community and housing surveys for different statistics periods at different geographic levels. Primarily, the U.S. DOT's *Census Transportation Planning Package* (CTPP) contains data on travel mode to work, allocating commuters among 18 different means of transportation to work categories in the 1990 and 2000 decennial censuses at the state, MSA, county, census tract, and transportation analysis zone (TAZ) levels. Secondarily, CTPP products based on the most recent American Community Survey (ACS) classify workers into 10 categories of means of transportation to work based on the 3-year (2006-2008) and 5-year (2006-2010) tabulations at the state, MSA, county, place, and public use microdata area (PUMA) levels. In addition, the U.S. Census Bureau annually conducts the *American Housing Survey* (AHS) to obtain up-to-date housing and household characteristics, including data on the numbers of housing units in 12 categories of principal means of transportation to work from 1973 to the present year on the MSA, county, central city/suburban status, and census tract scales. These secondary data sources, however, do not account for non-commute, daily chain, and long-distance trips. This considerably limits the understanding of intermodal competition in the national, state, regional, and local transportation markets where fixed-guideway transit projects are proposed. In the 2001-2002 and 2009 *National Household Travel Surveys* (NHTS), the U.S. DOT Bureau of Transportation Statistics (BTS) legislation addressed this deficiency. It specifically targeted data on the volumes and patterns of both long-distance and local-based travel for multiple non-commute purposes for 25 different modes of transportation at the census tract, block group, and household levels in order to analyze and evaluate the nation's new capital investments.

Intermodal connectivity indices among different passenger transportation systems can be computed by using the GIS point and line shapefiles included in the BTS/RITA's *National Transportation Atlas Database* (NTAD). Point shapefiles contain locations such as airports, Amtrak stations, fixed-guideway transit stations and intermodal terminal facilities; line shapefiles contain networks such as national railways, fixed-guideway transit lines, and navigable waterways. The nationwide NTAD database has been issued annually since 1996 (it is currently available for 2008, 2009, and 2010); however, NTAD has failed to consistently update its point and line shapefiles as new capital investments occur. Complementary to NTAD, the BTS/RITA's *Intermodal Passenger Connectivity Database* provides a nationwide table of passenger transportation terminals with data on the availability of intercity and commuter rail, air, and ferry services. This database has more frequently updated its files with new facility and service information since mid-2006, and heavy and light rail transit stations were added to this database in 2011. The scope of the *Intermodal Passenger Connectivity Database* is wide, including intercity buses, code-share buses, and supplemental service buses for intercity rail and air carriers, intercity ferries, and transit or local ferries, but it does not attempt to cover every possible transit bus stop in every street block.

Local information on feeder transit systems can be obtained in *General Transit Feed Specification* (GTFS) data for many local systems. Various transit operators in North America occasionally update their local service characteristics in the GTFS format (e.g., stations, stops, routes, transfers, runs, hours, frequency, and fares), but there is no comprehensively integrated nationwide database on local access availability around regional transit centers and corridors. Key data challenges arise around bus rapid transit (BRT) systems, parking facilities and policies, and pedestrian/bicycle facilities and amenities.

A.4 Unconventional Data Sources

Contemporary funding programs and academic studies have stressed the increasing importance of incorporating new factors and system types when evaluating fixed-guideway transit projects. We discuss BRT, parking, and urban design below.

A.4.1 BRT Data

In recent years, U.S. transit agencies have become increasingly interested in BRT systems. BRT systems are considered an attractive option for improving transit service due to perceived affordability and flexibility. There are numerous international examples, particularly in Latin America, where BRT systems offer high levels of service at costs far below those of rail-based alternative modes. As a result, U.S. agencies see BRT as a potential tool for improving transit service in environments where capital for transit expansion is limited.

Despite the growth of interest in BRT systems, obtaining data to study their potential success in U.S. environments is challenging. The two primary data constraints are the limited number of BRT systems operating in the United States and the recent nature of the systems that are in place. Due to these conditions, transit agencies considering the possibility of developing BRT systems have few comparable applications and limited historical data that can be analyzed. Meanwhile, although BRT systems in Bogota, Columbia; Curitiba, Brazil; Guangzhou, China; and numerous other global cities are widely considered successful, these cities often feature social, political, cultural, and economic differences from the United States that are so dramatic that any direct comparison would be problematic. Generally speaking, domestic experiences are available for the study of short-term responses to some forms of BRT in the United States, but long-term United States experience does not yet exist. The prediction of long-term BRT success may therefore require some form of international comparative analysis.

Besides the limited availability of data, there are also compatibility issues across BRT systems that are in place in the United States. Firstly, the concept of BRT is poorly defined. BRT is actually a toolbox of features that can be used to improve service and increase commercial operating speeds. A fully featured BRT system is one that includes most or all of the BRT toolbox features. The literature on BRT differentiates between “full BRT” and “BRT-light.” Although many U.S. transit agencies claim to operate BRT services, most examples are actually limited to bus routes with relatively higher service frequencies and longer stop spacing than regular bus services that operate in mixed traffic conditions. Of bus systems that do qualify as “full BRT” or “BRT-light,” there are significant differences in features that make direct comparisons problematic.

By definition, a bus system qualifies as BRT if and only if a separated right-of-way is present on at least part of its corridor. BRT systems that currently exist in the United States are listed below:

- LA MTA Orange Line
- Boston Silver Line
- Eugene, Oregon, EmX Line
- Cleveland Health Line
- NY MTA NYCT Fordham Road, 34th St., and 1st/2nd Aves Lines
- Pittsburgh

The relatively recent arrival of BRT applications in the United States precludes the possibility of longitudinal analysis of its long-term measures of success. However, short-term before-and-after analysis can be performed for most extant systems using data on service features and ridership at one time point before implementation and another following commencement of BRT operations. While land use patterns cannot be expected to adjust to service changes in a period ranging from mere months to a couple of years, short-term ridership changes can indicate the degree to which BRT service improves transit competitiveness for existing travel demand patterns.

Since one of the main driving factors behind BRT in the United States is that it is perceived as a more affordable alternative to rail transit, it is essential to gain a better understanding of its comparable costs and competitiveness. BRT capital and operational costs can be compared to rail systems on a mileage or passenger basis. This requires individual consideration of recent rail and BRT projects in the United States, a topic that recent literature has begun to address. Regarding competitiveness with rail, there are several metrics that should be considered. Firstly, a key concern of BRT skeptics is that BRT is less attractive to U.S. travelers than rail-based modes. This issue can be addressed through ridership studies comparing BRT and light rail systems in corridors of similar demographics. Other issues of concern include operating speeds, service reliability, required real estate footprint, and capacity constraints.

Due to a lack of available information necessary to answer the above questions, some comparative international analysis may be useful in predicting BRT success in the United States. Although Latin American cities have advanced BRT systems with long operational histories, the major differences between the United States and Latin America with respect to socioeconomic attributes, land densities, car ownership rates, culture and other factors complicate our ability to effectively apply Latin American lessons to U.S. systems. In order to better predict BRT desirability, operational limitations, user acceptance, capital costs, and operational expenses it would be ideal to consider examples in societies that are structurally similar to the United States. Canada is one such example, with comparable demographics, economic development and culture, in addition to a relatively extensive history of BRT experimentation. Ottawa, Canada, has over 30 years of experience with a full BRT system. BRT routes have also been in operation in Calgary since 2004, although one line is currently being converted to light rail. The cost structure, ridership, and long-term land use impacts of these systems could be compared to Canada's recent urban rail systems to inform expectations of BRT success in the United States.

A.4.2 Parking Data

Parking is considered an important factor in the success of fixed-guideway transit systems in multiple ways. Firstly, the availability and cost of parking is an element of overall user costs experienced by drivers of private vehicles. In dense urban centers the cost of parking can amount to a significant share of the overall cost and convenience of auto travel. These costs are incorporated into travel mode decisions that ultimately determine transit demand. When parking is located at travel destinations, it can be analyzed as part of the infrastructure supporting a mode that competes with fixed-guideway transit.

Parking supply can also serve as an important element of intermodal transit stations. Suburban fixed-guideway transit stations are often particularly dependent on parking capacity to facilitate commuter station access. While parking can act as a competing mode at trip destinations, the lack of parking availability at transit stations can instead constrain ridership.

Parking is not only a facility that can be present at a transit or activity node, but it also occupies physical space and has significant urban design attributes. Principally, the use of land for automobile storage can crowd out other activities, particularly in downtowns or destination areas where parking facilities occupy land that could otherwise serve different purposes. The result is a reduced density of other land uses that are supportive of and supported by transit service. Parking facilities are also often visually unappealing and may reduce the attractiveness of pedestrian environments. Meanwhile, at transit facilities where parking may be present in order to facilitate access, the use of land for parking lots or structures reduces the availability of land for transit-oriented development.

The supply of parking is often more complex than a private market reaction to demand. Most communities in the United States regulate the supply of parking and mandate some bundling of parking supply with other land uses. In this regard, local knowledge is critical for understanding the dynamics behind parking supply, ownership, and pricing in any given urban environment.

Despite being an important element in mode choice decisions, it is very difficult to acquire broad, aggregate information on parking availability and pricing. In fact, most municipalities have no inventory of parking capacity outside of their central business district (CBD) parking supply. Even at the local level, accurate information of parking supply is very difficult to find. Fortunately, in the case of park-and-ride facilities operated by transit agencies, parking capacity and pricing information can usually be collected from the agency itself with modest expense of effort.

For a unit of analysis at the metropolitan level, some private studies are also available to provide order of magnitude approximations of CBD parking prices. Two examples of these types of sources are Colliers International's *North America Central Business District Parking Rate Survey* and National Parking Association's *Parking in America Report*. If a more detailed study is necessary, several websites provide parking prices at various parking garages (e.g., www.bestparking.com). None of these data sources provide information about the supply, costs, or availability of on-street parking, the personal use of private parking, or the temporal distribution of demand, but the private parking lot prices that they do present can give an indication of the interaction of demand with land values (given local zoning ordinances associated with parking provision).

In preparation for the implementation of an information-technology driven adjustable rate parking system, the City of San Francisco performed an inventory of on-street and publicly owned parking garage capacity. The data generated from this SFPark program will prove invaluable for future analyses of parking supply and prices as predictors of transit success.

A.4.3 Urban Design Data

There is increased emphasis on urban design elements around fixed-guideway transit stations, as planners and policymakers recognize the importance of transit-supportive land uses and place-making efforts in promoting transit ridership, pedestrian/bicycle travels, public health and safety, community livability, social interactions, and economic innovations. Nevertheless, incorporating urban design criteria as predictors of transit success into fixed-guideway transit project evaluation is often hampered by a lack of nationwide data on human-scale built environments. Better information on the built environment around fixed-guideway transit stations might include types of public space;

street facilities; street locations, lengths, widths and physical conditions; street amenities; topography; and intersection/network characteristics.

The most common approach to measuring urban design characteristics is to compute the connectivity of local street networks within one-quarter- and/or one-half-mile of a fixed-guideway transit station using the U.S. Census Bureau's *TIGER/Line GIS shapefiles*. Despite its geographical comprehensiveness, analytical ease and practical usefulness for transit project evaluation at the local street level, the TIGER/Line shapefile application does contain limitations. A secondary data review conducted by the U.S. DOT Bureau of Transportation Statistics (BTS) in 2000 addressed two of these drawbacks: (i) the file does not contain any facility attributes (such as street widths, number of lanes, and presence of sidewalks); and (ii) the file does not contain pedestrian or bicycle connections that are not part of the street network (such as alleys, walkways, or pathways). In short, further details of transit-supportive design characteristics need to be frequently and accurately updated on the nationwide street-level GIS map. Indeed, progressive cities, counties, and metropolitan planning organizations independently establish and maintain their own GIS databases to describe the unrecorded bicycle and pedestrian amenities of fixed-guideway transit station areas, including sidewalk/bikeway continuity, street connectivity, topography, and other urban design elements (e.g., the city of Portland's *Corporate GIS*, the North Central Texas's *Rail Station Access*, and the San Francisco MTC's *GIS Data Category 2*).

In early 2011, the *National Dataset for Location Sustainability and Urban Form* became readily available through the Natural Resource Ecology Laboratory at the Colorado State University. Based on a road shapefile from the U.S. Census TIGER/Line 2009, this nationwide GIS database computed the weighted number of intersections within one-quarter-mile of each census block group as an urban *design* factor. In the technical report of this dataset, Theobaldi et al. (2011) noted that a methodological challenge to calculating this design variable is that either adjacent land uses (e.g., a park) or transportation corridors (e.g., railway line or Interstate highway) often limit pedestrian access, yet such physical barriers are not accounted for in the variable. Ideally a number of site-specific information would be included for each of these variables, such as sidewalk completeness, directness of pedestrian routes, and bicycle pathways. However, these local built environment attributes are hard to cover and update on a national scale and in a timely manner.

Facing this insufficiency of nationwide databases, the BTS report (2000) recommended: (i) standardizing formats and definitions of urban design characteristics to improve data comparability among local agencies and geographic areas; (ii) facilitating discussions among various data user groups to identify key urban design characteristics and provide guidance to state and local agencies responsible for collecting and maintaining data; and (iii) applying new technologies for database development, such as aerial photography and satellite imagery techniques, to improve the cost effectiveness of local-level data collection and management.

A.5 External Attributes

The literature also asserts that factors outside of the urban transportation systems themselves, such as land use impacts and urban density thresholds, should be analyzed as secondary measures and predictors of long-term transit success. Such external indicators can be obtained from multiple databases and studies on urban location shifts and economic development patterns in cross-industrial and micro-geographic realms.

A.5.1 Urban Development Data

Over the last decade, the demand for disaggregate data on urban development patterns has been growing in the United States, as the ability of transit-oriented development (TOD) to increase transit ridership, discourage urban sprawl, and promote economic development by densely locating a variety of property packages, business clusters, and residential communities around urban transit centers and along suburban transit corridors has been more importantly assessed as both the short-term predictor of success and the long-term measure of success by federal, state, and local decision makers. U.S. databases on urban development patterns are classified into: (i) residential location; (ii) business location; (iii) property transaction; (iv) multiple characteristic integration; and (v) urban simulation.

By tradition, the *U.S. Decennial Population and Housing Census* has long been the chief public data source to analyze long-term residential location patterns around national, state, regional, and local transportation systems on different geographic scales (e.g., states, metropolitan statistical areas, counties, urbanized areas, ZIP codes, tracts, and block groups). In recent years, however, some supplemental secondary databases have become available to cover short-term changes in residential location patterns between the decennial census years. The *GeoLytics Demographic Data*, for example, currently deals with disaggregate estimates of population, housing, and household and labor location characteristics on micro-geographic scales (e.g., ZIP codes, census tracts, and block groups) from 2001 through 2008. The *ESRI Updated Demographics* database annually offers disaggregate estimates of more than 2,000 population, household, and original industrial and occupation variables in a variety of U.S. jurisdictions and geographies as custom-order commercial products. Additionally, the U.S. Census Bureau's *Longitudinal Employer-Household Dynamics* (LEHD) database makes publicly available the residential location characteristics of workers by age, earning and standardized industrial categories at the census block-level from 2002 to 2008, excluding some state areas (New Hampshire, Massachusetts, Virgin Islands, and Puerto Rico).

Similarly, disaggregate databases on short-term business location characteristics are now publicly available. The *U.S. Economic Census Economy-Wide Key Statistics* (EWKS) supplies the number of establishments and employees by the North American Industry Classification System (NAICS) code, value of sales, shipments, receipts, revenue, and annual payroll, at the ZIP code level in 1997, 2002, and 2007. On the basis of annual economic surveys, the U.S. Census Bureau's *ZIP Code Business Patterns* (ZBP) series from 1994 through 2008 reports the number of establishments by employee size and total annual and quarter payroll figures. Notably, applying the long-term panel data in the ZBP series to examine cross-industrial composition changes is complicated by the fact that the classification system used to categorize establishments changed from the Standard Industrial Code (SIC) system to NAICS in 1997. While the LEHD database does keep the consistency of time-series data on the business location patterns of workers by age, earning, and industrial (NAICS) categories at the census block-level from 2002 to 2008, it excludes four state areas and a number of important business performance variables. Some private vendors offer time-series data on firm-level business inputs and outputs by industrial type, from which dynamic changes in business productivity around transit stations can be micro-geographically calculated as a measure of transit success in agglomeration economies. Walls & Associates, for instance, maintains the *National Establishment Time-Series* (NETS) Database, including over 36.5 million establishments with time-series information about their industries, locations, headquarters, ownerships, employment sizes, and annual sales over the period 1990 to 2009.

Hedonic price analysis around stations is more a common approach to measuring the capitalization impacts of fixed-guideway transit projects on both business and residential activities.

Generally, net price increases are estimated as the accessibility/agglomeration benefits generated by transit investments, and they are expected to help recover the upfront capital costs of fixed-guideway transit systems. Property transaction records in the United States are provided by several private entities. One of the largest national databases is the First American CoreLogic's *RealQuest Professional*. This online database system covers 97% of all U.S. real estate transactions, offers a geographic radius search tool to find target property records by proximity to transit stations and related facilities, and customizes up to 25,000 records in multiple downloadable data formats. *DataQuick* is another popular private database that contains more than 105 million assessor parcels in 2,300 jurisdictions, 85% of all properties in the top 100 MSAs, and 250 million historical recordings in 1,800 jurisdictions with geocodes, household level demographics, behavior, and lifestyle attributes. Also, Zillow, Inc. operates its newly established *Zillow.com*, an online real estate information system that provides very short-term data on home sales transactions for free. In the public sector, the Office of Federal Housing Enterprise Oversight (OFHEO) quarterly estimates the *House Price Indexes* (HPIs) for single-family detached properties using data on conventional conforming mortgage transactions obtained from the Federal Home Loan Mortgage Corporation (Freddie Mac) and the Federal National Mortgage Association (Fannie Mae). The Federal Housing Finance Agency's (FHFA) website presents quarterly HPI data for long-term trends from 1975 to the present year at the census division, state, and MSA levels. Looking at short-term trends, the U.S. Department of Housing and Urban Development's (HUD) *Aggregated USPS Administrative Data On Address Vacancies* website releases on a quarterly basis publicly available nationwide data on the total count and average number of days of vacant addresses, broken out by residential, business, and other property type, from 2005 to the present year at the census tract level. In general, these U.S. property transaction records are poorly integrated with other nationwide databases on fixed-guideway transit systems and urban development patterns, although dynamic trends in real estate markets importantly indicate the short-term predictors and long-term measures of success of fixed-guideway transit investments in transit-oriented developments.

Given the above secondary data sources, some non-profit and academic research institutes have recently been developing readily integrated nationwide databases on multiple urban development characteristics around fixed-guideway transit stations. The Center for Transit-Oriented Development (CTOD) and Center for Neighborhood Technology (CNT) conduct the *National TOD Database* project, organizing over 40,000 observations of population, household, housing, employment, and travel variables at the transit zone (one-quarter- or one-half-mile buffer around existing and proposed stations in 47 metropolitan areas), the transit shed (the spatial aggregate of transit zones), and the transit region (aligns with the MSA boundary) levels based on the 2000 Decennial Population and Housing Census, the Census Transportation Planning Package (CTPP), and the LEHD data. The Natural Resource Ecology Laboratory at the Colorado State University delivers the *National Dataset for Location Sustainability and Urban Form*, whose 2009 census tract and block group data includes: residential-employment balance, density of people, housing, and jobs; diversity of land uses; accessibility to destinations; distance to transit stations (the 5Ds factors); and (originally defined) smart location indices (SLIs). Both of these integrated nationwide databases are useful for measuring the short-term predictors of transit success on the basis of recent location characteristics, but since they are new they do not have panel data for an extended period of time and cannot aid in the examination of long-term measures of success in urban development changes.

Although U.S. decision makers have long faced a lack of longitudinal data on fixed-guideway transit investments and urban development impacts, several urban simulation models, such as

UrbanSim, *PECAS*, *ILUTE*, *TRANUS*, *MEPLAN*, and *DRAM/EMPAL*, are helping to shed light on predictors of long-term travel behavior and land use impact success. In their early stages, these large-scale simulation models had many deficiencies. They reflected too much real-world complexity, provided too coarse predictions to policymakers, required excessive data and money, imputed individual behaviors from aggregate data, and depended on unrealistic iterative processes (Lee 1973). The recent dynamic microsimulation models, however, have moved toward more realistic activity-based travel behaviors and more practical lot-level land uses based on understandable location theories, cost-efficient computations, and path-dependent interactions (Waddell 2011). Unfortunately, these technical improvements have made microsimulation models much more difficult for decision makers to use.

APPENDIX B: Data Collection and Construction of Variables

This appendix provides a detailed description of the data and data sources used as measures and indicators or transit success at the project and metropolitan levels of analysis. We compiled data on fixed-guideway transit projects and metropolitan areas across the United States, including station-level, project-level, and regional-level information on ridership levels, agency operating costs, demographics, employment and population density, gross domestic product (GDP), gas prices, parking availability and pricing, regulatory restrictiveness in land uses, neighborhood walkability, rail and highway networks, and transit service characteristics. In some cases we measured these characteristics ourselves and in others we used secondary data sources.

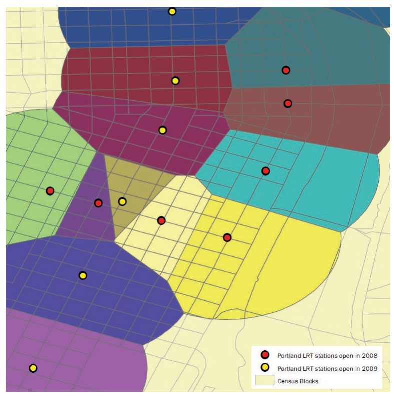
Below are the data utilized for our analysis (with data source, years collected, and geographic level):

- Transit system ridership (National Transit Database [NTD], 1997-2009, urbanized area) Transit system operating costs (NTD, 1997-2009, urbanized area)
- Transit system capital costs (Guerra and Cervero (2011), 2011, project)
- Population, household, income and employment demographics (Census SF1 and SF3, 2000, metropolitan area/county/block group/block)
- Population, household, income, and employment demographics (American Community Survey [ACS] 1-Year, 2005-2009, metropolitan area)
- Employment demographics (Longitudinal Employer-Household Dynamics [LEHD], 2002-2008, block)
- Total unemployment (U.S. Bureau of Labor Statistics [BLS], 1990-2009, county)
- Total jobs (U.S. Bureau of Economic Analysis [BEA], 1969-2009, metro area)
- Total personal income (BEA, 1969-2009, metro area)
- Total GDP (BEA, metro area)
- Consumer expenditures (BLS Consumer Expenditure Survey [CES], 2005-2009, metro area)
- Fuel cost (National Household Travel Survey [NHTS], 2009, county)
- Retail gasoline price (GasBuddy.com, 2000-2011, county)
- Average downtown parking price (Colliers International, 2009-2011, city)
- Off-street private parking prices (Parking In Motion Inc., 2011, rooftop geocodes)
- Highway congestion (Federal Highway Administration [FHWA], 1995-2009 and Texas Transportation Institute [TTI], 1995-2009, urbanized/urban area)
- Land use regulatory restrictiveness ((Pendall et al. 2006), municipality)
- Neighborhood walkability (walkscore.com, 2012, transit station)
- Weather (National Climatic Data Center [NCDC], 2012, metro area)
- Entropy indexes (various data from above; explained below)
- Route-miles, number of stations, opening year, mode (various sources, 2011-2012, project)
- Park-and-ride spaces, bus line connections (various sources, 2011-2012, project)

- Peak AM hour service frequency, average speed (various sources, 2011-2012, project)
- Track grade (FTA Capital Cost Database and Google Earth, 2010, project)

The multiple units of analysis employed for our study (metropolitan area, project, and station area) made it particularly challenging to collect and compile all of the necessary data. The different levels of data required that we take into account both the local information about a transit project and the regional information about the metropolitan area served by that project. We considered each potential success measure and predictor twice, at the project level and again at the metropolitan level. This challenge factored into both our data collection processes and our spatial data analyses. For example, we collected two sets of parking data from two different sources—the first on citywide parking prices and the second on localized rates around transit project stations. Additionally, we created catchment areas around each station for use at both the local project level of analysis and in aggregation up to the metropolitan level of analysis (Figure B-1.)

Figure B-1: Example Catchment Areas Around Urban Rail and Commuter Rail Stations



The extended time frame of our analysis also introduced complications into the process of data collection and compilation. For our panel dataset, we collected metropolitan-level information across seven years. The creation of annual catchment areas was particularly work-intensive, requiring the creation of new service area boundaries for each year that new stations opened.

The resulting data set is possibly the most complete existing for urban rail transit stations and networks in the United States, covering 3,263 transit stations in 44 metropolitan areas across the country, with network links, consistent station and metropolis identifiers, system type and transfer dummies, and station opening years. To these data we spatially joined station-level, project-level, and metropolitan area-level information on demographics, employment, costs of driving and parking, transit service characteristics, and other variables.

The majority of spatial data on transit lines and stations came from the NTAD, but we identified a number of gaps in that source's LRT and HRT networks using a complete list of transit lines and stations provided by NTD. We filled in the missing spatial information using Google Earth, transit agency maps, the Center for Transit-Oriented Development (CTOD) station database, and the website urbanrail.net.

B.1 Measures of Transit Project Success

To measure transit project success, we collected ridership and cost data on the transit systems in our 18 metropolitan areas of study and on the 55 individual transit projects we analyze.

In a UCTC-funded project, Guerra and Cervero (2011) probed the relationship between job and population densities around rail stations and various cost-effectiveness measures. Data on ridership and capital costs come primarily from the information compiled by Guerra and Cervero, with some additional data collection performed for this project.

For the transit system-level analysis, conducted for metropolitan areas, we collected total person miles traveled (PMT) from the National Transit Database (NTD), broken down by agency, mode, and operator from 1996 to 2009. We summed this information by metropolitan area and mode to create ridership statistics (measured in passenger miles traveled) for every fixed-guideway urban rail transit system across all relevant metropolitan areas in the United States. Since NTD data are broken down geographically by Urbanized Area (UZA), and not by census-defined metropolitan area, we mapped each UZA to its primary metro area to enable the metropolitan area-level analysis. U.S. Census Urban Areas served as the spatial link between UZA and metro area. Each UZA name was first matched to its affiliated urban area and then assigned to the primary metropolitan area in which the urban area falls. All transit agency operations are located within one metropolitan area, with the exception of NJ Transit, which operates in both the New York and Philadelphia metro areas. We chose to allocate NJ Transit's ridership and cost information to the New York metropolitan area (New York-Northern New Jersey-Long Island, NY-NJ-PA) over the Philadelphia metropolitan area (Philadelphia-Camden-Wilmington, PA-NJ-DE-MD), as presumably larger shares of NJ Transit trips are oriented to the New York metropolitan area over the Philadelphia metropolitan area.

Most project-level capital cost and ridership information data were from the Government Accountability Office (GAO), the Federal Transit Administration (FTA) (1994-2008), and individual transit agencies as part of previous work conducted by two members of our research team (Guerra and Cervero 2011). Building on their database of projects, we supplemented missing ridership information for over 10 transit lines, including newly built LRT and BRT systems, all CR systems, and any stations that were recently constructed as part of extensions or new lines. We collected average weekday boardings/alightings at the station level from individual agency websites and various other online sources, and we then assigned each station to the project of which it is a part.

B.2 Predictors of Transit Project Success: Metropolitan Area

To determine the factors that best predict a transit project's success, we collected information on demographics and employment, system rail and highway network connectivity, costs of driving and transit use, regulatory restrictiveness in land uses, and transit service characteristics.

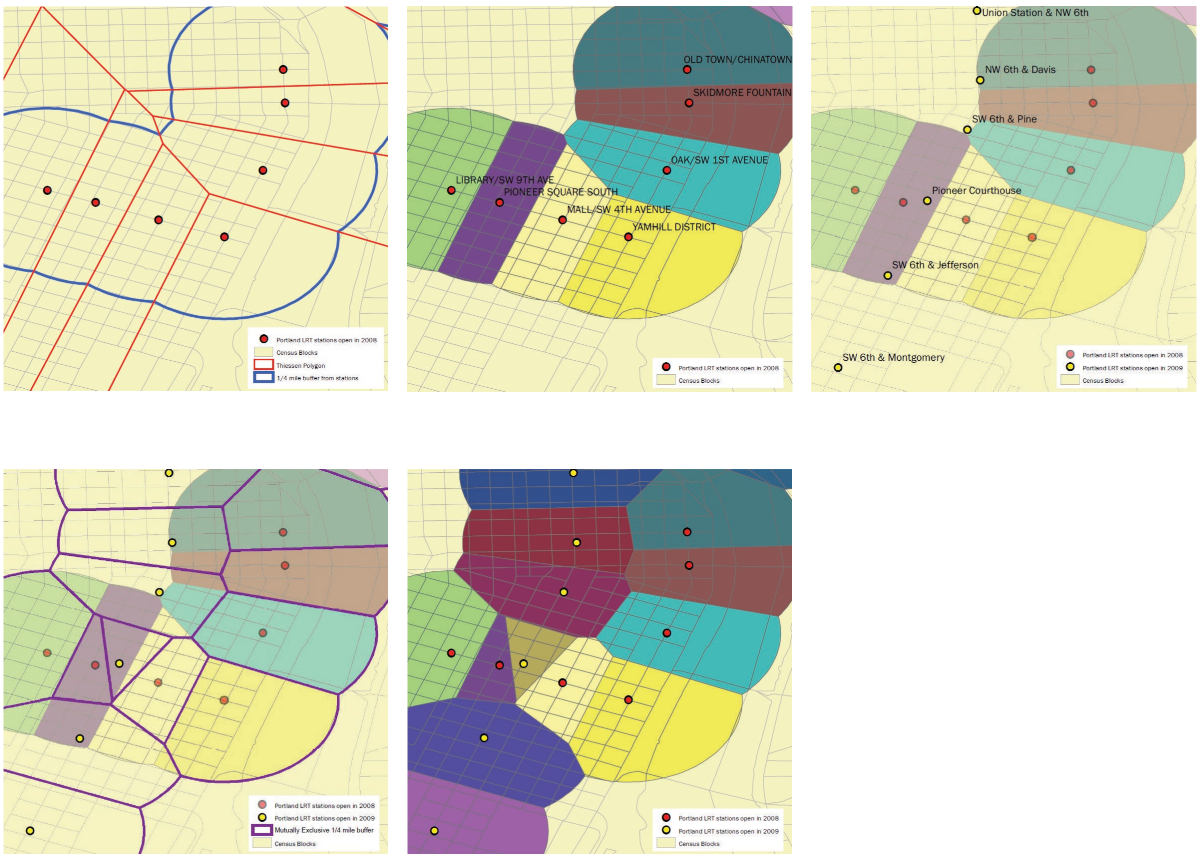
B.2.1 Regional Demographics and Employment

We compiled regional demographic information for the nationwide analysis of metropolitan areas from the U.S. Census 2000 and the 1-Year American Community Survey (2005-2009). We collected ACS data by metropolitan area and census data by county, which we then aggregated to the metropolitan area through either a summation or weighted average. Our selected data included population characteristics (race, median age), housing unit characteristics (occupancy, tenure, median rent and value), economic characteristics (median household income, per capita income, percentage of population below poverty line), and work force characteristics (workers per household, commute mode to work, vehicles per household). We also collected metropolitan-area economic data from the U.S. Bureau of Labor Statistics and the U.S. Bureau of Economic Analysis, including job counts, unemployment figures, personal income levels, and GDP from 2000 through 2009.

B.2.2 Catchment Area Demographics and Employment

To determine the demographic characteristics around each transit project, we created "catchment areas" surrounding each project station and spatially applied to them Census 2000 and LEHD block-level data that fell within the designated area. For our analysis, we aggregated the station catchment area information to the metropolitan level and the project level (Figure B-2).

Figure B-2: Catchment Area Creation Process



The first step in creating catchment measures was to delineate catchment areas spatially. We assigned each station to its respective block/block group using the geographic areas defined by ESRI Census 2000 TIGER/Line Data. Around each station we created straight-line-distance buffers of 0.25, 0.5, and 1 mile for urban rail systems and 0.5, 1, and 3 miles for commuter rail systems. We intersected these buffers with Thiessen polygons constructed around each station to ensure that each station's catchment area was mutually exclusive of the catchment areas around neighboring stations. We then clipped census blocks or block groups to each buffer to create shapefiles representing the portions of each block or block group within the catchment areas. We repeated this process for each year of station data available (2000-2009), since the opening of a new station in a given year sometimes changed the size and shape of the catchment areas.

Once the catchment areas were complete, we assigned Census 2000 block and block group data to each station catchment area, including residential demographics such as age, race, and commute mode/duration and household information such as size, occupancy, tenure, income, and automobile ownership, based on the land area share of each block falling within the buffer. We similarly incorporated LEHD block-level data on job counts by employment location from 2002-2008, broken down by industry and income group.

To incorporate this information, we first calculated the fraction of land area of each block/block group falling within a given catchment area. Some demographic indicators were only available at the block group level. Rather than re-creating catchment areas using block group shapefiles, we aggregated the existing census block catchment area shapefiles up to the block group level. In these cases, the clipped area (within the catchment area) of each block within the block group was added up and then divided by the land area (as reported by the census) of the containing block group. Demographic information was then multiplied by this fraction in a similar fashion.

We assigned census data to a catchment area based on that land area ratio. If an entire block/block group is within the bounds of a catchment area, the land area fraction would be equal to one and the full census count for a given demographic variable would be allocated to that catchment area. If only a portion of a block/block group falls within a catchment area, we applied the land area fraction and allocated only that percentage of the census count to the catchment area. We assigned a non-count census variable (e.g., median age) to a catchment area by taking weighted averages based on the catchment's population size.

Finally, we aggregated the characteristics of each station catchment area up to the regional level for our nationwide analysis of metropolitan areas through either a summation or a calculated average (in some cases weighted by population or households).

B.2.3 Rail Network Measures

Capturing the importance of the layout of the nodes and links of a transit network in determining its success, we created rail network connectivity measures by metropolitan area for all transit projects in our database. We conducted connectivity analyses in each of our metropolitan areas for every year between 2000 and 2010 in order to take into account annual changes in the system due to new line investments in a given year. The output measures are based on graph theory and spatial analysis tools. They quantify different network characteristics, allowing comparisons between networks and within networks over time. More details on the network index calculations are provided in Appendix D. We also utilized GIS to calculate additional network characteristics such as link and node density, network diameter, and nearest neighbor distance.

B.2.4 Job Accessibility Measures

There are two major approaches to analyzing job accessibility achieved through urban transportation networks: gravity-based and opportunity-based (isochrone). We applied a gravity-based measure to each transit station in 25 of our metropolitan areas, using LEHD employment location data and GIS-based network distance calculations between all stations in a transit project, and aggregated the results to the metropolitan area.

Gravity-based job accessibility was measured as follows:

$$ACC_i = \sum_j \frac{E_i \cdot E_j}{f(D_{ij})}$$

where
i is station i,
j is station j in the same metropolitan area,
E_i is the number of employment in the catchment of station i (zones 1, 2, and 3),
E_j is the number of employment in the catchment of station j (zones 1, 2, and 3),
$f(D_{ij})$ is an impedance function (linear, squared, exponential, powered 0.25, 0.50 and 0.75),
zone 1 is 0.25 mi. for urban rail and 0.50 mi. for commuter rail,
zone 2 is 0.50 mi. for urban rail and 1.00 mi. for commuter rail, and
zone 3 is 1.00 mi. for urban rail and 3.00 mi. for commuter rail.

To incorporate roadway-based job accessibility into our analyses we utilized existing data on opportunity-based job accessibility (Cervero and Murakami 2010). We geographically related to our transit station points the access values on nationwide 500-meter-grid-cells (i.e., total basic jobs accessible within 30 minutes through Interstate, freeway, and local arterial systems in 2003) and aggregated to the metropolitan area, weighted by population density.

B.2.5 Auto Cost Measures

To capture the costs of transportation alternatives in a region, in particular the time and monetary costs of the automobile, we compiled data on consumer transportation expenditures, gas prices, parking prices, and congestion.

The U.S. Bureau of Labor Statistics provides broadly categorized information on consumer expenditures for selected Core-Based Statistical Areas (CBSAs) from 2005 to 2009, including a breakdown of transportation expenditure into net outlay for vehicle purchases, gasoline/motor oil, other vehicle expenses, and public transportation.

We compiled measures of the market prices of gas and parking from various sources. First, we purchased average retail gasoline price data from GasBuddy.com for the years 2000-2011, which we aggregated up to the metropolitan area from the county level using a weighted average by Census 2000 population. We also calculated regional fuel cost using the 2009 National Household Travel Survey (NHTS), aggregated from the county to metropolitan level using a weighted average by population.

From Colliers International we gathered data on average city parking prices between 2009 and 2011, and we aggregated those to the metropolitan area by separately averaging “primary” and “secondary” cities within the metropolis. In addition, we purchased parking pricing data from Parking In Motion, Inc. (PIM), which included rate information for almost 10,000 off-street parking lots across the United States. PIM collects these data through a telephone survey of parking facility operators and follow-up field work. The format of the parking lot prices as provided was extremely messy, and we needed to determine one overall parking rate by parsing the information from various time categories such as daily, hourly, early bird, every 30 minutes, first 30 minutes + additional hourly, and daily max, to name a few. Once we assigned a general 8-hour parking rate to each lot, we used the geographic coordinates that were identified for each lot to geographically relate them and their parking rate information to the closest transit station in our database (and the respective investment, where relevant). This allowed us to determine average parking prices within a given catchment area around each station.

We attempted to collect traffic condition data at the corridor level, but the inconsistency of traffic database systems across U.S. cities led us to rely exclusively on two nationwide sources—the Federal Highway Administration’s (FHWA) *Annual Highway Statistics* and the Texas

Transportation Institute's (TTI) *Annual Urban Mobility Report*. For both we reassigned congestion data from UZA to metropolitan area based upon population. *Annual Highway Statistics* (Table HM-72) provided us with average daily vehicle miles-traveled (VMT) per freeway lane mile in 513 UZAs from 1995 through 2008, estimated as thousands of daily vehicle-miles traveled on freeways divided by total estimated freeway lane miles. The *Annual Urban Mobility Report* contains a travel time index, which measures road congestion by comparing travel conditions in the peak period to those in free-flow, in 85 selected UZAs from 1993 to 2009. The traffic conditions measured by FHWA are highly correlated with the travel time index calculated for TTI's 85 selected UZAs.

B.2.6 Other System-Level Predictors

As a measure of station-area walkability, we assigned a Walk Score to each station in our database. Walk Score is a number between 0 and 100 that measures the walkability of any address, from "car-dependent" to "walker's paradise." More walkable neighborhoods are characterized by more amenities (e.g., parks and grocery stores) within walking distance, higher intersection densities and shorter average block lengths. Across the United States our stations cover the full spectrum of possible Walk Scores, from 0 to 100, with a mean Walk Score of 73. For our system-level analysis we calculated the mean Walk Score within each region. Regional Walk Scores range from 29 (Poughkeepsie-Newburgh-Middletown, NY) to 85 (Hagerstown-Martinsburg, MD-WV), and the average regional Walk Score is 66.

To account for physical as well as built environment conditions, we collected from NCDC data on average temperature, sunlight, and precipitation within each region.

We measured regulatory restrictiveness using a 2003 survey of jurisdictions conducted in 2003 by Rolf Pendall (see Pendall 2006). Pendall surveyed more than 1,800 localities, asking about various land use ordinances in place in each jurisdiction, with questions about planning, zoning, expansion potential, housing construction, public facilities, and affordable housing. We selected 12 survey questions and indicated with a dummy variable whether the given regulation was in place for each jurisdiction. To aggregate to the regional level, we calculated the percentage of the surveyed population within each metropolitan area to which the given regulation applied.

B.3 Predictors of Transit Project Success: Project-Level

The project-level analysis utilized many of the same predictors, including some metropolitan area-level variables such as regional population, household, economic, and work force characteristics. We applied the station catchment area spatial analysis described above, but we aggregated the catchment area demographic data by project instead of by metropolitan area. Within the catchment areas we also investigated the effect of average private off-street parking lot prices. We calculated marginal changes in transit network connectivity and complexity as well as gravity-based job accessibility measures for each station and aggregated the results to the project level. We recorded the opening year, the number of stations, and the total route-miles of every project, which we compiled from transit agency websites, urbanrail.net, FTA reports, descriptions and maps on agency websites, and maps provided by the National Transportation Atlas Database (NTAD). We approximated a number of project-level service characteristics, including speed and frequency, using individual transit agency websites, maps, and schedules. Finally, we used federal databases, Google Earth, and transit agency websites to augment data originally collected by Guerra and Cervero (2011) on a project's service features, such as track grade, station park-and-ride spots, and bus connections from stations along line. Track grade for projects not included in their study was found using the FTA Capital Cost Database (Booz Allen Hamilton, Inc. 2005) when possible. In other cases, it was estimated using the ruler tool in Google Earth. Grade transitions were generally counted as not-at-grade. Supplemental data on station park-and-ride spots and bus connections for projects not examined by Guerra and Cervero were estimated using transit agency information on station amenities and bus routes.

B.4 Additional Variables Considered

In addition to the variables listed above, we considered information on numerous other potential measures and predictors of transit project success. A complete summary of our data (collected, tested, and modeled) can be found in Appendix E, including what data we compiled, the geographic level and date range of the data, the sources from which the data came, what data entered into our analysis and its observed effects on ridership and PMT.

APPENDIX C: All Fixed-Guideway Transit Projects in the United States

Note: This appendix is included in order to inform the reader about the fixed-guideway transit projects included in our modeling process. Projects were excluded when key data were unavailable, such as the LEHD data used to estimate employment near stations; data about parking cost in the CBD; and ridership, which we were sometimes unable to procure by station from the relevant transit agency. We also excluded some projects in early stages of our data collection process because capital cost data were not available. The first 55 projects in the table were those used in our ridership model.

State	City	Project Name	Mode	Type	Opening Year	Route-miles	Ridership Model	Reason Excluded
AZ	Phoenix	Metro Light Rail	LRT	Initial	2008	20	YES	
CA	Los Angeles	Long Beach Blue Line	LRT	Initial	1990	45	YES	
CA	Los Angeles	Green Line	LRT	Expansion	1995	20	YES	
CA	Los Angeles	Pasadena Gold Line	LRT	Expansion	2003	14	YES	
CA	Los Angeles	Red Line (Segment 1)	HRT	Expansion	1993	3	YES	
CA	Los Angeles	Red Line (Segment 2)	HRT	Expansion	2000	7	YES	
CA	Los Angeles	Red Line (Segment 3)	HRT	Expansion	1996/1999	7	YES	
CA	Los Angeles	Orange Line	BRT	Expansion	2005	14	YES	
CA	Sacramento	Sacramento Stage I	LRT	Initial	1987	18	YES	
CA	Sacramento	Mather Field Road Extension	LRT	Extension	1998	6	YES	
CA	Sacramento	South Phase 1	LRT	Expansion	2003	6	YES	
CA	Sacramento	Sacramento Folsom Corridor	LRT	Extension	2005	11	YES	
CA	San Diego	Blue Line	LRT	Initial	1981	25	YES	
CA	San Diego	Orange Line	LRT	Expansion	1986	22	YES	
CA	San Diego	Mission Valley East	LRT	Extension	2005	6	YES	
CA	San Francisco	Initial BART	HRT	Initial	1972	72	YES	
CA	San Francisco	BART SFO Extension	HRT	Extension	2003	9	YES	
CA	San Jose	San Jose North Corridor	LRT	Initial	1987	17	YES	
CA	San Jose	Tasman West	LRT	Expansion	1999	8	YES	
CA	San Jose	Tasman East	LRT	Expansion	2001	5	YES	
CA	San Jose	VTA Capitol Segment	LRT	Extension	2004	3	YES	
CA	San Jose	VTA Vasona Segment	LRT	Expansion	2005	5	YES	
CO	Denver	Central Corridor	LRT	Initial	1994	5	YES	
CO	Denver	Denver Southwest Corridor	LRT	Extension	2000	9	YES	
CO	Denver	Denver Southeast (T-	LRT	Expansion	2006	19	YES	

State	City	Project Name	Mode	Type	Opening Year	Route-miles	Ridership Model	Reason Excluded
		REX)						
FL	Miami	Metrorail	HR	Initial	1984	21	YES	
FL	Miami	South Florida Tri-Rail Upgrades	CR	Enhancement	2007	72	YES	
GA	Atlanta	North / South Line	HRT	Expansion	1981	22	YES	
GA	Atlanta	North Line Dunwoody Extension	HRT	Extension	1996	2	YES	
IL	Chicago	O'Hare Extension (Blue Line)	HRT	Extension	1984	8	YES	
IL	Chicago	Orange Line	HRT	Expansion	1993	9	YES	
IL	Chicago	Douglas Branch	HRT	Extension	2005	7	YES	
IL	Chicago	Metra North Central	CR	Expansion	1996	55	YES	
IL	Chicago	Metra Southwest Corridor	CR	Extension	2006	11	YES	
MD	Baltimore	Central Line	LRT	Expansion	1992	23	YES	
MD	Baltimore	Three extensions	LRT	Extension	1997	7	YES	
MD	Baltimore	Baltimore Metro	HRT	Initial	1983	12	YES	
MN	Minneapolis	Hiawatha Corridor	LRT	Initial	2004	12	YES	
NJ	Jersey City	Hudson-Bergen MOS 1 and 2	LRT	Expansion	2003	15	YES	
NJ	Newark	Newark Elizabeth MOS-1	LRT	Expansion	2006	1	YES	
NJ	Trenton	Southern NJ Light Rail Transit System	LRT	Expansion	2004	28	YES	
NY	Buffalo	Buffalo Metro Rail	LRT	Initial	1985	6	YES	
OH	Cleveland	Cleveland Healthline	BRT	Expansion	2008	7	YES	
OR	Eugene	Eugene EmX	BRT	Initial	2007	4	YES	
OR	Portland	Portland MAX Segment I	LRT	Initial	1986	15	YES	
OR	Portland	Portland Westside/Hillsboro MAX	LRT	Extension	1998	18	YES	
OR	Portland	Portland Airport MAX	LRT	Expansion	2001	6	YES	
OR	Portland	Portland Interstate MAX LRT	LRT	Expansion	2004	6	YES	
PA	Philadelphia	SEPTA Frankford Rehabilitation	HRT	Enhancement	2003	5	YES	
TX	Dallas	S&W Oak Cliff and Park Lane	LRT	Extension	1996	20	YES	
TX	Dallas	North Central	LRT	Extension	2002	13	YES	
UT	Salt Lake City	North-South Corridor	LRT	Initial	1999	15	YES	
UT	Salt Lake City	Medical Center Ext.	LRT	Extension	2003	2	YES	
UT	Salt Lake City	University Ext.	LRT	Extension	2003	3	YES	
WA	Seattle	Seattle Central Link	LRT	Initial	2009	14	YES	

State	City	Project Name	Mode	Type	Opening Year	Route-miles	Ridership Model	Reason Excluded
		Light Rail Project						
CA	Los Angeles	MetroLink	CR	Initial	1992		NO	
CA	Los Angeles	MetroLink Riverside Orange County Lines	CR	Expansion	1994		NO	Ridership
CA	Los Angeles	MetroLink Inland Empire Orange County Line	CR	Expansion	1995		NO	Ridership
CA	Los Angeles	MetroLink 91 Line	CR	Expansion	2002		NO	Ridership
CA	San Diego	Sprinter	LRT	Expansion	2008		NO	Ridership
CA	San Diego	Coaster	CR	Expansion	1995		NO	Ridership
CA	San Francisco	Muni J-Church Extension	LRT	Extension	1991		NO	
CA	San Francisco	Muni T-Third Extension	LRT	Expansion	2007		NO	
CA	San Francisco	BART Colma Extension	HRT	Extension	1996		NO	
CA	San Francisco	BART Pittsburgh Bay Point Extension	HRT	Extension	1996		NO	
CA	San Francisco	BART Dublin Pleasanton Extension	HRT	Expansion	1997		NO	
CA	San Jose	Altamont Commuter Express	CR	Expansion	1998		NO	Ridership
CO	Denver	Central Platte Valley	LRT	Expansion	2002		NO	
CT	New Haven	Shoreline East	CR	Expansion	1990		NO	Ridership
DC	Washington DC	Addison (G) Blue Line	HRT	Expansion	1977	4	NO	LEHD
DC	Washington DC	Glenmont (B) red	HRT	Extension	1978	12	NO	LEHD
DC	Washington DC	New Carrollton (D) Orange	HRT	Expansion	1978	12	NO	LEHD
DC	Washington DC	Yellow Line	HRT	Expansion	1983	14	NO	LEHD
DC	Washington DC	Shady Grove (A) red	HRT	Extension	1984	18	NO	LEHD
DC	Washington DC	Vienna (K) Orange	HRT	Extension	1986	12	NO	LEHD
DC	Washington DC	Franconia/Springfield (J/H) Blue Line	HRT	Extension	1997	4	NO	LEHD
DC	Washington DC	Anacostia Outer (F)	HRT	Extension	2001	7	NO	LEHD
DC	Washington DC	U street (E) green	HRT	Expansion	2001	2	NO	LEHD
DC	Washington DC	Largo Metrorail Extension	HRT	Extension	2004	3	NO	LEHD
DC	Washington DC	Virginia Railway Express	CR	Expansion	1992		NO	LEHD
FL	Miami	Tri-Rail	CR	Expansion	1989		NO	LEHD
GA	Atlanta	East-West Line	HRT	Initial	1979		NO	LEHD

State	City	Project Name	Mode	Type	Opening Year	Route-miles	Ridership Model	Reason Excluded
GA	Atlanta	Proctor Creek Branch	HRT	Expansion	1992		NO	LEHD
IL	Chicago	Metra UP West Corridor	CR	Rehab	2009	9	NO	Ridership
IL	Chicago	Green Line Rehabilitation	HRT	Rehab	1996		NO	
MA	Boston	Southwest Corridor	HRT	Expansion	1987	5	NO	LEHD
MA	Boston	MBTA Worcester Line	CR	Extension	1994		NO	LEHD
MA	Boston	MBTA Old Colony Lines	CR	Expansion	1997		NO	LEHD
MA	Boston	MBTA Greenbush Line	CR	Expansion	2007		NO	LEHD
MA	Boston	South Boston Piers - Phase 1	BRT	Expansion	2004		NO	LEHD
MD	Baltimore	Owings Mills Extension	HRT	Extension	1987		NO	
MD	Baltimore	Johns Hopkins Hospital Extension	HRT	Extension	1995		NO	
MN	Minneapolis	Northstar Line	CR	Expansion	2009		NO	Timeframe
MO	St. Louis	MetroLink	LRT	Initial	1993		NO	
MO	St. Louis	St. Louis St. Clair County Extension	LRT	Extension	2001		NO	Parking rate
MO	St. Louis	Cross County Extension	LRT	Extension	2006		NO	
NC	Charlotte	Charlotte South Corridor	LRT	Initial	2007	10	NO	Ridership
NJ	Newark	Hudson-Bergen MOS 1 and 2	LRT	Expansion	2000		NO	Parking
NJ	Newark	Midtown Direct	CR	Upgrade	1996		NO	
NJ	Newark	Montclair Connection	CR	Upgrade	2002		NO	
NM	Albuquerque	New Mexico Rail Runner Express	CR	Initial	2006		NO	
NY	New York	Archer Avenue Line	HRT	Extension	1988		NO	
OR	Portland	Portland Streetcar	LRT	Expansion	2001		NO	Ridership
OR	Portland	Green Line	LRT	Expansion	2009		NO	Timeframe
OR	Portland	WES	CR	Expansion	2009		NO	Timeframe
PA	Philadelphia	Center City Commuter Connection	CR	Upgrade	1984		NO	
PA	Philadelphia	SEPTA Airport Line	CR	Expansion	1985		NO	
PA	Pittsburgh	Light Rail Stage I	LRT	Expansion	1984	16	NO	Ridership
PA	Pittsburgh	Light Rail Stage II	LRT	Expansion	2004	5	NO	Ridership
PA	Pittsburgh	South Busway	BRT	Initial	1977		NO	
PA	Pittsburgh	East Busway	BRT	Expansion	1983		NO	
PA	Pittsburgh	West Busway	BRT	Expansion	2000		NO	
TN	Memphis	Memphis Medical Center	LRT	Expansion	2004		NO	

State	City	Project Name	Mode	Type	Opening Year	Route-miles	Ridership Model	Reason Excluded
TN	Nashville	Music City Star	CR	Initial	2006		NO	
TX	Austin	Capital MetroRail	CR	Initial	2010		NO	Timeframe
TX	Dallas	Northeast Extension	LRT	Extension	2002		NO	
TX	Dallas	Green Line	LRT	Expansion	2009		NO	Timeframe
TX	Dallas	Trinity Railway Express	CR	Expansion	1996		NO	
TX	Dallas	A-Train	CR	Expansion	2011		NO	Timeframe
TX	Houston	Houston METRO	LRT	Initial	2004		NO	
UT	Salt Lake City	Intermodal Hub Extension	LRT	Extension	2008		NO	
UT	Salt Lake City	FrontRunner	CR	Expansion	2008		NO	
WA	Seattle	South Lake Union Streetcar	LRT	Expansion	2007		NO	
WA	Seattle	Sounder Commuter Rail	CR	Initial	2000		NO	
WA	Tacoma	Tacoma Link	LRT	Initial	2003		NO	

APPENDIX D: Network Measures

We calculated and tested measures of network connectivity by metropolitan area for both railway and highway networks, as described below. As noted in the report, we found that these measures tended not to be statistically significant with the inclusion of simpler indicators.

- **Number of Nodes (v)** and **Links (e)**, and **Total Length of a Graph (L(G))**. Links are segments of track or roadway. Nodes are locations where segments meet (e.g., intersections). The term "graph" can be understood to mean "network." Total length is simply the summer linear length of links.
- Diameter (DM or D(d)) is the length of a straight path between the two nodes of a network that are farthest away from each other. (Similarly, the theoretical diameter length can be computed from the actual area of the region [= Pi *(DM/2)2].)
- **Number of Cycles (u),** or the maximum number of "independent cycles" in a graph, is estimated by the number of nodes, links (and sub-graphs, not explained here, which are usually equal to 1) in each metropolitan area. The more complex a network is, the higher the value of u, so the measure can be used as an indicator of the level of development and complexity in a transport system.

$$u = e - v + p$$

Based on the elements above, we computed the following network connectivity indices:

- **Alpha Index** measures connectivity by comparing the number of cycles in a graph with the maximum possible number of cycles. The higher the alpha value, the more connected the network. Trees and simple networks have an alpha value of 0, whereas completely connected networks have an alpha value of 1. The alpha index measures the level of connectivity independent of the number of nodes in the network.

$$\alpha = \frac{\mu}{2v - 5}$$

- **Beta Index** measures connectivity by evaluating the relationship between the number of links and the number of nodes. Trees and simple networks have a beta value of less than 1, connected networks with one cycle have a beta value of 1, and more complex networks have a beta value greater than 1. Complex networks have a high value of beta, as more links equates to more possible paths in the network (assuming fixed number of nodes).

$$\beta = \frac{e}{v}$$

- **Gamma Index** measures connectivity by evaluating the relationship between the number of observed links and the number of possible links. Values of gamma fall between 0 and 1, with a gamma value of 1 indicating a completely connected network. In reality, a gamma value equal to 1 is extremely unlikely. The gamma index is used to efficiently measure the progression of a network over time.

$$\varphi = \frac{e}{3(v-2)}$$

- **Eta Index** measures the average length per link. Adding a new node to a network while maintaining the overall length of a graph will cause a decrease in the eta value.

$$\alpha = \frac{\mu}{2v - 5}$$

- **Diameter Ratio** measures the relationship between the diameter of a graph L(G) and the theoretical diameter of a metropolitan area (Area). A high Diameter Index value reflects a relatively large-size network to the area (closer to or even more than 1); on the other hand, a low value (closer to 0) represent a relatively small-size network to the area.

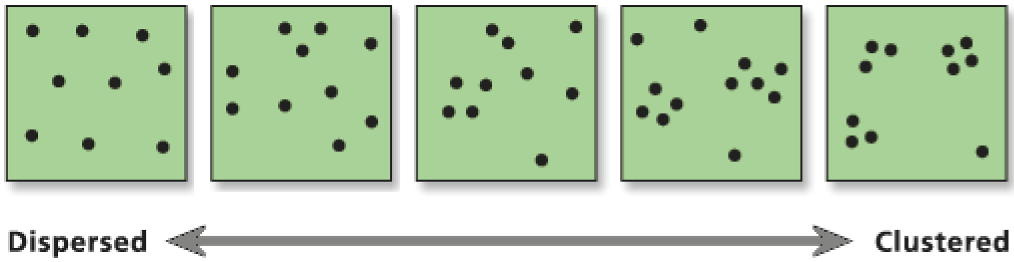
$$\mathrm{DI} = \frac{D(d)}{0.5\times(\frac{Area}{\pi})^{0.5}}$$

- **Pi Index** measures the ratio of the total length of a graph L(G) and the distance along its diameter. The index is labeled Pi because it closely resembles the actual Pi value (3.1415), which expresses the ratio between the circumference and the diameter of a circle. A high pi value reflects a well-developed network, whereas a low pi value (closer to 1) represents a linear corridor.

$$\Pi = \frac{L(G)}{D(d)}$$

We also generated another measure expressing the situation of a node (station) in each regional space (MSA):

- The **Average Nearest Neighbors Distance (NND) Index** measures the ratio of the Observed Mean Distance to the Expected Mean Distance. The expected distance is the average distance between neighbors in a hypothetical random distribution (our calculations are based on Euclidean distance). If the index is less than 1, the pattern exhibits clustering; if the index is greater than 1, the pattern is dispersed. This ratio can be automatically generated using ArcGIS.



Source: ArcGIS 10

APPENDIX E: Variables List

					Metropolitan-Level Models		Project-Level Models		
Indicator	**Geographic Level**	**Date Range**	**Source**	**Indicator**	**Considered**	**Observed Effect**	**Considered**	**Observed Effect (incl. endogenous vars)**	**Observed Effect (excl. endogenous vars)**
Transit Service Characteristics				*Transit Service Characteristics*					
Directional length of new service	Project		various sources	Directional length of new service			X		
Percent of track elevated	Project	2010	FTA Capital Cost Database; Google Earth	Percent of track elevated			X		
Percent of track at grade	Project	2010	FTA Capital Cost Database; Google Earth	Percent of track at grade			X	-0.08	
Percent of track below ground	Project	2010	FTA Capital Cost Database; Google Earth	Percent of track below ground			X		
Percent of track in highway median	Project	2010	FTA Capital Cost Database; Google Earth	Percent of track in highway median			X		
Presence of parking at stations (dummy)	Project	2011-2012	Transit agency websites	Presence of parking at stations (dummy)			X		
Number of park-and-ride spaces	Project	2011-2012	Transit agency websites	Number of park-and-ride spaces			X	0.37	
Frequency of service in morning peak hour	Project	2011-2012	Transit agency websites	Frequency of service in morning peak hour			X		
Average speed of service	Project	2011-2012	Transit agency websites	Average speed of service			X		

					Metropolitan-Level Models		Project-Level Models		
Indicator	**Geographic Level**	**Date Range**	**Source**	**Indicator**	**Considered**	**Observed Effect**	**Considered**	**Observed Effect (incl. endogenous vars)**	**Observed Effect (excl. endogenous vars)**
Number of bus lines that intersect project line	Project	2011-2012	various sources	Number of bus lines that intersect project line			X		
New line (dummy)	Project		various sources	New line (dummy)			X		
Expansion of existing line (dummy)	Project		various sources	Expansion of existing line (dummy)			X		
Enhancement of existing line (dummy)	Project		various sources	Enhancement of existing line (dummy)			X		
Extension to existing line (dummy)	Project		various sources	Extension to existing line (dummy)			X		
Capital cost (millions, 2009 dollars)	Project		Guerra and Cervero, 2011	Capital cost (millions, 2009 dollars)			X		
Received FTA New Starts funding (dummy)	Project	2010	FTA	Received FTA New Starts funding (dummy)			X		
Dollars spent per mile (millions, 2009 dollars)	Project		Guerra and Cervero, 2011	Dollars spent per mile (millions, 2009 dollars)			X		
Opening year	Project		various sources	Opening year			X		
Age	Project		various sources	Age			X	0.14	0.21
Number of stations	Project	2011-2012	various sources	Number of stations			X		
Number of terminals	Project	2011-2012	various sources	Number of terminals			X		
Number of airports served by project line	Project	2011-2012	various sources	Number of airports served by project line			X		
Mode heavy rail transit (dummy)	Project		various sources	Mode heavy rail transit (dummy)			X		
Mode bus rapid transit (dummy)	Project		various sources	Mode bus rapid transit (dummy)			X		
Mode light rail (dummy)	Project		various sources	Mode light rail (dummy)			X		
Transit Network Characteristics				*Transit Network Characteristics*					

					Metropolitan-Level Models		Project-Level Models		
Indicator	**Geographic Level**	**Date Range**	**Source**	**Indicator**	**Considered**	**Observed Effect**	**Considered**	**Observed Effect (incl. endogenous vars)**	**Observed Effect (excl. endogenous vars)**
Number of jobs within 0.5 mi of all fixed-guideway stations in metropolitan area	Region Catchments		LEHD	Number of jobs within 0.5 mi of all fixed-guideway stations in metropolitan area	X		X		
Population within 0.5 mi of all fixed-guideway stations in metropolitan area	Region Catchments		Census 2000	Population within 0.5 mi of all fixed-guideway stations in metropolitan area	X		X		
Directional route-miles of the transit network	Region	2002-2008	NTD	Directional route-miles of the transit network	X		X		
Directional route-miles of heavy rail transit	Region	2002-2008	NTD	Directional route-miles of heavy rail transit	X		X		
Directional route-miles of light rail	Region	2002-2008	NTD	Directional route-miles of light rail	X		X		
Total passenger miles traveled (thousands)	Region	2002-2008	NTD	Total passenger miles traveled (thousands)	X		X		
Network connectivity index a	Region Links	2008	GIS Calculations	Network connectivity index a	X				
Network connectivity index b	Region Links	2008	GIS Calculations	Network connectivity index b	X				
Network connectivity index c	Region Links	2008	GIS Calculations	Network connectivity index c	X				
Network connectivity index g	Region Links	2008	GIS Calculations	Network connectivity index g	X				
Network connectivity index e	Region Links	2008	GIS Calculations	Network connectivity index e	X				
Network connectivity index s	Region Links	2008	GIS Calculations	Network connectivity index s	X				
Network connectivity index p	Region Links	2008	GIS Calculations	Network connectivity index p	X				
Length of all rail links (meters)	Region Links	2008	GIS Calculations	Length of all rail links (meters)	X				
Number of links in the network	Region Links	2008	GIS Calculations	Number of links in the network	X				
Number of nodes	Region Links	2008	GIS Calculations	Number of nodes	X				
Link density (km per square km)	Region Links	2008	GIS Calculations	Link density (km per square km)	X				

					Metropolitan-Level Models		Project-Level Models		
Indicator	**Geographic Level**	**Date Range**	**Source**	**Indicator**	**Considered**	**Observed Effect**	**Considered**	**Observed Effect (incl. endogenous vars)**	**Observed Effect (excl. endogenous vars)**
Node density (number per square km)	Region Links	2008	GIS Calculations	Node density (number per square km)	X				
Diameter of rail network	Region Links	2008	GIS Calculations	Diameter of rail network	X				
Nearest neighborhood distance	Region Links	2008	GIS Calculations	Nearest neighborhood distance	X				
Percent of PMT traveled on bus	Region Links	2002-2008	NTD	Percent of PMT traveled on bus	X				
Station-Area Characteristics				*Station-Area Characteristics*					
Land area within 0.5 mi of project stations	Project Catchments	2008	Census	Land area within 0.5 mi of project stations			X		
Land area within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2008	Census	Land area within 0.5 mi of fixed-guideway stations in metropolitan area	X		X		
Population within 0.5 mi of project stations	Project Catchments	2000	Census	Population within 0.5 mi of project stations			X	0.05	0.04
Population within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2000	Census	Population within 0.5 mi of fixed-guideway stations in metropolitan area	X	-0.87	X		
White population within 0.5 mi of project stations	Project Catchments	2000	Census	White population within 0.5 mi of project stations			X		
White population within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2000	Census	White population within 0.5 mi of fixed-guideway stations in metropolitan area	X		X		
Latino population within 0.5 mi of project stations	Project Catchments	2000	Census	Latino population within 0.5 mi of project stations			X		
Latino population within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2000	Census	Latino population within 0.5 mi of fixed-guideway stations in metropolitan area	X		X		
Median age within 0.5 mi of project stations	Project Catchments	2000	Census	Median age within 0.5 mi of project stations			X		

Indicator	Geographic Level	Date Range	Source	Indicator	Metropolitan-Level Models: Considered	Metropolitan-Level Models: Observed Effect	Project-Level Models: Considered	Project-Level Models: Observed Effect (incl. endogenous vars)	Project-Level Models: Observed Effect (excl. endogenous vars)
Median age within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2000	Census	Median age within 0.5 mi of fixed-guideway stations in metropolitan area			X		
Number of residents under 18 within 0.5 mi of project stations	Project Catchments	2000	Census	Number of residents under 18 within 0.5 mi of project stations			X		
Number of residents under 18 within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2000	Census	Number of residents under 18 within 0.5 mi of fixed-guideway stations in metropolitan area	X		X		
Number of residents over 65 within 0.5 mi of project stations	Project Catchments	2000	Census	Number of residents over 65 within 0.5 mi of project stations			X		
Number of residents over 65 within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2000	Census	Number of residents over 65 within 0.5 mi of fixed-guideway stations in metropolitan area	X		X		
Number of housing units within 0.5 mi of project stations	Project Catchments	2000	Census	Number of housing units within 0.5 mi of project stations			X		
Number of housing units within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2000	Census	Number of housing units within 0.5 mi of fixed-guideway stations in metropolitan area	X		X		
Number of occupied housing units within 0.5 mi of project stations	Project Catchments	2000	Census	Number of occupied housing units within 0.5 mi of project stations			X		
Number of occupied housing units within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2000	Census	Number of occupied housing units within 0.5 mi of fixed-guideway stations in metropolitan area	X		X		
Number of vacant housing units within 0.5 mi of project stations	Project Catchments	2000	Census	Number of vacant housing units within 0.5 mi of project stations			X		

					Metropolitan-Level Models		Project-Level Models		
Indicator	Geographic Level	Date Range	Source	Indicator	Considered	Observed Effect	Considered	Observed Effect (incl. endogenous vars)	Observed Effect (excl. endogenous vars)
Number of vacant housing units within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2000	Census	Number of vacant housing units within 0.5 mi of fixed-guideway stations in metropolitan area	X		X		
Number of owner-occupied housing units within 0.5 mi of project stations	Project Catchments	2000	Census	Number of owner-occupied housing units within 0.5 mi of project stations			X		
Number of owner-occupied housing units within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2000	Census	Number of owner-occupied housing units within 0.5 mi of fixed-guideway stations in metropolitan area	X		X		
Number of renter-occupied housing units within 0.5 mi of project stations	Project Catchments	2000	Census	Number of renter-occupied housing units within 0.5 mi of project stations			X		
Number of renter-occupied housing units within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2000	Census	Number of renter-occupied housing units within 0.5 mi of fixed-guideway stations in metropolitan area	X		X		
Number of one-person households within 0.5 mi of project stations	Project Catchments	2000	Census	Number of one-person households within 0.5 mi of project stations			X		
Number of four-person households within 0.5 mi of project stations	Project Catchments	2000	Census	Number of four-person households within 0.5 mi of project stations			X		
Number of seven-person households within 0.5 mi of project stations	Project Catchments	2000	Census	Number of seven-person households within 0.5 mi of project stations			X		
Number of households with no vehicles within 0.25 mi of project stations	Project Catchments	2000	Census	Number of households with no vehicles within 0.25 mi of project stations			X		

					Metropolitan-Level Models		Project-Level Models		
Indicator	**Geographic Level**	**Date Range**	**Source**	**Indicator**	**Considered**	**Observed Effect**	**Considered**	**Observed Effect (incl. endogenous vars)**	**Observed Effect (excl. endogenous vars)**
Number of households with one vehicle within 0.25 mi of project stations	Project Catchments	2000	Census	Number of households with one vehicle within 0.25 mi of project stations			X		
Number of households with two vehicles within 0.25 mi of project stations	Project Catchments	2000	Census	Number of households with two vehicles within 0.25 mi of project stations			X		
Number of households with three vehicles within 0.25 mi of project stations	Project Catchments	2000	Census	Number of households with three vehicles within 0.25 mi of project stations			X		
Number of households with four vehicles within 0.25 mi of project stations	Project Catchments	2000	Census	Number of households with four vehicles within 0.25 mi of project stations			X		
Number of households with five+ vehicles within 0.25 mi of project stations	Project Catchments	2000	Census	Number of households with five+ vehicles within 0.25 mi of project stations			X		
Number of jobs within 0.5 mi of project stations	Project Catchments	2002-2008	LEHD	Number of jobs within 0.5 mi of project stations			X	0.18	0.21
Number of jobs within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Number of jobs within 0.5 mi of fixed-guideway stations in metropolitan area	X	-0.67	X		
Percent of metropolitan-area jobs that fall within 0.5 mi of fixed-guideway stations	Region Catchments	2002-2008	LEHD	Percent of metropolitan-area jobs that fall within 0.5 mi of fixed-guideway stations	X				
Number of workers under 30 within 0.5 mi of project stations	Project Catchments	2008	LEHD	Number of workers under 30 within 0.5 mi of project stations			X		

Indicator	Geographic Level	Date Range	Source	Indicator	Metropolitan-Level Models: Considered	Metropolitan-Level Models: Observed Effect	Project-Level Models: Considered	Project-Level Models: Observed Effect (incl. endogenous vars)	Project-Level Models: Observed Effect (excl. endogenous vars)
Number of workers under 30 within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Number of workers under 30 within 0.5 mi of fixed-guideway stations in metropolitan area	X		X		
Number of workers aged 30-54 within 0.5 mi of project stations	Project Catchments	2008	LEHD	Number of workers aged 30-54 within 0.5 mi of project stations			X		
Number of workers over 54 within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Number of workers over 54 within 0.5 mi of fixed-guideway stations in metropolitan area	X				
Number of jobs paying less than $1250 per month within 0.25 mi of project stations	Project Catchments	2008	LEHD	Number of jobs paying less than $1250 per month within 0.25 mi of project stations			X		
Number of jobs paying less than $1250 per month within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Number of jobs paying less than $1250 per month within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Number of jobs paying more than $1250 and less than $3333 per month within 0.25 mi of project stations	Project Catchments	2008	LEHD	Number of jobs paying more than $1250 and less than $3333 per month within 0.25 mi of project stations			X		
Number of jobs earning more than $3333 per month (higher wage jobs) within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Number of jobs earning more than $3333 per month (higher wage jobs) within 0.5 mi of fixed-guideway stations in metropolitan area	X	0.44			
Agriculture, Forestry, Fishing and Hunting jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Agriculture, Forestry, Fishing and Hunting jobs within 0.25 mi of project stations			X		

					Metropolitan-Level Models		Project-Level Models		
Indicator	**Geographic Level**	**Date Range**	**Source**	**Indicator**	**Considered**	**Observed Effect**	**Considered**	**Observed Effect (incl. endogenous vars)**	**Observed Effect (excl. endogenous vars)**
Agriculture, Forestry, Fishing and Hunting jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Agriculture, Forestry, Fishing and Hunting jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Mining, Quarrying and Oil and Gas Extraction jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Mining, Quarrying and Oil and Gas Extraction jobs within 0.25 mi of project stations			X		
Mining, Quarrying and Oil and Gas Extraction jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Mining, Quarrying and Oil and Gas Extraction jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Utilities jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Utilities jobs within 0.25 mi of project stations			X		
Utilities jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Utilities jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Construction jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Construction jobs within 0.25 mi of project stations			X		
Construction jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Construction jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Manufacturing jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Manufacturing jobs within 0.25 mi of project stations			X		
Manufacturing jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Manufacturing jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Wholesale Trade jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Wholesale Trade jobs within 0.25 mi of project stations			X		

Indicator	Geographic Level	Date Range	Source	Indicator	Metropolitan-Level Models: Considered	Metropolitan-Level Models: Observed Effect	Project-Level Models: Considered	Project-Level Models: Observed Effect (incl. endogenous vars)	Project-Level Models: Observed Effect (excl. endogenous vars)
Wholesale Trade jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Wholesale Trade jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Retail Trade jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Retail Trade jobs within 0.25 mi of project stations			X		
Retail Trade jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Retail Trade jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Transportation and Warehousing jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Transportation and Warehousing jobs within 0.25 mi of project stations			X		
Transportation and Warehousing jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Transportation and Warehousing jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Information jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Information jobs within 0.25 mi of project stations			X		
Information jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Information jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Finance and Insurance jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Finance and Insurance jobs within 0.25 mi of project stations			X		
Finance and Insurance jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Finance and Insurance jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Real Estate and Rental and Leasing jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Real Estate and Rental and Leasing jobs within 0.25 mi of project stations			X		

					Metropolitan-Level Models		Project-Level Models		
Indicator	Geographic Level	Date Range	Source	Indicator	Considered	Observed Effect	Considered	Observed Effect (incl. endogenous vars)	Observed Effect (excl. endogenous vars)
Real Estate and Rental and Leasing jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Real Estate and Rental and Leasing jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Professional, Scientific and Technical Services jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Professional, Scientific and Technical Services jobs within 0.25 mi of project stations			X		
Professional, Scientific and Technical Services jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Professional, Scientific and Technical Services jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Management of Companies and Enterprises jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Management of Companies and Enterprises jobs within 0.25 mi of project stations			X		
Management of Companies and Enterprises jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Management of Companies and Enterprises jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Administrative and Support and Waste Management and Remediation Services jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Administrative and Support and Waste Management and Remediation Services jobs within 0.25 mi of project stations			X		
Administrative and Support and Waste Management and Remediation Services jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Administrative and Support and Waste Management and Remediation Services jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		

					Metropolitan-Level Models		Project-Level Models		
Indicator	Geographic Level	Date Range	Source	Indicator	Considered	Observed Effect	Considered	Observed Effect (incl. endogenous vars)	Observed Effect (excl. endogenous vars)
Educational Services jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Educational Services jobs within 0.25 mi of project stations			X		
Educational Services jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Educational Services jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Health Care and Social Assistance jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Health Care and Social Assistance jobs within 0.25 mi of project stations			X		
Health Care and Social Assistance jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Health Care and Social Assistance jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Arts, Entertainment and Recreation jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Arts, Entertainment and Recreation jobs within 0.25 mi of project stations			X		
Arts, Entertainment and Recreation jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Arts, Entertainment and Recreation jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Accommodation and Food Services jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Accommodation and Food Services jobs within 0.25 mi of project stations			X		
Accommodation and Food Services jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Accommodation and Food Services jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Other Services (except Public Administration) jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Other Services (except Public Administration) jobs within 0.25 mi of project stations			X		

					Metropolitan-Level Models		Project-Level Models		
Indicator	**Geographic Level**	**Date Range**	**Source**	**Indicator**	**Considered**	**Observed Effect**	**Considered**	**Observed Effect (incl. endogenous vars)**	**Observed Effect (excl. endogenous vars)**
Other Services (except Public Administration) jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Other Services (except Public Administration) jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Public Administration jobs within 0.25 mi of project stations	Project Catchments	2008	LEHD	Public Administration jobs within 0.25 mi of project stations			X		
Public Administration jobs within 0.25 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Public Administration jobs within 0.25 mi of fixed-guideway stations in metropolitan area	X		X		
Retail, entertainment and food jobs (attraction-based) within 0.5 mi of fixed-guideway stations in metropolitan area	Region Catchments	2002-2008	LEHD	Retail, entertainment and food jobs (attraction-based) within 0.5 mi of fixed-guideway stations in metropolitan area	X	0.68			
Gravity-based job accessibility measure: linear, 0.25 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: linear, 0.25 mi catchment			X		
Gravity-based job accessibility measure: linear, 0.5 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: linear, 0.5 mi catchment			X		
Gravity-based job accessibility measure: linear, 1 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: linear, 1 mi catchment			X		
Gravity-based job accessibility measure: exponential, 0.25 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: exponential, 0.25 mi catchment			X		

					Metropolitan-Level Models		Project-Level Models		
Indicator	**Geographic Level**	**Date Range**	**Source**	**Indicator**	**Considered**	**Observed Effect**	**Considered**	**Observed Effect (incl. endogenous vars)**	**Observed Effect (excl. endogenous vars)**
Gravity-based job accessibility measure: exponential, 0.5 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: exponential, 0.5 mi catchment			X		
Gravity-based job accessibility measure: exponential, 1 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: exponential, 1 mi catchment			X		
Gravity-based job accessibility measure: 0.25 power law, 0.25 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: 0.25 power law, 0.25 mi catchment			X		
Gravity-based job accessibility measure: 0.25 power law, 0.5 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: 0.25 power law, 0.5 mi catchment			X		
Gravity-based job accessibility measure: 0.25 power law, 1 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: 0.25 power law, 1 mi catchment			X		
Gravity-based job accessibility measure: 0.5 power law, 0.25 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: 0.5 power law, 0.25 mi catchment			X		
Gravity-based job accessibility measure: 0.5 power law, 0.5 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: 0.5 power law, 0.5 mi catchment			X		
Gravity-based job accessibility measure: 0.5 power law, 1 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: 0.5 power law, 1 mi catchment			X		
Gravity-based job accessibility measure: 0.75 power law, 0.25 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: 0.75 power law, 0.25 mi catchment			X		
Gravity-based job accessibility measure: 0.75 power law, 0.5 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: 0.75 power law, 0.5 mi catchment			X		

					Metropolitan-Level Models		Project-Level Models		
Indicator	Geographic Level	Date Range	Source	Indicator	Considered	Observed Effect	Considered	Observed Effect (incl. endogenous vars)	Observed Effect (excl. endogenous vars)
Gravity-based job accessibility measure: 0.75 power law, 1 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: 0.75 power law, 1 mi catchment			X		
Gravity-based job accessibility measure: 2 power law, 0.25 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: 2 power law, 0.25 mi catchment			X		
Gravity-based job accessibility measure: 2 power law, 0.5 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: 2 power law, 0.5 mi catchment			X		
Gravity-based job accessibility measure: 2 power law, 1 mi catchment	Region Catchments	2008	GIS and LEHD	Gravity-based job accessibility measure: 2 power law, 1 mi catchment			X		
Interaction of jobs and population within 0.5 mi of all project stations with daily parking rates in the CBD	Project Catchments		Census, LEHD and Parking In Motion	Interaction of jobs and population within 0.5 mi of all project stations with daily parking rates in the CBD			X	0.39	0.659
Interaction of jobs and population within 0.5 mi of all fixed-guideway stations in metropolitan area with average daily traffic per fwy lane mile	Region Catchments		Census, LEHD and FHWA	Interaction of jobs and population within 0.5 mi of all fixed-guideway stations in metropolitan area with average daily traffic per fwy lane mile	X	0.57			
Metropolitan Area Characteristics				*Metropolitan Area Characteristics*					
Population of metropolitan area	Region	2002-2008	BEA	Population of metropolitan area	X	0.12	X		
Total income of metropolitan area	Region	2002-2008	BEA	Total income of metropolitan area	X				

					Metropolitan-Level Models		Project-Level Models		
Indicator	**Geographic Level**	**Date Range**	**Source**	**Indicator**	**Considered**	**Observed Effect**	**Considered**	**Observed Effect (incl. endogenous vars)**	**Observed Effect (excl. endogenous vars)**
Per capita income of metropolitan area	Region	2002-2008	BEA	Per capita income of metropolitan area	X				
Population growth rate of metropolitan area	Region	2002-2008	BEA	Population growth rate of metropolitan area	X				
Real GDP of metropolitan area	Region	2002-2008	BEA	Real GDP of metropolitan area	X				
Per capita real GDP of metropolitan area	Region	2002-2008	BEA	Per capita real GDP of metropolitan area	X				
Percent white residents in metropolitan area	Region	2000	Census	Percent white residents in metropolitan area	X				
Percent Hispanic residents in metropolitan area	Region	2000	Census	Percent Hispanic residents in metropolitan area	X				
Percent residents under 18 in metropolitan area	Region	2000	Census	Percent residents under 18 in metropolitan area	X				
Percent residents over 65 in metropolitan area	Region	2000	Census	Percent residents over 65 in metropolitan area	X				
Percent residents enrolled at undergraduate university in metropolitan area	Region	2000	Census	Percent residents enrolled at undergraduate university in metropolitan area	X				
Percent residents that immigrated since 2000 in metropolitan area	Region	2000	Census	Percent residents that immigrated since 2000 in metropolitan area	X				
Number of commuters who commute by motorcycle in metropolitan area	Region	2000	Census	Number of commuters who commute by motorcycle in metropolitan area	X				
Number of jobs in metropolitan area	Region	2002-2008	BEA	Number of jobs in metropolitan area	X		X		
Population-weighted average congestion of metropolitan area	Region	2002-2008	TTI	Population-weighted average congestion of metropolitan area	X		X		
Average daily VMT per freeway lane mile in metropolitan area	Region	2002-2008	FHWA	Average daily VMT per freeway lane mile in metropolitan area	X	-0.03			

					Metropolitan-Level Models		Project-Level Models		
Indicator	**Geographic Level**	**Date Range**	**Source**	**Indicator**	**Considered**	**Observed Effect**	**Considered**	**Observed Effect (incl. endogenous vars)**	**Observed Effect (excl. endogenous vars)**
Share of jurisdictions covered with a comprehensive plan in metropolitan area	Region	2003	Pendall et al.	Share of jurisdictions covered with a comprehensive plan in metropolitan area	X		X		
Share of jurisdictions subject to zoning ordinances in metropolitan area	Region	2003	Pendall et al.	Share of jurisdictions subject to zoning ordinances in metropolitan area	X		X		
Share of jurisdictions subject to low-density-only zoning in metropolitan area	Region	2003	Pendall et al.	Share of jurisdictions subject to low-density-only zoning in metropolitan area	X		X		
Share of jurisdictions subject to high-density allowed zoning in metropolitan area	Region	2003	Pendall et al.	Share of jurisdictions subject to high-density allowed zoning in metropolitan area	X		X		
Share of jurisdictions that employ growth management tools in metropolitan area	Region	2003	Pendall et al.	Share of jurisdictions that employ growth management tools in metropolitan area	X		X		
Share of jurisdictions with building moratoria in metropolitan area	Region	2003	Pendall et al.	Share of jurisdictions with building moratoria in metropolitan area	X		X		
Share of jurisdictions with an Adequate Public Facilities ordinance in metropolitan area	Region	2003	Pendall et al.	Share of jurisdictions with an Adequate Public Facilities ordinance in metropolitan area	X		X		
Share of jurisdictions with an Affordable Housing density bonus in metropolitan area	Region	2003	Pendall et al.	Share of jurisdictions with an Affordable Housing density bonus in metropolitan area	X		X		
Share of jurisdictions with affordable housing inclusionary zoning in metropolitan area	Region	2003	Pendall et al.	Share of jurisdictions with affordable housing inclusionary zoning in metropolitan area	X		X		

					Metropolitan-Level Models		Project-Level Models		
Indicator	Geographic Level	Date Range	Source	Indicator	Considered	Observed Effect	Considered	Observed Effect (incl. endogenous vars)	Observed Effect (excl. endogenous vars)
Share of jurisdictions where the allowable density was reduced since 1994 in metropolitan area	Region	2003	Pendall et al.	Share of jurisdictions where the allowable density was reduced since 1994 in metropolitan area	X		X		
Share of jurisdictions where the allowable density was increased since 1994 in metropolitan area	Region	2003	Pendall et al.	Share of jurisdictions where the allowable density was increased since 1994 in metropolitan area	X		X		
Share of jurisdictions with building or population growth restrictions in metropolitan area	Region	2003	Pendall et al.	Share of jurisdictions with building or population growth restrictions in metropolitan area	X		X		
Average annual precipitation (inches) of metropolitan area	Region	2012	NCDC	Average annual precipitation (inches) of metropolitan area	X		X		
Percent of possible sunlight in metropolitan area	Region	2012	NCDC	Percent of possible sunlight in metropolitan area	X		X		
Average temperature of metropolitan area	Region	2012	NCDC	Average temperature of metropolitan area	X		X		
Average number of days per year with highs over 90°F in metropolitan area	Region	2012	NCDC	Average number of days per year with highs over 90°F in metropolitan area	X		X		
Average number of days per year with lows below 32°F in metropolitan area	Region	2012	NCDC	Average number of days per year with lows below 32°F in metropolitan area	X		X		
Average snowfall per year (inches) in metropolitan area	Region	2012	NCDC	Average snowfall per year (inches) in metropolitan area	X		X		
Daily parking rate within 0.5 mi of project stations	Project Catchments	2011	Parking In Motion	Daily parking rate within 0.5 mi of project stations			X		

					Metropolitan-Level Models		Project-Level Models		
Indicator	**Geographic Level**	**Date Range**	**Source**	**Indicator**	**Considered**	**Observed Effect**	**Considered**	**Observed Effect (incl. endogenous vars)**	**Observed Effect (excl. endogenous vars)**
Daily parking rate in the CBD	Region	2011	Parking In Motion	Daily parking rate in the CBD			X	-0.07	-0.08
Maximum hourly parking rate	Region	2009	Colliers International	Maximum hourly parking rate			X		
Maximum parking rate for 12 hrs	Region	2009	Colliers International	Maximum parking rate for 12 hrs			X		
Maximum parking rate for 24 hrs	Region	2009	Colliers International	Maximum parking rate for 24 hrs			X		
Maximum monthly parking rate (r)	Region	2009	Colliers International	Maximum monthly parking rate (r)			X		
Maximum monthly parking rate (u)	Region	2009	Colliers International	Maximum monthly parking rate (u)			X		
Average gas price within counties within the metropolitan area	Region	2009	NHTS	Average gas price within counties within the metropolitan area	X				
Population-weighted average gas price within counties within the metropolitan area	Region	2009	NHTS	Population-weighted average gas price within counties within the metropolitan area	X				
Average distance to the CBD of project stations	Project	2008	GIS	Average distance to the CBD of project stations			X		
Average Walk Score at all station locations within project	Project	2012	Walk Score	Average Walk Score at all station locations within project			X		
Average Walk Score at all station locations in metropolitan area	Region	2012	Walk Score	Average Walk Score at all station locations in metropolitan area	X		X		

APPENDIX F: Fixed-Guideway Projects Included in Analysis

State	City	Project Name	Mode	Type	Opening Year	Route-miles	Avg Daily Wkdy Ridership	Capital Cost (M$2009)	Station-Area Employment	Station-Area Population	Daily CBD Parking
AZ	Phoenix	Metro Light Rail	LRT	Initial	2008	20	40,772	1,231	187,816	74,135	5
CA	Los Angeles	Long Beach Blue Line	LRT	Initial	1990	45	79,349	1,658	185,178	180,511	15
CA	Los Angeles	Green Line	LRT	Expansion	1995	20	30,935	1,225	66,818	74,088	15
CA	Los Angeles	Pasadena Gold Line	LRT	Expansion	2003	14	23,681	1,022	102,982	105,065	15
CA	Los Angeles	Red Line (Segment 1)	HRT	Expansion	1993	3	26,073	2,566	136,311	48,170	15
CA	Los Angeles	Red Line (Segment 2)	HRT	Expansion	1996	7	45,410	2,891	70,634	174,905	15
CA	Los Angeles	Red Line (Segment 3)	HRT	Expansion	1999	7	30,138	1,733	25,292	28,817	15
CA	Los Angeles	Orange Line	BRT	Expansion	2005	14	21,940	371	46,107	83,112	15
CA	Sacramento	Sacramento Stage I	LRT	Initial	1985	18	31,071	360	63,851	42,573	12
CA	Sacramento	Mather Field Road Extension	LRT	Extension	1998	6	6,711	44	7,599	18,996	12
CA	Sacramento	South Phase 1	LRT	Expansion	2003	6	9,877	225	9,559	27,610	12
CA	Sacramento	Sacramento Folsom Corridor	LRT	Extension	2004	11	6,587	274	40,202	15,579	12
CA	San Diego	Blue Line	LRT	Initial	1981	25	41,361	986	187,905	93,665	16
CA	San Diego	Orange Line	LRT	Expansion	1986	22	23,113	633	38,798	81,575	16
CA	San Diego	Mission Valley East	LRT	Extension	2005	6	4,203	521	10,650	18,710	16
CA	San Francisco	Initial BART	HRT	Initial	1974	72	284,162	6,960	311,300	269,182	30
CA	San Francisco	BART SFO Extension	HRT	Extension	2003	9	19,501	1,598	27,877	14,065	30
CA	San Jose	San Jose North Corridor	LRT	Initial	1987	17	11,272	757	100,999	56,579	14

State	City	Project Name	Mode	Type	Opening Year	Route-miles	Avg Daily Wkdy Ridership	Capital Cost (M$2009)	Station-Area Employment	Station-Area Population	Daily CBD Parking
CA	San Jose	Tasman West	LRT	Expansion	1999	8	1,977	416	38,728	15,101	14
CA	San Jose	Tasman East	LRT	Expansion	2001	5	3,340	335	17,452	20,494	14
CA	San Jose	VTA Capitol Segment	LRT	Extension	2004	3	2,385	205	4,819	29,645	14
CA	San Jose	VTA Vasona Segment	LRT	Expansion	2005	5	3,848	374	29,902	38,766	14
CO	Denver	Central Corridor	LRT	Initial	1994	5	36,403	161	96,104	25,269	13
CO	Denver	Denver Southwest Corridor	LRT	Extension	1999	9	8,728	228	16,780	9,893	13
CO	Denver	Denver Southeast (T-REX)	LRT	Expansion	2006	19	16,298	876	86,349	26,811	13
FL	Miami	Metrorail	HRT	Initial	1984	21	58,121	2,366	146,439	109,235	9
FL	Miami	South Florida Tri-Rail Upgrades	CR	Enhancement	2007	72	36,510	394	76,384	52,405	9
GA	Atlanta	North / South Line	HRT	Expansion	1985	22	113,948	3,194	176,597	47,472	7
GA	Atlanta	North Line Dunwoody Extension	HRT	Extension	1996	2	9,381	611	16,327	4,253	7
IL	Chicago	O'Hare Extension (Blue Line)	HRT	Extension	1984	8	21,350	469	30,026	10,811	29
IL	Chicago	Orange Line	HRT	Expansion	1993	9	32,334	778	20,176	65,718	29
IL	Chicago	Douglas Branch	HRT	Extension	2005	7	16,035	503	28,652	115,554	29
IL	Chicago	Metra North Central	CR	Expansion	1996	55	2,201	247	23,971	34,463	29
IL	Chicago	Metra Southwest Corridor	CR	Extension	2006	11	4,125	211	14,978	35,312	29
MD	Baltimore	Central Line	LRT	Expansion	1992	23	24,541	531	106,966	62,984	14
MD	Baltimore	Three extensions	LRT	Extension	1997	7	4,448	140	35,891	15,304	14
MD	Baltimore	Baltimore Metro	HRT	Initial	1985	12	39,023	2,040	72,145	59,848	14
MN	Minneapolis	Hiawatha Corridor	LRT	Initial	2004	12	30,518	454	167,692	42,224	11
NJ	Jersey City	Hudson-Bergen MOS 1 and 2	LRT	Expansion	2003	15	40,100	1,809	88,742	211,414	38
NJ	Newark	Newark Elizabeth MOS-1	LRT	Expansion	2006	1	1,065	214	16,108	19,599	38
NJ	Trenton	Southern NJ Light Rail Transit System	LRT	Expansion	2002	28	8,150	1,166	24,910	64,862	24
NY	Buffalo	Buffalo Metro Rail	LRT	Initial	1984	6	24,076	951	65,298	45,417	7
OH	Cleveland	Cleveland Healthline	BRT	Expansion	2008	7	12,850	197	114,837	32,797	12
OR	Eugene	Eugene EmX	BRT	Initial	2007	4	6,600	26	27,994	17,128	4

State	City	Project Name	Mode	Type	Opening Year	Route-miles	Avg Daily Wkdy Ridership	Capital Cost (M$2009)	Station-Area Employment	Station-Area Population	Daily CBD Parking
OR	Portland	Portland MAX Segment I	LRT	Initial	1986	15	60,229	508	116,225	63,679	9
OR	Portland	Portland Westside/Hillsboro MAX	LRT	Extension	1996	18	34,223	1,320	64,900	54,053	9
OR	Portland	Portland Airport MAX	LRT	Expansion	2001	6	3,005	156	5,319	3,108	9
OR	Portland	Portland Interstate MAX LRT	LRT	Expansion	2004	6	7,992	333	16,343	18,279	9
PA	Philadelphia	SEPTA Frankford Rehabilitation	HRT	Enhancement	2005	5	45,103	1,186	24,336	110,510	24
TX	Dallas	S&W Oak Cliff and Park Lane	LRT	Extension	1997	20	46,713	1,137	145,557	68,864	6
TX	Dallas	North Central	LRT	Extension	2002	13	12,304	450	57,228	20,750	6
UT	Salt Lake City	North-South Corridor	LRT	Initial	1998	15	31,405	412	74,476	27,619	12
UT	Salt Lake City	Medical Center Ext.	LRT	Extension	2003	2	3,358	87	22,057	1,709	12
UT	Salt Lake City	University Ext.	LRT	Extension	2001	3	7,285	111	17,532	15,945	12
WA	Seattle	Seattle Central Link Light Rail Project	LRT	Initial	2006	14	19,719	2,583	161,394	61,817	22

APPENDIX G: Model Technical Information

The project-level ridership models were executed in Stata using the regress command. The coefficients were estimated using ordinary least squares and robust errors to account for clustering across metropolitan areas. The system-level PMT models were executed in Stata using the xtreg command with metropolitan-area ID as the cluster-level variable and maximum likelihood parameter estimation. A comprehensive guide to implementing panel regressions in Stata is *Multilevel and Longitudinal Modeling Using Stata* by Sophia Rabe-Hesketh and Anders Skrondal (2nd Edition, Stata Press, College Station TX, 2005). To compare the goodness-of-fit between multiple models, we employed the Bayesian Information Criterion (BIC) post-estimation statistic. BIC is a penalized goodness-of-fit measure that approximates the probability that a model is most likely given the data (Washington, Karlaftis & Mannering 2011, p. 400). Generally BIC values closer to zero are associated with better models, and we used this value to iteratively compare pairs of models with different forms.

APPENDIX H: Focus Groups, Phase 2, Topic Responses

The sections below provide more detail on responses to the following questions:

- Would a spreadsheet tool as proposed be useful to you? In what circumstances might you use it?
- Who would be the audience for the model outputs?
- What sorts of outputs would be most helpful for you?
- How hard would it be for you to generate the input data needed to apply the tool?
- What improvements can be made to the tool's input and output interfaces?
- How can we make the handbook most useful to practitioners?

Question: Would a spreadsheet tool as proposed be useful to you? In what circumstances might you use it? Who would be the audience for the model outputs?

Participants in the focus group at the APTA Rail Conference agreed that the tool would be useful for a quick evaluation of corridors and/or new transit lines that are often suggested by transit agency board members and the public. It would demonstrate to board members and citizens where their ideas fall, in terms of ridership and cost per rider, compared to national examples. The tool would show some communities whether or not the rail transit they want has potential merit. It could also be used for scenario testing, such as testing changes in land use and parking policy, changes in land use, and changes in alignment and station locations. Regional prioritization of potential corridors was also mentioned as a potential use. Participants in the Houston–Galveston Area Council (HGAC) focus group and the telephone interviews had a similar reaction with regard to the spreadsheet's utility for quickly comparing scenarios.

Those attending the focus group held with staff at the San Francisco Bay Area Metropolitan Transportation Commission (MTC) thought that the spreadsheet tool might be of use by some of the transit agencies and local jurisdictions in the Bay Area. They noted that project sponsors generally do these sorts of analyses before presenting projects to MTC. As far as the MTC itself is concerned, however, the sense was that they would continue to use the regional model for planning analyses. Their impression was that the spreadsheet tool would not save much time, and they would have less confidence in the reliability of the results. It was agreed that the tool is not a substitute for a good regional model.

One of the MTC participants asked why a regression framework had been used, which he said does not capture how people behave when they travel and does not offer insights into the potential competitiveness of other modes. He wondered what the outputs of the model tell the user, i.e., what the user learns that can be acted upon.

The telephone interviewees found utility in the spreadsheet tool, however. One interviewee, from a smaller transit agency, thought that the tool could be useful for prioritizing corridors and for conversations with local governments about station-area development plans/policies. A second small transit agency interviewee called the tool “just what we need.” Another interviewee, from a large MPO, saw utility for scenario planning and noted that the regional model could not be used for everything.

These responses suggest that some agencies may find the outputs helpful while others may not.

Question: What sorts of outputs would be most helpful for you?

Participants in the APTA Rail focus group suggested several additional histograms or bar charts allowing users to compare proposed projects with others in the database. In addition to cost per rider, it was suggested that users be able to compare projects in terms of the number of riders per mile. They would like to be able to turn off and on bars in the chart so comparisons can be made with similar projects (e.g., compare with other starter lines, same mode, peer cities, etc.). Participants would like to be able to add all their existing lines and highlight them in the histogram, so that new projects could be compared to existing lines within the same urban area. Both focus group participants and telephone interviewees said that users would also like to be able to save scenario results so that they can easily compare one scenario with another.

Question: How hard would it be for you to generate the input data needed to apply the tool?

Participants in the focus groups and telephone interviews noted that assembling the station-area population and employment data using GIS was somewhat demanding, but expressed no significant concerns other than the time required. Most planning agencies are thought to have the necessary capability. One MPO interviewee stated that agencies should be “doing this anyway” to evaluate alternative projects and corridors. At the MTC focus group, one participant suggested that the tool would be easier to use if population and employment data were embedded into the database. Users would still have to create their own buffers around stations, but the base data would be there.

The focus group at the APTA Rail Conference pointed out that some entries on the input screen use terms that have different meanings in the transit industry. The input screen should ask for end-to-end travel time, rather than speed, because speed is often interpreted as average top speed between stations. The meaning of “bus connections” needs to be spelled out—is it the number of bus routes or number of buses? The meaning of “route-miles” needs to be made explicit.

A participant in the MTC focus group cautioned that some smaller MPOs do not have the capability to use macros in Excel.

Question: What improvements can be made to the tool’s input and output interfaces?

One of the telephone interviewees from a small transit agency suggested that, in addition to reporting out ridership and cost per rider, the tool might identify those inputs which were most favorable to ridership and those where the project could be strengthened. The user would then know where to focus efforts to enhance a project’s likelihood of success.

It was also suggested by the HGAC focus group that a help function be added to the tool. For example, users might like to be able to click on the inputs on the input screen to get a pop-up box with definitions or instructions.

Question: How can we make the handbook most useful to practitioners?

The HGAC focus group said that their confidence in the tool's results would be greater if the handbook explained the inner workings of the spreadsheet tool and how it was validated. This might include a comparison between what the tool might have predicted for completed projects, compared with the actual ridership. Noting that there were likely to be outliers in the data, one might question the tool's reliability for particular cases. They suggested that the handbook express appropriate caveats on the use of results.

Similarly, an interviewee urged that the handbook explain the inner workings of the spreadsheet sufficiently that users could explain it to elected officials and other interested parties.

There was also discussion, in the HGAC and MTC focus groups, of putting the handbook and spreadsheet tool online for ease of access. A participant in the MTC group urged us to make the tool fun and easy to use, like a game. He pointed the research team to a Transit Competitiveness Index tool prepared for MTC's Sustainability Study, and specifically to that tool's graphical interface, that made the application fun to use. Similarly, a telephone interviewee referred the research team to a user-friendly tool on Portland Metro's website that allows users to test a variety of transit scenarios and make trade-offs.

Some participants believed that the method would be useful for an initial evaluation of potential transit projects, helping prioritize alternatives, providing a means for scenario testing, and demonstrating to the community the implications of different options. Comments were offered on additional capabilities that would make the tool more useful, including improved visualization of the tool's outputs in the form of charts and tables. Overall, participants expressed no significant concerns about the difficulty of generating the input data for the tool, aside from time required. Many requested that the handbook provide clear and detailed information on the underlying mechanisms of the spreadsheet tool in order to feel more confident about the validity of its results and to better explain the tool's outcomes to interested parties.

APPENDIX I: Detailed Case Study Write-Ups and Regional Profiles

I.1 South Line (Charlotte, NC)

The South Line, now called the LYNX Blue Line, is a 9.6-mile, 15-station light rail project extending south from Uptown Charlotte (the city's central business district) to Interstate 485 in southern Mecklenburg County near the South Carolina State border. The facility, completed in 2007, generally parallels North-South Interstate 77 and serves considerable commuter traffic accessing the 80,000 jobs located in Charlotte's CBD. This case study suggests that transit planning can be driven by land use aspirations as well as transit criteria. Additionally, the case demonstrates the complex balancing act that occurs as planners seek to achieve multiple goals, as well as the detrimental sacrifices that can occur in an attempt to maximize a single measure of success. This case study highlights the art of transit planning as opposed to the engineering and quantitative rigor often associated with major transportation projects.

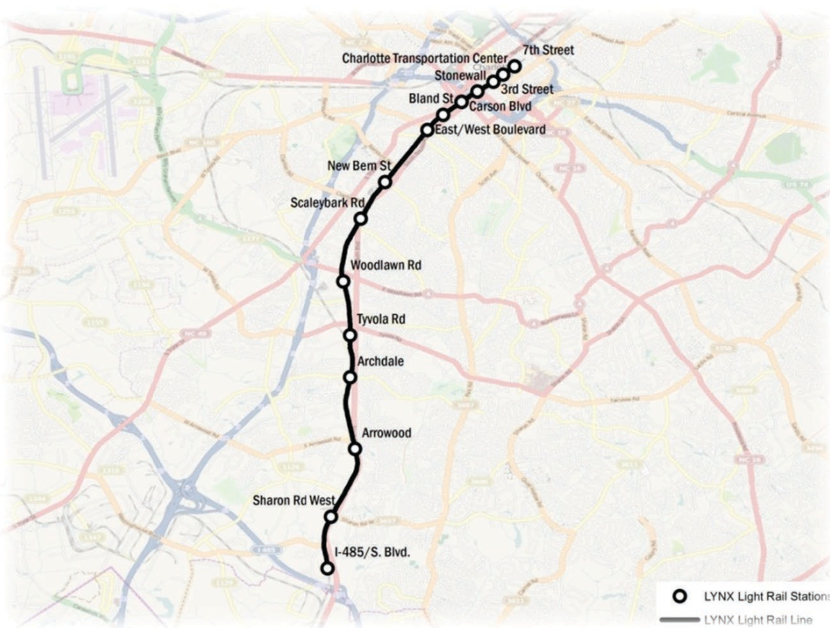


Figure I-1: Route Diagram for LYNX Blue Line, Charlotte, North Carolina

I.1.1 Establishing Charlotte Rail Transit

Rail transit planning was initiated in Charlotte in the 1980s and culminated in the *Transit Corridor System Planning Study* of 1989 (FTA and CATS 2002). By 1994, the *Charlotte Transitional Analysis* had identified rail transit corridors that would support the region's overall *Centers and Corridors Concept Plan,* which identified five radial corridors of dense urban development with wedges of low-density single-family housing in between. In 1998, Mecklenburg County residents voted for a half-cent sales tax measure that was dedicated to implementing the region's *2025: Integrated Transportation and Land Use Plan* (FTA and CATS 2003).

In 1997, before citizens approved the transit tax, the city purchased a 3.3-mile segment of abandoned Norfolk Southern Railroad right-of-way south of Uptown Charlotte and began operating a historic trolley over just a few miles of the tracks between downtown and several emerging pockets of redeveloped warehouses.[1] After passage of the 1998 tax measure, planning began for light rail transit along a much longer segment of that same Norfolk Southern Railroad right-of-way and culminated with the *South Corridor Major Investment Study* in 2000 (FTA and CATS 2002). The FTA approved the South Corridor LRT project for preliminary engineering in August 2000, and a Record of Decision on the project's environmental documentation was issued in May 2003 (FTA NSFA 2005).

On May 6, 2005, the FTA entered into a Full-Funding Grant Agreement (FFGA) providing a federal commitment of $192.94 million in New Starts funds. The total project cost under the Full-Funding Grant Agreement (FFGA) was $426.85 million, with the majority of funds coming from state and local sources (FTA SCLRT 2005). In addition to and separate from the project budget, the City of Charlotte provided $72 million in complementary infrastructure improvements as part of the South Corridor Infrastructure Program (SCIP) (CATS 2012). The South Corridor project, called the LYNX Blue Line, opened for revenue service in November 2007.

The South Corridor's northern terminus is at the intermodal Charlotte Transportation Center (CTC) in the heart of Uptown Charlotte, which houses approximately 80,000 jobs and 15,000 residents.[2] Major central city destinations include Charlotte's convention center and two major league sports arenas. The route heads south from there through the mixed-use South End neighborhood and parallels South Boulevard (NC 521) and I-77 until it reaches its terminus at a park-and-ride station near Interstate 485, roughly three miles from the South Carolina border.

The South Corridor was the first rail corridor to be built among several rail corridors envisioned for the Charlotte region. The decision to construct this line before others provided us with useful insight into indicators that have been used to predict transit project success. Based on a high-level assessment of right-of-way availability, constraints on parallel regional travel network segments, and opportunities to promote regional agglomeration, the South Corridor was prioritized over others.

Notably, there was very little debate about the selection of this alignment and few alternatives were seriously considered. In one circumstance, the City of Pineville was originally imagined as the rail line's terminus south of Interstate 485, but the rail line proposal was truncated when the city's council declined rail transit. While their decision was politically divisive and represented one of the few times that the Charlotte region's political bodies were not united behind the centers and corridors vision, the shorter line was considered by many to be a benefit for transit operations and capital costs that made the project more attractive for federal funding.[3]

---

[1] Interviewee AR, telephone conversation, 5/18/12.
[2] Charlotte Center City Partners; http://www.charlottecentercity.org; Accessed 10/22/12.
[3] Interviewee AS, in-person conversation, 8/30/12.

I.1.2 South Line Operations

Though the South Corridor remains the only operating rail transit segment in Charlotte, a $1.2 billion extension of the South Corridor recently received federal funding and will double the extent of the rail system upon opening in 2017 (Spanberg 2012). The rail system is complemented by Charlotte Area Transit System's (CATS') extensive bus operations. At the time the South Corridor was planned, CATS operations were divided between express, local, and cross-town bus services (CATS 2012). Local and express bus services had typically terminated downtown at the Charlotte Transportation Center (CTC). When the South Corridor opened, many routes of the regional bus system were reoriented to serve as rail feeder services. Additionally, the sales tax funding used for the South Corridor helped expanded bus services throughout the region. As of 2012, 28% of rail riders also boarded buses during their trips.

CATS rail services are branded distinctly from bus services. LYNX rail service along the South Corridor is called the Blue Line and operates seven days a week (weekdays 5:20 am to 2 am, Saturday 5:45 am to 1:56 am, Sunday 6:25 am to 12:26 am).[4] During peak hours in the peak direction, headways are as low as 10 minutes. Generally, service is offered at 15-minute headways, with 20-minute headways later in the evening.

In its first few months of operation, the Blue Line averaged between 12,000 and 17,000 weekday riders (CATS 2012). Ridership grew steadily, peaking at 21,700 in the fourth quarter of 2008.[5] However, in the years since then ridership dropped to a consistent average weekday estimate of approximately 15,000 boardings (CATS 2012). Fluctuations in ridership were attributed to the 2008 peak in gas prices and bus service cuts due to declining sales tax receipts during the recession. Nearly 80% of ridership emanates from origin locations within the defined South Corridor study area, and over half of all trips are to and from downtown Charlotte.

Actual ridership in 2009 exceeded the projected 2010 ridership estimates by approximately 2,800 trips. This is attributed to the fact that transportation models underestimated the number of riders that would travel long distances to ride the line for relatively short rail trips (CATS 2012). Interestingly, transit agency staff had anticipated this travel pattern based on parking costs to access government buildings and special event venues in the Uptown area.[6]

I.1.3 Planning a Successful Transit Project

Close collaboration of local agencies led to a transit project that epitomizes transportation and land use coordination.[7] The South Corridor project was planned by a consortium of Charlotte-Mecklenburg County agencies. CATS is the builder and operator of the line as well as an agency of the consolidated city-county local government. As such, it is part of the same organization as the Charlotte Department of Transportation (CDOT) and the Charlotte-Mecklenburg Planning Department (Planning), two other significant players in the planning and implementation of the South Corridor transit project.[8] In addition, planning of the line was strongly influenced by the Federal Transit Administration, which provided nearly half of the funding for the project. As discussed below, several interviewees suggested that federal measures of transit project success led

---

[4] Lynx Service; http://charmeck.org/city/charlotte/cats/Pages/default.aspx; Accessed 10/22/12.
[5] APTA; http://www.apta.com/resources/statistics/Documents/Ridership/2008_q4_ridership_APTA.pdf; Accessed 7/20/12.
[6] Interviewee AS, in-person conversation, 8/30/12.
[7] Interviewee AT, telephone conversation, 8/27/12.
[8] Interviewee AR, telephone conversation, 5/18/12.

to decisions that undermined the quality of the South Corridor and contributed to its costly retrofit as the Blue Line is extended to northeast Charlotte.

The selection of the South Corridor as Charlotte's first rail investment over the four other corridor options identified in the *Centers and Corridors Concept Plan* could be interpreted as a choice that optimally met the diverse interests of three stakeholder local departments—CDOT, CATS, and Planning—by addressing traffic concerns, selecting a viable route from a cost perspective, and aiding land use change. As several interviewees shared with me on separate occasions, the Charlotte City Council selected the South Corridor in the 1990s for three primary reasons: the corridor was parallel to heavily congested Interstate 77 in the fastest growing corridor in the region; the corridor coincided with available Norfolk Southern right-of-way; and there was tremendous potential for redevelopment along the corridor that was fitting with the region's long-range land use vision.[9,10,11,12,13]

During the 1990s, the second-largest U.S. banking center established itself in Charlotte's downtown, one of the fastest growing cities in the nation in one of the nation's fastest growing regions at the time (FTA and CATS 2003). Much of the region's housing and commercial development in the 1980s and 1990s occurred between the Interstate 77 corridor and the Independence Boulevard corridor, which proceeds radially southeast out of downtown Charlotte.[14] High-end shopping malls were expanded in the quadrant, high-end housing was built within the belt loop, and sprawl continued to spread further south in South Carolina. Freeways north of Charlotte had not yet been expanded and growth had not yet occurred there. As one transit professional put it, "There was momentum to the south."

With growth came congestion. Though touted as providing a transport alternative for transit-dependent populations, in many ways the South Corridor project was framed in community meetings as a release valve for growing traffic as more and more households moved to northern South Carolina and workers commuted to downtown Charlotte.[15] The major transportation infrastructure within the area was at its maximum physical capacity.[16] In South Carolina and just inside the North Carolina border, Interstate 77 was an eight-lane roadway. Within the Interstate 495 beltway, urban development and bridge bottlenecking constrained the expansion of the Interstate to six lanes. There were few alternate radial routes into the city, and gridlock was common on the Interstate.

One of the possible alternate routes was the South Boulevard radial arterial that paralleled Interstate 77. South Boulevard extended from central Charlotte to the Interstate 485 belt loop and was four lanes with vehicle volumes exceeding 65,000 along much of its length.[17] Paralleling the corridor was a Norfolk Southern Railroad right-of-way, part of which was disused and part of which was a limited-use spur to access a handful of industrial sites. The remainder of the railroad right-of-way, paralleling the southern reaches of South Boulevard before crossing south of Interstate 495, was a fully operational Norfolk Southern mainline.

---

[9] Interviewee AD, telephone conversation, 8/24/12.
[10] Interviewee AN, in-person conversation, 8/30/12.
[11] Interviewee AS, in-person conversation, 8/30/12.
[12] Interviewee AT, telephone conversation, 8/27/12.
[13] Interviewee AR, telephone conversation, 5/18/12.
[14] Interviewee AD, telephone conversation, 8/24/12.
[15] Interviewee AU, in-person conversation, 8/30/12.
[16] Interviewee AD, telephone conversation, 8/24/12.
[17] Interviewee AT, telephone conversation, 8/27/12.

In 1997, the City of Charlotte purchased 3.3 miles of disused rail property to preserve for future transit use.[18] In 1998, the city council allocated $16.7 million to build along it a two-mile trolley line from Uptown Charlotte to Charlotte's Historic South End.[19] It was intended to accommodate vintage trolley services and serve as a capital "down payment" on eventual light rail transit services.

The Charlotte Trolley operation was embraced by the community and delineated a clear path forward for expanded rail services. One city planner suggested that, "It was a Disney-like ride but it got the imagination going, and property owners were very enthusiastic about expanding the transit operations."[20] When it came time to grow Charlotte's transit system, the planner thought "we had a clear and obvious location for the route along an abandoned freight rail right-of-way. It was a fairly simple decision-making process."

The congested Interstate 77 corridor and available right-of-way coincided with Charlotte's overall regional development vision. As one transit planner noted, "The driver that started the Charlotte Transit program was really the community's vision for how they wanted to develop as a city."[21] As a land use planner explained, "We had planted the seed of rapid transit in the early to mid-1980s"[22] The regional vision was enumerated in the '2025: Integrated Transportation and Land Use Plan'.

Generally, the idea of the plan was to concentrate the majority of future regional growth into five radial corridors. Per a transit professional, "The idea was to [use the] transit system to help create an environment for higher density, pedestrian-friendly, mixed-use, so-called transit-oriented or transit-supportive land use."[23] This smart growth strategy would allow for growth while minimizing traffic impacts and maintaining the suburban single-family neighborhoods that defined much of Charlotte. Regional discussions were focused on providing options to a diverse population with diverse interests, so that the region could remain competitive in the long term.[24]

According to public sector staff, the community was very much in favor of the holistic transportation and land use vision for the South Corridor. When discussing the importance of affirming the regional vision before advocating for a particular transportation project, one planner stated that "we didn't sell the South Corridor, we sold a system."[25] The South Corridor was considered an obvious place to begin implementation. As evidence of the consensus on this matter, one City of Charlotte staffer noted that after numerous public meetings they received approximately five comments on the South Corridor's draft environmental statement and only one comment on the final.[26] Additionally, a 2007 measure to repeal the county's transit sales tax was soundly defeated by voters just weeks before the South Corridor opened for revenue service.[27]

Consensus was also sought within government. In discussing land use planning that occurred alongside the project, a planner reminisced about their refrain during the South Corridor planning process: "Transit isn't the end, it's the means for us to accomplish this new community that we're trying to build."[28] As another transit planner noted, "We had these joint collaborative meetings and

---

[18] Interviewee AS, in-person conversation, 8/30/12.
[19] Charlotte Trolley; http://www.charlottetrolley.org; Accessed 11/2/12.

[20] Interviewee AR, Telephone conversation, 5/18/12.
[21] Interviewee AT, telephone conversation, 8/27/12.
[22] Interviewee AN, in-person conversation, 8/30/12.
[23] Interviewee AD, telephone conversation, 8/24/12.
[24] Interviewee AN, in-person conversation, 8/30/12.
[25] Interviewee AN, in-person conversation, 8/30/12.
[26] Interviewee AT, telephone conversation, 8/27/12.
[27] Interviewee AV, in-person conversation, 8/30/12.
[28] Interviewee AN, in-person conversation, 8/30/12.

we did things which I think are pretty unique for transit agencies. We met [with the other departments] and talked about where we wanted the parking lots. Not just, 'Where's the demand [for parking] going to be?'"[29]

Transit professionals were also at the forefront of the land use conversation. As one transit veteran explained, "One of the things that always concerned me about our plan here in Charlotte was its fit with the size of the downtown population." [30] Reflecting the research of Pushkarev and Zupan, the veteran went on to say, "We were talking about 55,000-60,000 jobs in the downtown area on a daily basis and that worried me. I always had that in mind that we needed to have at least 100,000 jobs to support five corridors of rapid transit. I had a lot of discussion with the downtown business interest about attracting additional major employers for the downtown area." Also a reflection of the Pushkarev and Zupan research, transit planners referenced land use plans when refining station locations. As one transit planner recalled telling a land use planner, "Land has to be [planned to] a certain intensity for us to consider a station there."[31]

The selection of the South Corridor over one of the other four corridors was partly predicated on localized economic development potential. As one planner described the selection process, "There was so much more momentum, in terms of fulfilling and achieving truly transit-oriented development. I think that corridor had a lot more momentum behind it from the development community, from property owners, from [our interpretation of] where we could be successful. And I don't think there were many of the other corridors that were as [well] positioned as the South Corridor was." [32] Also, several property-owning constituents who had been proponents of the trolley alignment had promised to invest in the South Corridor.[33] As the planner described it, "We also had some grassroots folks who were in what's now called South End who were strong advocates for a pedestrian-friendly type of development, either with rapid transit or not. […] So I think we had to head south."

The design of the South Corridor project was also based on local real estate development potential. A transit planner explained, "The emphasis for locating the stations was almost more development first, access second. Where did it make sense from a […] development perspective and the land use perspective to have stations, and then how can we provide access to those locations?"[34] Based on this set of criteria, the original proposal for the project included 19 stations. As a land use planner explained, "The stations were considered beads on a chain, and they moved up and down as we considered the walkability of areas and other factors."[35] The interviewee went on to say, "There was political pressure to have more stations closer together. Every property owner wants to be right at the station and not farther away."

Transit planners worked with land use planners to eliminate some proposed stations to improve transit efficiency. As a transit planner explained, "I didn't want to have a street car—a light rail running on a street car line, if you will—with stations every couple of blocks." Transit planners added grade separations, shifted station locations, and balanced the operational requirements of light rail with the land use intentions of the region and local land use planners.

[29] Interviewee AW, in-person conversation, 8/30/12.
[30] Interviewee AD, telephone conversation, 8/24/12.
[31] Interviewee AR, telephone conversation, 5/18/12.
[32] Interviewee AN, in-person conversation, 8/30/12.
[33] Interviewee AN, in-person conversation, 8/30/12.
[34] Interviewee AT, telephone conversation, 8/27/12.
[35] Interviewee AR, telephone conversation, 5/18/12.

The entire alignment was even shifted off the existing right-of-way in one circumstance to accommodate real estate development near a proposed station. Scallybark station and several hundred yards of track were located in the median of South Boulevard to provide access to land that was considered ripe for development by urban planners. The original Norfolk Southern Railroad tracks had been slightly elevated on a berm at the edge of South Boulevard, blocking access to several undeveloped acres. To promote transit-oriented development, "We took out the berm and made the land accessible to the major thoroughfare and a rail station."[36]

As an alignment option that addressed regional traffic concerns, had an existing right-of-way adequate for light rail transit services, and aided land use change, the South Corridor was the obvious choice for a rail project in Charlotte. In fact, there were no serious alternatives officially considered. One alternative in the Draft Environmental Impact Statement (DEIS) considered an extension of the light rail alignment to Pineville south of Interstate 485 but the northern portions of the proposal were nearly identical to what was ultimately built (FTA and CATS 2002). While some of the earliest studies included 19 stations, most station locations were initially aligned with major East-West arterials and were never significantly altered (CATS 2012). Other alternatives in the final environmental documents included a no-build alternative and a "Transportation Systems Management" option that included enhanced bus services on South Boulevard (FTA and CATS 2003). Interviewees repeatedly suggested that there was consensus about the South Corridor alignment's design and that the locally preferred transit alignment was an obvious solution. As one planner put it, "I really think it was by accident that all the planets aligned for us to move forward with the South Corridor."[37]

In spite of the consensus around the South Corridor's selection and light rail proposal, some problems did arise because the success metrics used to define, select, and design the South Corridor were not synonymous with the federal funding criteria. Interviewees in Charlotte suggested that prioritizing one measure of success over others, as was the case with the federal New Starts funding criteria during the George W. Bush administration, was not a valid means of evaluating success. As one transit professional framed it, "There's an art associated with making these projects happen."[38] In fact, they considered the FTA's focus on a single quantitative measure detrimental to the project's success.

Economic development, walkability, and sustainability were strong considerations in Charlotte but were not highly regarded by the Federal Transit Administration at that time. "That stuff was important to us locally but wasn't important to those people who were evaluating whether or not they wanted to invest a couple of hundred million dollars in the construction of this project."[39] Federal funding evaluations included a ridership-based cost-effectiveness hurdle regardless of the other benefits of the project.

Charlotte, with its focus on changing the way the region developed, did not meet the cost-effectiveness hurdle in early evaluations. Modifications for the sake of cost savings were required. Planners could lower costs by increasing proposed train frequencies and thereby reducing the number of train cars that needed to be purchased, running two-car operations rather than three-car train sets.[40] This allowed them to correspondingly reduce platform lengths, power system units, and

[36] Interviewee AD, telephone conversation, 8/24/12.
[37] Interviewee AN, in-person conversation, 8/30/12.
[38] Interviewee AD, telephone conversation, 8/24/12.
[39] Interviewee AD, telephone conversation, 8/24/12.
[40] Interviewee AT, telephone conversation, 8/27/12.

track ballast quality. As one planner put it, "We ended up coming up with a [plan] that justified the project according to their cost-effectiveness criteria and travel time savings."[41] One land use planner suggested that Charlotte was doing whatever it took to get their first line and get the system plan off the drawing boards.[42]

Today, demand exceeds the two-car train sets that are operated on the line, and the extension of the Blue Line to northeast Charlotte will further increase that demand. With considerable inconvenience and at great expense, CATS is currently retrofitting the existing South Line to accommodate three-car trains. The FTA's singular focus on cost effectiveness led to short-sighted decision-making that complicated matters in the future.

In addition to considering the federal cost-effectiveness criteria and the three measures of success enumerated above—alleviation of traffic, viable completion, and beneficial land use impacts — Charlotte interviewees noted two other measures of success they considered during the planning of the South Corridor. First, they sought to make the corridor safer. Prior to the implementation of the line, pedestrians were subjected to hostile environments along South Boulevard and its cross streets. The project and attendant land use changes were planned to address some of these concerns.[43] Second, there had been a number of fatalities resulting from collisions between freight rail traffic and automobiles crossing the railroad tracks.[44] Roadway intersection conditions that had caused traffic to sometimes back up across the tracks were addressed with South Boulevard intersection improvements. Also, the light rail line was elevated over several arterials to reduce dangerous interactions with high-volume roadways. From the standpoint of project planners, the light rail project had to improve safety conditions on the corridor to be successful.

Additionally, transit project stakeholders sought to design a project that could successfully launch the region's overall transit system implementation.[45] The South Corridor line was selected because it had the greatest chance of success and would provide local political momentum for further investment. Inadvertently, the project also paved the way for the region's second project, the northeast extension of the South Line, by setting a precedent with the North Carolina Department of Transportation (NCDOT). South Boulevard was also the North Carolina state highway NC 521, and the shift of the Scallybark station to the median of South Boulevard was the first implementation of light rail on a NCDOT facility.[46] Numerous issues had to be addressed on that short segment of shared road space, including the city taking responsibility for maintenance along that section of roadway. As one planner explained, "With the state being able to see that it does work, our next project is going to be in a U.S. route for the majority of it. If we hadn't done that, we might have a lot stiffer opposition to move ahead in the next project."[47]

In addition to the numerous measures of success considered by South Corridor stakeholders, Charlotte planners also mentioned several qualitative "rules of thumb" that they considered when predicting the potential success of the LYNX Blue Line. The most often mentioned of these were threshold indicators of political support that suggested to planners that the project would actually be implemented. One planner recalled how he evaluated a job offer to join the transit planning team during the early stages of the project and made his decisions based on three project champions: the

[41] Interviewee AD, telephone conversation, 8/24/12.
[42] Interviewee AN, in-person conversation, 8/30/12.
[43] Interviewee AV, in-person conversation, 8/30/12.
[44] Interviewee AT, telephone conversation, 8/27/12
[45] Interviewee AS, in-person conversation, 8/30/12
[46] Interviewee AU, in-person conversation, 8/30/12
[47] Interviewee AU, in-person conversation, 8/30/12

mayor, a county commissioner, and the new chief executive of the transit agency.[48] The mayor and county commissioner were from different political parties and took turns touting the project depending on the audience at their joint appearances.[49] The mayor's focus was making sure the project was "driven by data, technical information, [and] the ability to really build our community. [He asked], "where's the need, where's the economic development potential, where's the best ridership?""[50] To implement the transit system expansion, the city hired the then Chair of the American Public Transportation Association. This was a clear sign that the project leadership was skilled and politically savvy.[51]

Additionally, the team leading the rail system planning had considered how attractive each of Charlotte's proposed rail corridors would be to the North Carolina congressional delegation that would be relied upon to advocate for the project.[52] Coming out of the '2025 Plan' process, they decided to pursue the South Corridor because it would have the support of several members of the South Carolina congressional delegation as well.

Planners also thought that building the region's first line to the South Carolina border was an indicator of ridership potential. Fast-growing South Carolina suburbs represented a major origin of transit trips and served as one end of a "barbell," with the South Corridor's northern terminus in downtown as the other end.[53] Initially, the southern end of the transit line's "barbell" was intended to be the local mall in fast-growing Pineville.[54] However, it was determined that a parking garage near Interstate 485 would serve as a much larger ridership generator because it could attract patrons from Pineville as well as other southern suburbs.

Another indicator of ridership noted by project planners was the expansion of bus services and the realignment of bus routes that coincided with the start of Blue Line revenue service.[55] For instance, several long haul bus routes were converted into multiple rail feeder bus routes. Planners considered this an access extension for bus service that allowed buses to reach further into neighborhoods that had only been served at the periphery prior to rail.

Rising downtown parking costs also served as an indicator of potential ridership.[56] Park-and-ride license plate surveys have borne this out. A measureable portion of riders drove from east and west Charlotte to ride the train north into downtown. Parking lot owners in downtown have also confirmed a decline in demand at their facilities.

The South Corridor case study suggests that transit project planners consider a wide array of success indicators to predict performance across a number of measures. Those measures may be more related to indirect transit outcomes like land use impacts than to direct measures of success like ridership. This case study suggests that transit planning is a complex art that uses both qualitative indicators and quantitative forecasts to balance a number of expectations for a single fixed-guideway transit project.

---

[48] Interviewee AT, telephone conversation, 8/27/12
[49] Interviewee AS, in-person conversation, 8/30/12
[50] Interviewee AN, in-person conversation, 8/30/12
[51] Interviewee AT, telephone conversation, 8/27/12
[52] Interviewee AS, in-person conversation, 8/30/12
[53] Interviewee AS, in-person conversation, 8/30/12
[54] Interviewee AR, in-person conversation, 8/30/12
[55] Interviewee AS, in-person conversation, 8/30/12
[56] Interviewee AV, in-person conversation, 8/30/12

I.2 North Central Corridor (Dallas, TX)

The North Central Corridor, completed in 2002, is a rail extension of the original DART light rail starter system that opened in 1996. The 13.8-mile Red Line extension was located in a former Southern Pacific rail corridor paralleling North-South United States Highway 75, known locally as the North Central Expressway. The light rail corridor passes through the cities of Dallas and Richardson, terminating in the City of Plano. The project consists of nine new stations and the reconstruction of Park Lane Station, the former terminus of the Red Line.

This North Central Corridor case study suggests that rail transit may be implemented as a release valve in highly congested, auto-oriented locations. For the North Central Corridor, the transit planning process focused on automobile congestion on parallel routes, park-and-ride stalls, and other auto-related criteria. Predictors of choice riders were a keen focus for planners, because only through their mode choice shift would the project achieve its traffic mitigation intent. While the project ultimately failed to meet its ridership targets, the project was still considered a success according to a number of alternative measures. Most fundamental, several of the alternative measures relate to the fact that a regional rail project was actually completed in this auto-oriented metropolis and that it remains in service today.

I.2.1 Expanding Dallas Rail Transit

In the early 1980s, the North Central Texas Council of Governments (NCTCOG) worked with the Urban Mass Transportation Administration (UMTA) to develop a rail plan for greater Dallas. (UMTA 1982) In 1983, the Dallas Area Rapid Transit Authority (DART) was formed upon the passage of a referendum in 14 cities and Dallas County.[57] By 1984, DART was operating commuter-oriented, non-stop express bus service from Plano and Richardson in the northern Dallas suburbs to downtown Dallas.

Also in 1984, the DART Board adopted light rail as the preferred mode for a planned 147-mile network of regional rail. This original plan included the North Central Corridor.[58] Given revenue constraints, the system plan was reduced to 93 miles and later to 65 miles, but plans never excluded the North Central Corridor. As one DART planner described it, the North Central Corridor was expected to be such an outstanding corridor in terms of cost and ridership that it “might have been able to stand alone.”[59]

The cost of the corridor was anticipated to be relatively low for several reasons. In April 1988, DART purchased 34.5 miles of railroad right-of-way from the Southern Pacific Transportation Company, including rails paralleling the North Central Expressway.[60] Additionally, the systems’ planners phased transit implementation. They determined that the line could be built in two waves, first to Arapaho Road in Richardson and later to Parker Road in Plano. (DART 1991) They also planned to implement a single track north of the Arapaho station until ridership demand dictated a second track. Finally, they constructed DART’s express bus facilities at proposed rail station sites so that some North Central Corridor infrastructure would be built in advance.

---

[57] DART; “DART History”; http://www.dart.org/about/history.asp; Accessed 10/26/12
[58] DART; “DART History”; http://www.dart.org/about/history.asp; Accessed 10/26/12
[59] Interviewee AX, Telephone conversation, 7/24/12
[60] DART; “DART History”; http://www.dart.org/about/history.asp; Accessed 10/26/12

In 1991, the *Richardson Transit Center* opened for bus park-and-ride and bus transfer operations.[61] It would later become the Arapaho Center Station on the North Central Red Line. In 1992, the East Plano Transit Center opened just north of downtown Plano. It would later become Parker Road Station, the terminus station of the North Central Red Line. Reflecting the congestion-oriented nature of DART's mission, DART's bus facilities were also aligned with DART-funded high-occupancy vehicle (HOV) lanes on US-75 and other major Dallas freeways.

By 1992, DART had broken ground on its light rail "starter system" and began the official federal planning process for the North Central Corridor.[62] The starter system extended north from a downtown Dallas Transit Mall (a vehicle-free city street) to Park Lane (a station on the North Central Corridor and the initial station of the North Central Corridor extension). It continued south of downtown Dallas to Leddbetter Road on a South Oak Cliff alignment and to Westmoreland Road on a West Oak Cliff alignment. While the North Central Corridor extension was projected to be the best extension based on ridership, cost, and a comparison of benefit-cost ratios, it was decided that other lines would be built first.[63] The decision to prioritize the southern routes was motivated by the transit-dependent population in the south Dallas area.

As DART began the official federal planning process for the North Central Corridor, there was little debate over the preferred alignment or station locations.[64] At various points, alternatives under consideration included a no-build alternative, an HOV expansion on the parallel freeway, an HOV facility within the rail right-of-way, and a shared rail and HOV facility in the rail right-of-way. However, with a former freight rail right-of-way already purchased by the agency, most alternatives were put forward as straw men, and the light rail facility was the clear intent of DART's board and staff.[65]

In 1996, the first 11 miles of the 20-mile starter system opened for revenue operations, and the following year service was initiated at the Park Lane Station—the starting point of the North Central Corridor extension.[66] At the time, the DART Board voted to accelerate light rail construction to the member cities of Garland, Richardson and Plano, including the installation of double-track north of Arapaho Station on the North Central Corridor.[67] This decision eliminated two cost-saving measures—staged implementation of the full line and single track on the northern segment.

Construction on the North Central Corridor north of Park Lane began in February 1999, just before DART signed a Full-Funding Grant Agreement with the Federal Transit Administration in October 1999. (DART 2006)[68] The North Central Corridor extension opened in two phases: the first nine miles to Galatyn Park in July 2002, and the remaining three miles to Parker Road in December of that year.[69]

---

[61] DART; "DART History"; http://www.dart.org/about/history.asp; Accessed 10/26/12
[62] DART; "DART History"; http://www.dart.org/about/history.asp; Accessed 10/26/12
[63] Interviewee AX, Telephone conversation, 7/24/12
[64] Interviewee AJ, in-person conversation, 6/5/12
[65] Interviewee AY; Telephone conversation, 9/7/12
[66] DART; "DART History"; http://www.dart.org/about/history.asp; Accessed 10/26/12
[67] DART; "DART History"; http://www.dart.org/about/history.asp; Accessed 10/26/12
[68] Federal Transit Administration; http://www.fta.dot.gov/printer_friendly/12304_3053.html; Accessed 10/26/12
[69] DART; "DART History"; http://www.dart.org/about/history.asp; Accessed 10/26/12

Figure I-2: Route Diagram for DART North Central Corridor, Dallas, Texas

I.2.2 North Central Operations

The North Central Corridor project is an extension to the DART Starter System. It connects to the system at Park Lane Station, two stations north of Mockingbird Station where the Blue Line splits with the Red Line to head northeast to Garland, TX. South of Mockingbird, rails continue into the downtown Dallas Transit Mall, where they also merge with Green Line operations. All DART LRT lines serve the Dallas Transit Mall. After passing through the Transit Mall, Orange Line and Green Line trains turn northwest, while the Red Line trains (with Blue Line service) continue southeast before turning south. A few miles south of downtown Dallas, the Blue Line service continues southward while Red Line rails turn southwest to Westmoreland Station near Interstate 20 in southwest Dallas.

Upon opening in 2002, Red Line service on the North Central Corridor operated from Arapaho Center Station in the northern Dallas suburbs to Westmoreland in the southeastern Dallas suburbs.[70] In late 2002, trains began to serve the far north-Dallas suburbs from the Parker Road Station. In 2009, with the opening of the first Green Line stations to the northwest of downtown Dallas, Orange Line service began to share Red Line tracks along the North Central Corridor but split off from the Red Line after the Dallas Transit Mall using Green Line tracks heading northwest.

As of October 2012, Red Line trains operate at 15-minute headways during morning and evening peaks, at 20-minutes headways throughout midday, and at 20-minute to 30-minute headways in the early morning and at night.[71] Orange Line trains operate all the way to Parker Road Station at approximately 15-minute headways from around 5:30AM to 8:00AM and from 3:30PM to 7:00PM. In the midday and at night, Orange Line trains operate as far north as LBJ/Central Station at

[70] DART; "DART History"; http://www.dart.org/about/history.asp; Accessed 10/26/12
[71] DART; http://www.dart.org/schedules/schedules.asp; Accessed 10/26/12

approximately 20-minute headways. During the peak, the North Central Corridor service between downtown Dallas and Plano operates at an effective headway of 7.5 minutes due to the overlapping Orange Line and Red Line services.

As of 1996, DART estimated that over 11,000 daily riders would use the North Central Corridor extension in the year 2010. (FTA 1996) With double tracking and updated modeling, estimates were expanded to 17,000 riders in the year 2010. (FTA 1998) As of 2010, approximately 11,000 weekday riders boarded at the nine new stations of the North Central Corridor extension. As of 2010, approximately 18% of total LRT system ridership boarded along the North Central Line (which represented 23% of the system's stations). (DART 2012)

The difference in riders has been primarily attributed to DART service levels though a number of confounding issues also affected patronage. (DART 2006) As the Federal Transit Administration summarized:

> "The total efficiency and effectiveness of the LRT system is impacted by numerous factors outside the control of DART, such as economic conditions and developments and construction near station sites. However, factors controlled by DART, such as parking availability, station locations and bus system interactions, also affect ridership noticeably." (DART 2006)

Due to the agency's budget constraints, DART reduced rail service frequencies from those present on opening day, which had already been reduced from planned frequencies. (DART 2006) DART also reduced bus services in the region through route consolidation and changes to service frequency. In addition, reduced employment in the Telecom Corridor impacted commute travel in the area. Only three stations have exceeded ridership forecasts. The three northernmost stations along the extension were anticipated to have approximately 4,000 riders, but their ridership has approached 5,000. (DART 2012, DART 2006) Two of the stations that exceeded ridership expectations (Parker Road and Bush Turnpike) serve as large park-and-ride facilities adjacent to major Interstate interchanges. Parking demand at these facilities led to the construction of additional parking stalls. The third station that has exceeded ridership forecasts is the downtown Plano station that experienced significant real estate investment in the walk-shed over the last decade. It was built in anticipation of 450 daily users while approximately 600 boarded at the station on weekdays in 2010.

I.2.3 Planning a Successful Transit Project

The North Central Corridor was part of a much larger transit system envisioned by NCTCOG, UMTA, and DART. UMTA's funding criteria put significant emphasis on executing low-cost, high-ridership projects, which led to the prioritization of the North Central Corridor as an early expansion of the core system that passed through downtown Dallas. (DART, 1991)

Expectations of a low-cost alignment were driven by the fact that right-of-way had been procured from Southern Pacific in the 1980s.[72] Dallas planners had sought out continuous corridors where rail transit infrastructure could be accommodated. That included highway corridors, railroad corridors, and even electricity transmission line corridors. The availability of the freight rail corridor parallel to the North Central Expressway was considered unusual and fortunate.

[72] Interviewee AY, Telephone conversation, 9/7/12

The freight rail corridor paralleled U.S. Highway 75, which was high volume and over capacity. The route also ran north though the City of Dallas to Richardson and Plano, two of the fastest growing suburbs in the 1980s.[73] The roadway itself was slated for reconstruction and expansion due to the high demand. At one point, planners imagined the rail could be built quickly enough to serve frustrated drivers during the reconstruction slated for much of the 1990s.

Because automobile congestion was a major impetus for the transit project, planners focused on providing a competitive alternative in terms of travel time.[74] While early planning studies determined most riders would be transit-dependent, planners focused on attracting choice ridership. Therefore, travel time savings became a primary consideration and roadway levels of service were a primary indicator of where transit could have a competitive advantage. Average operating speeds had been an issue on earlier system investments that ran in arterial roadway medians and interacted heavily with traffic at intersections. This motivated planners to consider a multi-mile tunnel from downtown Dallas to the area near present day Mockingbird Station and to elevate tracks over roadways as often as possible throughout the Dallas and Richardson portions of the alignment.

While the right-of-way had been procured, tunnels and elevated tracks added to the cost of the line and had to be justified to the Federal Transit Administration—a major project funder—on the basis that these features provided travel time savings that would attract significantly more riders to the line.[75] Planners "knew it would be successful from a ridership standpoint" because it would connect fast-growing suburbs with downtown Dallas along an existing congested traffic corridor, and regional travel models were used to validate this assertion.[76]

Employment growth along the North Central Corridor was another justification for the route.[77] There was a dense employment node at the Presbyterian Hospital campus near the proposed Walnut Hill Station and additional technology job centers near several stations north of Walnut Hill. While the route was typically considered a downtown commuter line, it was politically important for the DART Board to provide service to transit-dependent populations and minority populations. While there were some Asian American enclaves along the North Central Corridor in Richardson, it was mainly argued that the Starter System would provide access from predominantly African American communities near south Dallas station areas to jobs in downtown Dallas, and the North Central Corridor would later provide access from south Dallas to jobs in the emerging Telecom Corridor north of Dallas.

Connections to job opportunities along the extension were touted frequently. For instance, a planned station at Campbell Road was deferred until anticipated demand finally warranted a station nearby. Interest from the City of Richardson to build a station near some proposed office developments motivated DART to eliminate the Campbell Road Station from plans and construct Galatyn Park Station just to the north of the planned Campbell Road site.[78] This was considered proof of the economic development potential of the proposed line and became part of the rhetoric that the extension would not merely serve Plano and Richardson commuters bound for downtown Dallas.

Yet, Texas Instruments, one of the largest employers in North Texas, declined to put a station near its headquarters and several of their major manufacturing facilities that were located adjacent

---

[73] Interviewee AX, Telephone conversation, 7/24/12
[74] Interviewee AY, Telephone conversation, 9/7/12
[75] Interviewee AJ, in-person conversation, 6/5/12
[76] Interviewee AJ, in-person conversation, 6/5/12
[77] Interviewee AX, Telephone conversation, 7/24/12
[78] Interviewee AJ, in-person conversation, 6/5/12

to the rail corridor.[79] Transit planners did not consider wading into the politics of advocating for station locations near Texas Instruments largely because their campuses were auto-oriented and were considered unlikely to generate ridership. Though DART planners did not explicitly measure the density of the projects at the time, they tacitly considered campus-style technology offices a low-density use that—per their understanding of research on the topic of density and rail transit—would not support light rail service.[80]

In spite of arguments to the contrary, the line was considered a park-and-ride-accessed facility for downtown office workers and only modestly as a service upgrade for transit-dependent bus riders.[81] Station locations were set in the very earliest plans based largely on where the line intersected with major East-West arterial roadways and where physical geometries allowed for long linear station platforms.[82] Such locations were typically strip commercial or light industrial uses that had co-existed with freight rail operations. While this meant that there was some employment within walking distance of stations, evaluations found that there was very little housing near the line and it was expected that many nearby residents would opt to drive a short distance to the station.[83] In fact, after initial station sites were selected, DART conducted accessibility studies that considered park-and-ride and bus feeder access. Walk-up potential and transit-oriented development potential were only marginally considered and were, for the most part, not influential in the design of facilities.

In one exceptional instance, the City of Plano worked with DART to build a station near downtown Plano to help spur economic development.[84] The city helped develop a large apartment complex adjacent to the line, improved streetscapes and parks near the station, and promoted the rejuvenation of their downtown commercial storefronts. However, in most instances, plans developed in final engineering focused on auto-centric priorities and were only modified in instances where parking capacity was added. For instance, the project's surplus capital funds were used to add parking at Walnut Hill Station.[85] Also, DART later supplemented parking at the Bush Turnpike and Parker Road stations to accommodate demand.

Aside from the minor changes enumerated above, there were few modifications to the initial project proposal. In addition, there were no legitimate alternatives ever considered for implementation.[86] As one planner stated, "The line was fixed in space [based on the fright rail right-of-way] so it was a matter of making tweaks to maximize ridership."[87]

In spite of ridership that has underperformed relative to projections, the line is today considered a great success.[88] For one, planners, politicians, and others believe it has mitigated some level of highway congestion and, thus, helped the region avoid detrimental impacts to its economic development.

In general, rail transit is considered a significant regional economic advantage. To regional planners, DART makes the region more marketable as it competes for jobs and growth in a global

---

[79] Interviewee AJ, in-person conversation, 6/5/12
[80] Interviewee BA, in-person conversation, 8/14/12
[81] Interviewee AX, Telephone conversation, 7/24/12
[82] Interviewee AF, in-person conversation, 8/13/12
[83] Interviewee AF, in-person conversation, 8/13/12
[84] Interviewee AX, Telephone conversation, 7/24/12
[85] Interviewee AX, Telephone conversation, 7/24/12
[86] Interviewee AZ, in-person conversation, 8/14/12
[87] Interviewee AJ, in-person conversation, 6/5/12
[88] Interviewee AZ, in-person conversation, 8/14/12

marketplace.[89] Rail transit is also considered a prerequisite for being classified as a global city and the Dallas region has focused on its ability to build DART's light rail infrastructure when other Texas cities have failed to do so.[90]

Irrespective of ridership, Texas political leaders proudly focus on the fact that DART operates the longest light rail system in the country.[91] Also irrespective of performance, DART and its regional partners are proud to be in the process of connecting their system to both of the region's major passenger airports.[92] It would seem that in the eyes of many Dallas stakeholders the most important measure of success for the North Central Corridor extension—and any other DART projects—is that rail transit was ever built in unabashedly automobile-centric Dallas, Texas.

I.2.4 Commuter Rail Insights – Trinity Railway Express

The Dallas-Fort Worth region is also home to the successful Trinity Railway Express (TRE) commuter rail service between downtown Dallas and downtown Fort Worth. We asked interviewees about their planning of commuter rail service, the differences they see between commuter rail and other fixed-guideway services, and the applicability of our indicator-based method to such transit proposals.

The 35-mile, 10-station TRE project opened in three phases between 1996 and 2001.[93] Right-of-way for the line was procured from the Chicago Rock Island and Pacific Railroad in 1983 by the cities of Dallas and Fort Worth at the same time as railroad right-of-way was procured for the Dallas North Central light rail alignment. The TRE rail is now jointly owned by DART and the Fort Worth transit agency, The T. The project was planned by North Central Texas Council of Governments, built by DART and The T, and is currently operated by a private vendor. Project funding came from the region and the Federal Transit Administration.

TRE service connects downtown Dallas and downtown Fort Worth with stations in between. Most stations have free park-and-ride facilities with bus transfer centers.[94] The route generally parallels Texas Highway 183, the DFW Airport Freeway. Fares are zone-based. Trains operate from 5:00AM to 11:00PM on weekdays and 9:00AM to 11:00PM on Saturdays with additional trains for special events. Headways are as frequent as 20 minutes at the peak of the AM peak and as infrequent as two hours in late evenings and on weekends. Freight railroads continue to use the tracks during off-peak times.[95]

North Central Texas Council of Governments planners characterized the project as an "opportunistic" rail transit investment.[96] The right-of-way was purchased well in advance of the service being planned and at significantly less than it would cost to procure right-of-way today. The service was started because upgrade costs were minimal and operations costs were also marginal.

The initial project was not expected to generate significant ridership.[97] The more costly extension from the outskirts of Dallas to downtown Fort Worth was justified by the incremental ridership that

[89] Interviewee AO, in-person conversation, 8/14/12
[90] Interviewee AY, Telephone conversation, 9/7/12
[91] Interviewee AJ, in-person conversation, 6/5/12
[92] Interviewee AF, in-person conversation, 8/13/12
[93] DART; www.dart.org; "TRE Facts"; Accessed 10/19/12
[94] Trinity Railway Express; http://www.trinityrailwayexpress.org; Accessed 10/19/12
[95] DART; www.dart.org; "TRE Facts"; Accessed 10/19/12
[96] Interviewee AZ, in-person conversation, 8/14/12
[97] Interviewee AO, in-person conversation, 8/14/12

the longer, two-ended route could generate. The project benefited from having major downtown business districts at both ends of the line because bi-directional traffic could be generated. The line also serves a hospital complex outside of downtown Dallas that is a major regional traffic generator.

While ridership has been substantial and has justified service expansion, regional planners believe service frequency hampers attracting more ridership and attracting TOD investment.[98] They hope to transition the service from locomotive push-pull train sets to lighter weight, faster, and more efficient DMU trains like those that now operate on the region's new northern commuter rail service. They believe this technological change will allow for service changes that can make the service significantly more attractive to riders and to real estate investors.

Planners felt that our indicator-based method could be adapted for use on commuter rail projects if it was sensitive to service frequency and the varied peak and off-peak schedules common to commuter services.[99] In their own practice, NCTCOG planners have never formally added commuter rail service to their regional model. Instead, their models consider TRE to be an oversized commuter bus service. While they believed the indicator-based method would be useful in other circumstances, they were not sure that it would have been employed to evaluate TRE. They felt this particular commuter rail project was so obvious based on much simpler indicators—providing connections between two downtowns on an inexpensive freight rail right-of-way—that modeling was not required to justify the initial right-of-way purchase or the station locations. More sophisticated and FTA-approved regional travel models were used to apply for federal funding and there were few instances during that process when an intermediate ridership prediction tool would have been valuable.

[98] Interviewee AO, in-person conversation, 8/14/12
[99] Interviewee BB, in-person conversation, 8/14/12

I.3 EmX Phase I Bus Rapid Transit (Lane County, Oregon)

The EmX Phase I project is a four-mile, 10-station bus rapid transit (BRT) facility connecting downtown Eugene and downtown Springfield in Lane County, OR. As the transit connection between the region's two major transit hubs, the $25 million investment is considered the backbone of a proposed 61-mile regional BRT system. In operation since January 2007, the line has exceeded ridership forecasts from opening day. This case study suggests that many of the same rail transit planning "rules of thumb" identified in other TCRP H-42 case studies are also relevant for fixed-guideway bus projects.

I.3.1 Establishing Lane County Bus Rapid Transit

The EmX concept arose out of comprehensive transportation and land use planning conducted in Lane County, OR.[100] In the 1970s, the Lane County metropolitan area was required by Oregon state law to develop comprehensive regional land use plans and urban growth boundaries. Throughout the 1970s and 1980s, the regional government discussed focusing urban growth in walkable, mixed-use development nodes. Because the designated nodes were typically existing commercial crossroads, these regionally significant locations were already served by Lane Transit District (LTD) bus routes.

The EmX enhanced bus service arose from environmental interests.[101] In response to the national

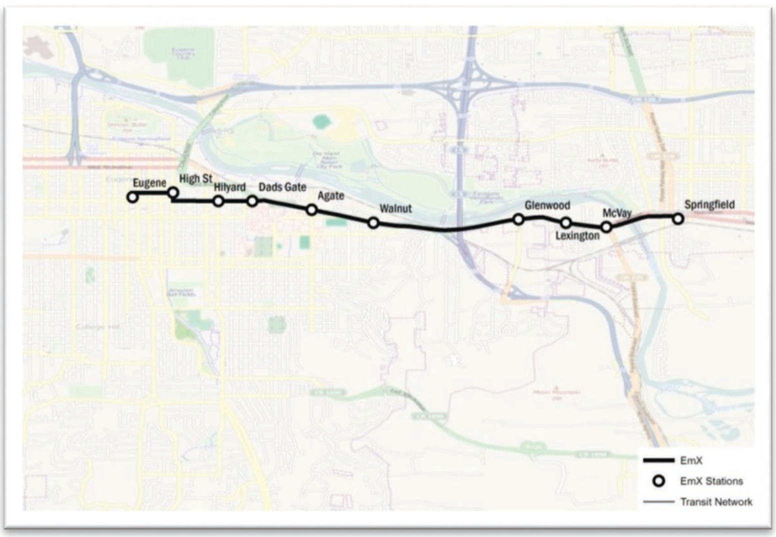


Figure I-3: Route Diagram for EmX in Eugene and Springfield, Oregon

1992 Clean Air Act Amendment, the State of Oregon enacted Transportation Planning Rule Goal 12, which required Oregon cities to gradually reduce vehicle-miles traveled (VMT). In 1996, as part of a Regional Transportation Plan update, dedicated guideway bus service was promoted as an option that could make bus service more attractive than automobile travel and therefore achieve VMT reduction goals. Although many citizens encouraged regional planners to implement light rail, an urban rail feasibility study in the late 1990s deemed the mode to be out of scale with the land use density of the region and with LTD's expansive service area, in addition to being too expensive to construct.[102] By 2001, an extensive network of bus-only transitways connecting many of the

[100] Interviewee BC, in-person conversation, 8/08/12
[101] Interviewee BC, in-person conversation, 8/08/12
[102] Interviewee BC, in-person conversation, 8/08/12

region's designated growth nodes was adopted in the long-range transport plan by Eugene, Springfield, Lane County, and LTD.

The 2011 regional transport plan includes 61 miles of BRT in its fiscally constrained long-range project list (Central Lane MPO 2011). Opened in 2007, the Phase I EmX line from downtown Eugene to downtown Springfield was the first BRT route implemented in the region. EmX service was subsequently extended with a route that departs from the easternmost end of the Phase I project and proceeds in a loop through north Springfield. Recently, plans were approved for an additional extension that will extend EmX service from the westernmost end of the Phase I alignment at the Eugene Station through west Eugene.

Though alternate versions of the Phase I alignment were considered, interviewees consistently agreed that the Phase I route was the consensus favorite among starter line options and provided the best opportunity to showcase the new technology and advance the vision of the 2001 regional transportation policy.

Construction on the Phase I EmX route began in 2004 and was budgeted to be approximately $25 million.[103] Funding came from Federal Transit Administration Section 5307 and 5309 funding sources ($19.2 million) and LTD transit funds. The project was completed under budget and on time with service initiated in January 2007.

I.3.2 EmX Phase I Operations

The Phase I alignment runs from the Eugene Station bus terminal to the Springfield Station bus terminal. Most bus service in the eastern part of the urbanized area passes through the Springfield Station's eight bus bays, while approximately 30 bus routes pass through the Eugene Station's 20 bus bay facilities.

Sixty percent of the Phase I corridor consists of exclusive bus lanes.[104] Also, queue jumping lanes exist at the McVay Station, and signal priority exists at other locations. A 1.5-mile portion of the alignment passing along Franklin Boulevard through the Glenwood area was not constructed with exclusive right-of-way due to extremely low intersection density and because that portion of the corridor is slated for major roadway improvements in coming years, which could include EmX upgrades if ridership demand necessitates it.[105]

The EmX operation utilizes distinct buses from the rest of the LTD fleet.[106] The hybrid-electric buses are 60-foot articulated New Flyer buses with three doors on the right side and two doors on the left side of the bus. They have low floors that allow level boarding from roadside platforms. The buses accommodate multiple wheelchairs and multiple bicycles.

EmX runs approximately every 10 minutes on weekdays, every 15 minutes during weekday evenings and on Saturdays, and every 30 minutes during late evenings and on Sundays.[107]

Ridership on Route 11, EmX's predecessor, averaged just under 2,700 weekday boardings.[108] The LTD predicted EmX ridership would average 4,200 weekday riders (FTA 2009). Initial

[103] Lane Transit District; "EmX History"; http://www.ltd.org/; Accessed 7/20/12
[104] Lane Transit District; "EmX History"; http://www.ltd.org/; Accessed 7/20/12
[105] Interviewee BD, in-person conversation, 8/08/12
[106] Lane Transit District; "EmX"; http://www.ltd.org/; Accessed 7/20/12
[107] Lane Transit District; "EmX"; http://www.ltd.org/; Accessed 7/20/12
[108] Interviewee BD, in-person conversation, 8/08/12

observations greatly surpassed this prediction, with ridership hitting 6,600 per weekday by October of 2008. That year EmX reached a single-day ridership record of over 8,000 riders.[109]

Ridership declined by approximately 10% after proof of payment was required on the EmX route in September 2009, but it has since recovered.[110] Service was provided free of charge until an off-board payment technology could be implemented (a larger order of fare collection machines was planned as part of the expansion of EmX services into north Springfield with the Gateway extension project).[111] Prior to the implementation of fare collection, onboard surveys found that fewer than one-quarter of all riders on the Phase I alignment would require cash payments. The vast majority of riders possessed Lane Transit District group passes, typically because riders were University of Oregon students or staff, middle and high school students in the public school district, or employees of the regional hospital—all transit pass participants.

I.3.3 Planning a Successful Transit Project

The planning of the Phase I EmX was a collaborative effort spearheaded by an LTD board member. Key participating agencies included Lane Council of Governments, Oregon DOT, Lane Transit District, the cities of Eugene and Springfield, Lane County, the Federal Transit Administration, and the Federal Highway Administration. In the mid-1990s Rob Bennett, a former city councilman, an LTD board member, and an MPO policy committee member, responded to the statewide VMT reduction mandate with a visionary challenge.[112] He applied his business operations experience, particularly marketing, to the discussion of transportation mode choice. He asked transportation staff at the MPO and LTD to produce a "quantum leap forward" in transit service. With his challenge in mind, the region set out to reduce VMT by making transit more attractive than driving.

The LTD board identified several key components that would make transit competitive with automobile travel.[113] Paramount was dedicated guideway to remove transit vehicles from congested roadways. Secondary were distinct vehicles that provided an enhanced in-vehicle experience and off-board fare payment that took the hassle out of boarding transit. Lastly, the service would need to be provided along major corridors to coordinate the transport investment with the region's nodal land use aspirations. According to the personal experiences of most Oregonians, these features were readily available with light rail technology like that found in Portland, OR. Many public commenters argued on the basis of regional pride and the availability of funding at the state and federal level that Eugene "deserved" light rail transit.[114]

Cost was at the center of a debate between rail fans and those who believed enhanced bus service could achieve the same benefits.[115] Bus detractors focused on bus service's perceived unreliability, environmental impacts, and impermanent infrastructure. Bus advocates set out to alleviate concerns about impermanence with unique station designs, addressed environmental impacts by specifying hybrid bus technology, and sought to eliminate reliability issues with dedicated guideways, signal preemption technology, and digital wait-time indicators. In addition, advocates promoted the idea

[109] Lane Transit District; "History"; http://www.ltd.org/; Accessed 7/20/12
[110] Interviewee BE, in-person conversation, 8/06/12
[111] Interviewee BD, in-person conversation, 8/08/12
[112] Interviewee BE, in-person conversation, 8/06/12
[113] Interviewee BE, in-person conversation, 8/06/12
[114] Interviewee BC, in-person conversation, 8/08/12
[115] Interviewee BC, in-person conversation, 8/08/12

that any enhanced bus corridor would be ready for conversion to light rail if demand supported the conversion. Advocates of bus focused their arguments against light rail on total cost and investment efficiency. While it was clear that rail would be considerably more expensive than enhanced bus services, it was arguments about the densities required to support rail service that became the lynchpin of their pro-bus advocacy. Consults were retained to conduct a feasibility study that rested on the notion that efficient transit services of various technologies required commensurate population densities to support them.

Ultimately, the decision to pursue BRT was a contingent one.[116] To address the uncertainty of an untested, unfamiliar technology, a Eugene City Councilman established policy laying out the conditions with which LTD would need to comply to gain the city's support for the regional BRT plan: demonstrate that local governments unanimously supported the final design, that funding was available, and that outputs from the regional model indicated the proposed project would increase the transit mode share along a corridor.

With these assurances, the regional BRT plan was adopted and an initial project was identified. Very little analysis was conducted to select the first project.[117] LTD decided to replace Route 11 because it was the agency's highest ridership route.[118] The original concept for the Route 11 BRT upgrade was an 11-mile corridor from east Springfield to west-central Eugene.[119] In addition to high ridership, the portion of the route in the City of Eugene had a grass median along an arterial roadway—Franklin Boulevard—that could accommodate a two-lane busway. It served two existing hubs and was located next to the University of Oregon campus, which had plans to expand without adding parking supply and instead raising parking prices.[120] The route was also considered politically feasible because of its regional scope; it would serve the two primary cities in Lane County.[121] Additionally, many staff and board members advocated for the Route 11 alternative because "it made sense as a pilot case to form a basis for future expansion."[122]

Upon receiving pushback from several city council members who believed LTD should instead prioritize the improvement of low ridership routes, LTD staff carried out a back-of-the-envelope evaluation of proposed BRT routes.[123] The evaluation considered bus and car travel times between route ends, existing bus ridership on the proposed routes, and the ease of implementing dedicated bus lanes on the corridors. Without producing a prediction of ridership based on the region's travel model or another method, these success criteria validated the prioritization of the Route 11 upgrade.

Despite the cost-based arguments for BRT over light rail, the 11-mile EmX project proved difficult to fund.[124] The unproven service and estimated cost levels were not compatible with many transit funding programs and guidelines. To comply with funding source requirements, LTD and regional planners eventually scaled the project down to keep its costs in line with a particular Federal Transit Administration funding category.[125] This, along with staff and local funding

[116] Interviewee BC, in-person conversation, 8/08/12
[117] Interviewee BE, in-person conversation, 8/06/12
[118] Lane Transit District; "EmX History"; http://www.ltd.org/; Accessed 7/20/12
[119] Interviewee BE, in-person conversation, 8/06/12
[120] Interviewee BF, in-person conversation, 8/08/12
[121] Interviewee BE, in-person conversation, 8/06/12
[122] Interviewee BE, in-person conversation, 8/06/12
[123] Interviewee BE, in-person conversation, 8/06/12
[124] Interviewee BE, in-person conversation, 8/06/12
[125] Interviewee BD, in-person conversation, 8/08/12

capacity constraints, ultimately led to the diminution of the project from the proposed 11 miles to the "backbone" four-mile segment between the two existing transit hubs.

Once the four-mile alignment was selected, few alternatives were compared because it was an established route with existing bus stops located at critical intersections.[126] The route was modified in only one instance, where Walnut Station was adjusted one block from the bus stop's original location to be adjacent to a vacant auto dealership and a former Oregon Department of Transportation yard that were both slated for redevelopment. While farther from existing land uses, the revised station location also worked better from an engineering perspective.

The EmX Phase I BRT project is considered a success because it has attracted new ridership with only modest investment and few changes to the Route 11 services. As one planner put it, "The [regional transportation] models couldn't even handle the concept because the old service and the new service had 10-minute headways, but we knew that the old bus route was invisible to [citizens] and we were making [major service enhancements]."[127] The notion was to simplify and re-brand bus transit to attract new riders. "[EmX] was point A to B, it looked different, no timetables necessary, no system maps needed." Several interviewees attribute the doubling of ridership along the route to a profound change in transit service perceptions rather than operational improvements attributable to dedicated right-of-way.

For politicians who approved the first EmX project, its success hinged on growing choice ridership and reducing VMT.[128] It was generally believed by interviewees that EmX has successfully attracted those riders. As one regional planner argued during our interview, "LTD was running the Number 11 [bus] every ten minutes. Students had a class pass just as they do now. So, two of the factors that are key to attracting ridership were the same with the regular bus service that preceded BRT and the BRT that was implemented."[129] Therefore, planners believe that at least some of the new riders on EmX have shifted from another travel mode to the BRT service.

In addition to benefitting from an increase in choice riders, LTD has seen bus operations improve.

> We argued [for BRT] on the basis of the quantum leap needed to attract choice riders and didn't really put together a business case for why these operations would actually benefit our bottom line. In fact, the BRT service reduced [bus] travel times by 35%, increased corridor boardings by 270%, and reduced cost per boarding by 30% relative to the Number 11 service that operated on the corridor. BRT helped LTD overcome the biggest conundrum in bus operations. If you want to serve corridors where people want to access popular establishments or concentrations of dwellings, then one must operate a bus on a congested corridor. BRT provides, in particular, the transit infrastructure and service elements that overcome [that congestion].[130]

In retrospect, local planners believe operational benefits were a primary benefit, second to successfully attracting choice riders with a relatively inexpensive infrastructure investment. As one

[126] Interviewee BE, in-person conversation, 8/06/12

[127] Interviewee BE, in-person conversation, 8/06/12
[128] Interviewee BG, in-person conversation, 8/08/12
[129] Interviewee BH, in-person conversation, 8/08/12
[130] Interviewee BC, in-person conversation, 8/08/12

planner put it, "Operations cost are more important locally than capital costs. Operating burden is local and capital cost burden is partially taken on by [the state and federal governments]."[131]

Another fundamental success of the project was its focus on accessibility.[132] LTD was the first agency to provide universal wheelchair accessibility on all of it routes.[133] EmX stations were designed with audible signals at busy intersections, platforms that provide level boarding, and buses equipped with rear facing wheel chair bays that allow for unassisted ingress and egress (LTD brochure Date Unknown).

Ultimately, the Phase 1 EmX project is considered successful because of the political support it garnered for future investments. Because LTD services are funded by a payroll tax, "some of [our local business owners] pay close attention."[134] Many business owners have stepped forward to defend EmX expansion when other local business owners have complained about new services impacting their street frontages. It would seem that the stature of LTD has been elevated. Just prior to our case study visit, representatives from New Zealand had visited Eugene to tour the EmX facilities. A map on the wall indicated over 100 visits by delegations from all over the globe. EmX is a point of political pride in Lane County, Oregon. "We have the mayors of Eugene and Springfield talking about EmX every opportunity they get."[135]

In spite of significant tea party opposition to the latest 8.8-mile extension of EmX into west Eugene, a third phase of EmX development, the city council affirmed implementation in a 7-1 vote on September 26, 2012, and the LTD board of directors voted 5-1 on October 8, 2012, in favor of initiating design of the new corridor.[136]

[131] Interviewee BE, in-person conversation, 8/06/12
[132] Interviewee BC, in-person conversation, 8/08/12
[133] Interviewee BD, in-person conversation, 8/08/12
[134] Interviewee BC, in-person conversation, 8/08/12
[135] Interviewee BI, in-person conversation, 8/08/12
[136] Lane Transit District; "West Eugene EmX Extension;" www.ltd.org; Accessed 10/29/12

I.4 Interstate MAX (Portland, OR)

The Portland, Oregon, region, the 23rd most populous metropolitan area in the United States, operates a 50-mile MAX light rail system that was envied by several of our interviewees from much larger regions. The Interstate MAX project, a 5.8-mile extension of Portland's system, was completed in 2004. The line connects downtown Portland to its northern suburbs in the state of Oregon and was designed with an intent to eventually extend the line further north, over the Columbia River, to Vancouver, WA. This Interstate MAX case study suggests that definitions of "success" are fungible and that qualitative factors may outweigh quantitative evaluation metrics.

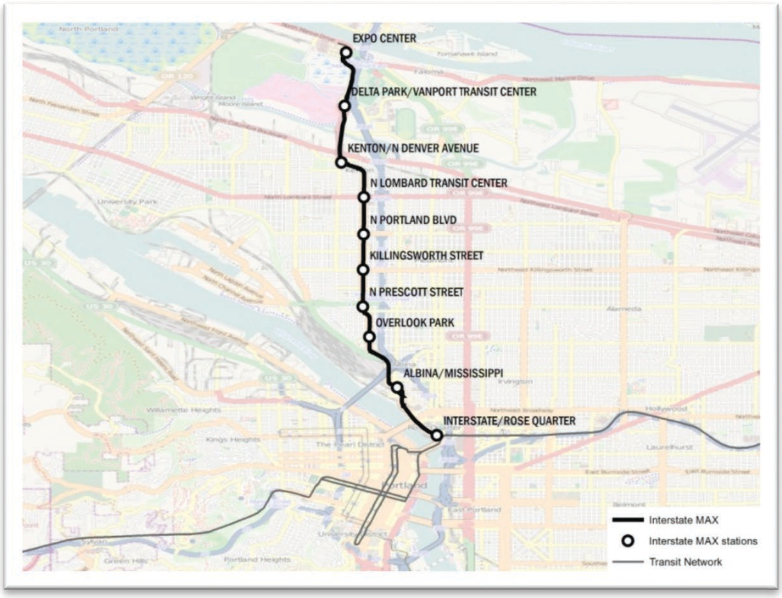


Figure I-4: Route Map for Interstate MAX, Portland, Oregon

I.4.1 Expanding Portland Rail Transit

The Interstate MAX project was part of a longstanding plan to expand Portland's MAX light rail system. The long-range plans for the Portland region's light rail system are based largely on Metro's 1982 *Light Rail System Plan*, which identified bus routes with high enough ridership to justify conversion to higher-capacity transit.[137] Construction of Eastside MAX (part of today's Blue Line) commenced in 1982, and the line from downtown Portland to Greshman was opened in September 1986.[138] Building on that line's success, voters approved the Westside MAX (also part of today's Blue Line service) to Beaverton and Hillsboro in 1990. After the completion of the EIS for TriMet's Westside MAX line in 1994, regional transit planning focus shifted to the region's next priority, the South/North Transit Corridor, which stretched from the southern suburb of Milwaukie in Clackamas County through Portland and across the Columbia River into Vancouver, WA. The Interstate MAX alignment that was ultimately constructed had been identified in the plan as one of two "Northern Alternatives" connecting downtown Portland with Vancouver.

---

[137] Interviewee AA, in-person conversation, 8/7/12
[138] TriMet; www.TriMet.org; Accessed 10/2/12

The FTA had already approved Metro's request to undertake alternatives analysis on the South/North Corridor in 1993, and light rail was selected as the locally preferred alternative in December of 1994 (Metro 1998). As one planner suggested, "The mode was pre-selected for us based on the mode chosen for the previous [MAX light rail] projects."[139] In contrast to the official framing of the federally-overseen alternatives analysis process, early system planning focused on selecting routes where light rail would succeed. Planners did not identify problematic travel corridors and then select the optimal transportation improvement. In fact, local jurisdictions were fighting to be the next city in the Portland region to get a light rail project and took whatever actions they had available to them to help justify light rail.[140]

In 1994, Portland area voters approved a bond measure to finance their portion of the South/North Light Rail Project. However, voters in Washington State voted against a bond measure that would have financed their portion of the South/North Transit Corridor. TriMet continued planning the Portland portion of the line, but the project failed to win support at the ballot in 1998. Portland region voters ultimately rejected a $475 million General Obligation bond measure that would have funded the project's construction later that year. Though the regional bond failed, results showed that 54% of city of Portland voters and 55.1% of Portland residents within one-half-mile of the alignment north of downtown supported the bond measure.

In March 1999, a group of local business and community leaders asked TriMet to investigate a scaled back alignment on the northern portion of the corridor, from the Rose Quarter to Expo Center (city of Portland 2001). TriMet, Metro, and the Portland City Council were able to complete and adopt a *Final EIS and Conceptual Design Report* for the Interstate MAX project later that year. The FTA and TriMet signed a full-funding agreement (FFGA) in September 2000.[141] TriMet reports the total project cost as $350 million, of which nearly 74% ($257.5 million) was federally funded. The remainder of the project was paid for by the city of Portland, Metro, and TriMet.

Construction started in November 2000, and lasted almost four years. Major features included the 4,000-foot-long Vanport Bridge, significant streetscape enhancements, including a tripling in the number of street trees along the corridor, and the relocation of a 37-foot-tall Paul Bunyan statue in the Kenton neighborhood.[142] Interstate MAX opened on May 1, 2004, four months ahead of schedule.

I.4.2 Interstate MAX Operations

Today, Interstate MAX (Yellow Line) is a 5.8-mile, 10-station line from downtown Portland, through North Portland neighborhoods to the Expo Center, near the border with Washington State. The northern terminus was selected to enable future expansion across the Columbia River to Vancouver, WA. The southern end of the line initially tied into the original East-West downtown transit alignment on SW Morrison and Yamhill Streets, shared with the Red and Blue Lines. Currently the Yellow Line utilizes the revitalized North-South Portland Transit Mall to travel through downtown Portland to its current terminus at Portland State University.

The Yellow Line runs seven days a week, from roughly 5AM to 1AM, with 15-minute headways. During early mornings, midday, and in the evening, service is slightly less frequent. The vast

---

[139] Interviewee AA, telephone conversation, 7/11/12
[140] Interviewee BJ, in-person conversation, 8/6/12
[141] Interviewee AA, telephone conversation, 7/11/12
[142] TriMet; "Interstate MAX: Yellow Line"; www.TriMet.org; Accessed 10/2/12

majority of trains operate the full length of the current line, from Portland State University on the south side of downtown to the Expo Center terminus in North Portland.

TriMet's planning model (run in 2000) forecast 13,900 Interstate MAX riders in 2005, and between 18,100 and 18,860 by 2020 (FTA 2007). Actual 2005 ridership was slightly lower than projected, at 11,830, but it has been growing steadily at a rate of about a thousand additional weekday riders per year. Given the ridership growth trends, the FTA expected the project to "easily achieve better than 80 percent of its predicted ridership by the forecast year(s), indicating a relatively reliable ridership forecast" (FTA 2007).

Presently, the Portland-Milwaukie light rail line is being constructed from the current terminus of the Yellow Line south to inner Southeast Portland, Milwaukie, and Oak Grove in north Clackamas County.[143] The route follows a southern portion of the original South/North Transit Corridor Project.

I.4.3 Planning a Successful Transit Project

The primary agencies involved in the planning of the Interstate MAX were Metro, Portland's unique elected regional government; TriMet, the regional transit agency covering Multnomah, Clackamas and Washington counties; and the city of Portland. Metro is responsible for the planning of the region's transportation system and publishes the *Regional Transportation Plan* (RTP), which includes a plan for capital investments in high-capacity transit corridors. For the Interstate MAX project, Metro and TriMet worked together, with Metro as lead agency, to prepare environmental documents and secure funding from the FTA.[144] TriMet managed the project's construction. The city of Portland's Office of Transportation conducted an expansive community outreach effort, building local support for the line, soliciting feedback on design details, and ensuring minimal negative impacts on local businesses during construction.[145] This came on the heels of another community planning effort called the *Albina Community Plan* that was considered by transit planners to encompass the land use and economic development goals of the neighborhoods around much of the Interstate MAX corridor.

To understand the planning of Interstate MAX, one must understand the planning of its predecessor, the South/North Transit Corridor. This corridor had been identified in the region's 1982 rail plan. The success of the overall transit plan was considered to hinge on connecting the Portland region's major poles, particularly transit centers (transfer hubs) and concentrations of employment.[146] As one transit planner explained, in most instances the transit alignments defined on early plans were based on professional intuition using aerial photographs and accreted knowledge of regional travel patterns.[147] Reflecting this planning technique, north of downtown Portland, the proposed South/North light rail alignment exited downtown's Transit Mall to pass through the Rose Quarter event district, served several hospital campuses, skirted one of the region's remaining port and industrial districts, served the city of Portland's Exposition Center near the Columbia River, and passed through downtown Vancouver, WA—a fast-growing, northern suburb of Portland. Early

---

[143] TriMet; "Portland-Milwaukee: a vital transportation link"; www.TriMet.org; Accessed 10/2/12
[144] Interviewee BK, in-person conversation, 8/7/12
[145] Interviewee BJ, in-person conversation, 8/6/12
[146] Interviewee AK, in-person conversation, 8/6/12
[147] Interviewee BK, in-person conversation, 8/7/12

considerations for station locations focused on serving these centers and also aligning transfer points for bus patrons on cross-town routes along major East-West thoroughfares.[148]

Between downtown Portland and the Columbia River, both the South/North corridor and Interstate MAX projects were planned in two segments. One segment consisted of track from the Banfield project's existing downtown rail right-of-way to the Kaiser Hospital campus just northwest of the Interstate 5/Interstate 405 interchange. A second segment consisted of the straight route north from Kaiser to the Expo Center on Portland's northernmost border.

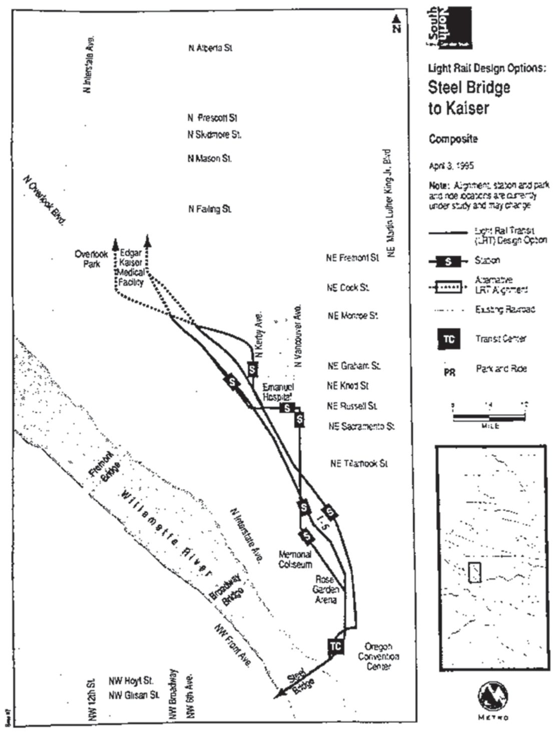


Figure I-5: Segment 7: Steel Bridge to Kaiser (Metro 1995)

Throughout the planning of the South/North corridor, two possible alignments were considered for the segment of the light rail from the Kaiser facility, north of downtown Portland, to the border with Vancouver, WA. These alignments were called "Interstate Avenue" and "I-5" because one alignment would run down the center line of Interstate Avenue for much of the way (a four-lane state route that served as the primary North-South traffic artery prior to the opening of Interstate 5) and the other route would parallel Interstate 5 in right-of-way along the west side of the Interstate. An equal number of stations were to be located along the two routes and the stations were proposed at the same cross streets along the route.

[148] Interviewee AA, in-person conversation, 8/7/12

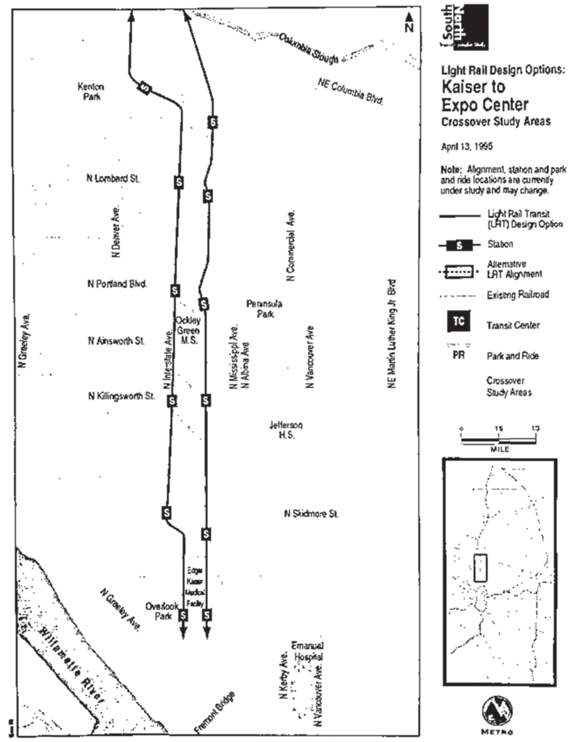


Figure I-6: Segment 8: Kaiser to Expo Center[149]

As of 1994 evaluations, comparative characteristics of the two alignments suggest that the I-5 alternative was to be cheaper, faster, have higher ridership, and have fewer nuisance impacts on the neighborhood than the Interstate Avenue alignment.

Table I-1: Summary Characteristics of Proposed Alignments (PMG 1998)

Characteristic	Interstate Avenue	I-5
Year of Expenditure Cost (millions)	$1,199	$1,085
LRT Weekday Ridership from Oregon City to 179th	64,000	65,400
Total Weekday Corridor Transit Ridership	131,350	132,800
Effective LRT Operating Cost (millions) from Oregon City to 179th	$18.14	$18.02
Cost-Effectiveness Ratio (lower is better)	8.36	7.94
Residential and Business Displacements (Interstate Avenue variations reflect different roadway designs to accommodate varied levels of automobile capacity)	40/65/120	70

According to planning documents, there were significantly more advantages related to the I-5 proposal when compared to the Interstate Avenue alternative (PMG 1998). Modeling of the I-5 proposal suggested that the project would yield higher transit system ridership as well as higher ridership on the route. Much of that ridership differential from the Interstate Avenue alignment was

[149] Portland Metro; "Segments and Design Options"; Portland Metro; April 13, 1995; p. 53

related to the shorter travel time along the I-5 route (two minutes shorter) that would make the service more attractive to Clark County, WA, residents as a commute alternative to downtown Portland. The I-5 alignment was also expected to have lower capital and operating costs than the Interstate Avenue alignment. Thus, the I-5 alignment was preferable when benefit-cost was measured as capital cost per rider and operating cost per rider. Planners also thought the I-5 alignment would provide better access to the Portland Community College (PCC) campus on N.E. Killingsworth and neighborhoods east of Interstate 5 while providing excellent accessibility to the high-density development between Interstate Avenue and Interstate 5 that was identified during the city's Albina Community Plan process. The I-5 alignment also would have had significantly fewer impacts on businesses and residents during construction. Operating noise impact would have also been minimal along the I-5 alignment because noise walls would have been installed along the route. The walls would have also provided sound protection from Interstate 5 traffic noise.

According to the planning documents, the Interstate Avenue alignment had fewer advantages relative to the I-5 option. Interstate Avenue operations would have provided more rail visibility and more direct access to existing retail, commercial, and residential properties along Interstate Avenue and within the Kenton area. The alignment would have provided equal accessibility benefits for new dense developments considered within the Albina Community Plan while providing greater accessibility to residential areas west of Interstate Avenue.

One Portland planner suggested that the neighborhood was primarily interested in achieving dense development along Interstate Avenue—neighborhood-serving retail per the Albina Community Plan—and thought the development potential would be maximized if the rail ran along the Interstate Avenue corridor.[150] Transport planners were interested in the operational benefits of the I-5 line, which minimized grade crossings and maximized travel speeds. The Project Management Group suggested that a modified alternative be studied, one that merged the two concepts by utilizing the Interstate 5 right-of-way between stations and then diverting the line several blocks to accommodate station platforms on Interstate Avenue (PMG 1994). Planners considered several hybrid variations of the alignment.[151] However, the operational benefits were considered much too small relative to the number of property impacts that would have occurred. The final recommendations for Draft Environmental Impact Statement (DEIS) alternatives focused on the Interstate Avenue and I-5 options and suggested that a tradeoff would exist between cost and enhancing certain "land use opportunities." (PMG 1996)

While not explicitly mentioned in any transit planning documents we reviewed, interviewees pointed to safety concerns as an issue that tipped the scales in favor of the Interstate Avenue alignment. In the case of the I-5 alternative, stations had to be set back from major cross streets to accommodate conflicts with Interstate 5 on-ramps and off-ramps. Planners believed that real and perceived lack of safety for patrons accessing stations and waiting on platforms near Interstate 5 could negatively impact ridership on that alignment and harm the MAX brand. As one transit planner described the process, "Part of the argument [for the Interstate Avenue alternative] was that the stations would be safer in the middle of Interstate Avenue where there are eyes on the streets, people passing by, grocery stores, restaurants, and bicyclists, as opposed to near the freeway where—because these [rail] cars are 190 feet long—part of the station is going to be isolated. How are you going to protect it?"[152] As part of their practice, the planner asks, "How do you make

[150] Interviewee BJ, in-person conversation, 8/6/12
[151] Interviewee AA, in-person conversation, 8/7/12
[152] Interviewee AK, in-person conversation, 8/6/12

it an attractive and a comfortable space for your daughter who is 16 years old?" While the region's ridership models did not account for perceived safety, planners had learned from experience on the Banfield line, Portland's first light rail line, that platform safety was a critical issue for light rail operations.

By 1995, the Interstate Avenue and I-5 options were viewed largely through the lens of the revitalizing potential and perceived safety of the Interstate Avenue alignment, making it a clear preference among the community and regional planners.[153] Attention began to focus on the second segment of the project, the approach into downtown Portland. Project alternatives showed the South/North project entering downtown from the north across Portland's Steel Bridge, sharing tracks with the existing Gresham LRT line (PMG 1995). This accommodated a station in the existing transit center located between the Oregon Convention Center and the Rose Garden Arena on the east side of the Willamette River. Per Portland's planning imperative to connect employment centers, four alternatives showed the line continuing from the transit center and passing along either the east or west side of Interstate 5 with stations at the Emanuel Hospital facility. The advantages of these alignments were the access provided to the Emanuel Hospital employment center and the Eliot neighborhood. In fact, an evaluation of advantages and disadvantages consistently described the number of employees and residential units accessible within a five and ten minute walk of the proposed stations (PMG 1995).

Concerns regarding the alignments focused on operating issues as well as costly design components (PMG 1995). In at least one of the four options, the Emanuel Hospital station would have been a costly underground station. Other concerns about the alignments included operations impacts when passing through the Rose Quarter during events, the cost of passing either over or under Interstate 5 (in some instances, multiple times), and potential operating conflicts when running on non-exclusive right-of-way (i.e., in neighborhood streets).

As of early 1996, two route options for the segment of the project from downtown Portland to the Kaiser facility had been identified for inclusion in a DEIS. Both options passed through the Rose Quarter transit center, had stations when crossing Broadway, and had stations adjacent to the Emanuel Hospital facilities (PMG 1996). Notably, no alternative alignment west of Interstate 5 was recommended for further analysis because such a route would not provide access to the Eliot neighborhood or Emanuel Hospital, which were considered priority service areas (access from a station west of Interstate 5 to the neighborhood would have necessitated crossing the Interstate and negotiating an 80-foot grade change). This alternative was not included for further analysis also because the station on the west side of Interstate 5 would have been located in a zone designated for continued urban industrial uses, and it was feared that a station would have produced "non-industrial redevelopment pressures which contradict city objectives for this area" (PMG 1996).

Planning proceeded after 1996 toward another major funding milestone. Within the Portland metropolitan region, Oregon voters had approved funding for the South/North line in 1994 while Washington State voters had not. In 1998, Portland voters were asked to approve a local bond to finance the South/North project using the pre-approved revenues. Portland voters rejected the measure, though a majority of North Portland voters did vote for the bond.

In response to the failed vote, regional elected officials held a series of "listening posts" to determine next steps. The community suggested moving forward with a shorter, less expensive project in North Portland where voters were supportive of the funding measure. Planning for the shorter route proceeded quickly based on prior planning conducted for the South/North project.

[153] Interviewee BL, in-person conversation, 8/7/12

Business leaders formally requested a segment be built between downtown Portland and the Expo Center in March 1999 (City of Portland 1991). By April 1999, staff had prepared a *Supplemental Draft Environmental Impact Statement* (SDEIS). By June 1999, the Interstate Avenue alignment was identified as the preferred route in the North Corridor by the Portland City Council, TriMet, and Metro. Finally, in October 1999, Portland City Council adopted the Final Environmental Impact Statement (FEIS).

The project that was ultimately approved in 1999 consisted of the Interstate Avenue alignment in the northern segment and, for the segment leaving downtown Portland, a route along the Willamette River, significantly west of the Interstate 5 corridor—a route not studied in the mid-1990s planning process but one subsequently considered because of the project's limited budget. After leaving downtown Portland via the Steel Bridge, the line diverged from shared tracks at an intersection prior to the pre-existing transit center in the Rose Quarter. While all prior proposals had passed through that transit center, transferring patrons would walk as much as several hundred yards to reach certain bus bays. This change accommodated a sharp left turn to the northwest so that the alignment could follow an existing multilane arterial through an industrial zone—a much lower cost route than previously conceived. Unlike prior plans, no station was provided at Broadway and no access was provided to the Eliot neighborhood or Emanuel Hospital complex. Planners determined that the cost of providing those connections far outweighed the benefits of actually getting a project built within the limited budget.[154]

Part of the motivation for the original South/North alignment was to serve as a salve for community interests upset over prior government interventions.[155] The Eliot neighborhood and Rose Quarter had been significantly impacted by urban renewal projects. The area's neighborhoods, predominantly minority and lower income than much of Portland, had also been impacted by the construction of the Interstate 5 corridor. Relatively recent displacements for the construction of the convention and arena complexes were also fresh on the mind of community and local government officials. Even so, access to many of these communities was sacrificed for a lower cost route on the segment leaving downtown Portland.

On the other hand, there was not an option for the segment from Kaiser to Expo Center that was magnitudes cheaper than other alternatives but there was one option that could serve as the salve for prior government interventions. As one planner stated, "The residents saw the value of transit and [attendant] reinvestment [to] recreate a neighborhood that was lost because of the freeway [construction]."[156] Planners were persuaded to pursue the Interstate Avenue alignment over the I-5 alignment even though the I-5 alternative was superior by most quantitative metrics.

Further cost-saving measures were also identified. One such tradeoff reduced auto-mobility and impacted transit operations to reduce costs while simultaneously meeting neighborhood preferences. Whereas the original Interstate Avenue route plans had assumed that as many as 125 businesses and residences would have to be displaced to accommodate road widening, transportation planners determined that the Interstate Avenue tracks could be built without significant changes to the existing road right-of-way. Taking lanes without replacing them reduced automobile throughput capacity but provided adequate capacity for near-term automobile demand. To address longer-term auto demand, some automobile turn movements were accommodated in lanes shared with light rail tracks. However, the interactions between automobiles and trains negatively impacted the proposed

[154] Interviewee AK, in-person conversation, 8/6/12
[155] Interviewee BJ, in-person conversation, 8/6/12
[156] Interviewee BJ, in-person conversation, 8/6/12

transit operations along the Interstate Avenue alignment. That said, the changes allowed the transit project to be built where the community wanted it, without displacements, and within the available budget.

In a retrospective evaluation of the project's performance, it was found that planners overestimated the travel time impacts of operating light rail in city streets and underestimated the attractiveness of the service to non-commuters (FTA 2008). Additionally, FTA found that planners calibrated their ridership models with land use changes that did not materialize and used walk-up and park-and-ride ridership assumptions that were overly optimistic. Ultimately, the project was built on budget and attracted approximately the number of riders predicted during the planning phases of the project.

All of our interviewees believed that the Interstate MAX project was a success. When asked what they might do differently, no one suggested that the less costly I-5 alignment would have been preferable. Some interviewees believed that more could have been done to capitalize on the project through proactive land use planning.[157] Likewise, some suggested that even stronger community engagement would have been beneficial had more funding been available.[158] Another thought it had been successful at attracting riders but not necessarily the choice riders that are highly prized by the regional agency.[159] Despite the line's minor shortcomings, it is widely believed that Interstate MAX has provided several years of travel benefits for citizens, generated significant community development benefits for the neighborhoods it currently serves, and preserved opportunities to expand the project as envisioned by the original South/North Corridor project. In fact, planning for an extension of the Interstate MAX line to Vancouver, WA, is ongoing, and an extension of the line to the south is under construction.

I.4.4 Commuter Rail Insights – Westside Express

The Portland region is also home to Westside Express Service (WES), a commuter rail project extending from Wilsonville in the southwest of the region to Beaverton in the central-west of the region. Similar to Dallas, we asked interviewees about their planning of commuter rail service, the differences they see between commuter rail and other fixed-guideway services, and the applicability of our indicator-based method to such transit proposals.

The 14.7-mile, five-station WES project cost $161MM to build and opened in 2009.[160] The project was implemented by TriMet on an operating freight railroad right-of-way in partnership with Washington County, Oregon Department of Transportation, Metro, and the cities of Wilsonville, Tualatin, Tigard, and Beaverton. TriMet and Washington County shared costs above base elements funded by FTA.

The suburb to suburb line connects four communities in the southwest of the region to the MAX light rail system via an intermodal station in Beaverton on the Westside LRT line. The service generally parallels a North-South highway corridor consisting of Interstate 5 in the south and state highway 217 in the north. Service operates on 30-minute headways, Monday through Friday, during the morning and afternoon peak.[161]

---

[157] Interviewee BL, in-person conversation, 8/7/12
[158] Interviewee BJ, in-person conversation, 8/6/12
[159] Interviewee AI, in-person conversation, 8/7/12
[160] TriMet; http://trimet.org/about/history/wes.htm; Accessed 10/19/12
[161] TriMet; http://trimet.org; Accessed 10/19/12

The project was envisioned and advocated by stakeholders in the western part of the Portland region.[162] Due to low anticipated ridership relative to cost and alternative regional projects, the project was not initially supported by either the regional MPO or the rail transit agency.[163] Before models were even run, Oregon Metro argued against the line because of the extremely low housing densities near the right-of-way. Regional funding equity drove the decision to move forward with planning and a downsizing of the project made it a justifiable investment. Ridership on the line has met projections made early in the planning process but is far short of the revised numbers that were eventually used to justify federal and regional funding.[164]

In spite of the heavy rail technology required by the Federal Railroad Administration on the alignment and limited operating schedule, neither Metro nor TriMet consider this a commuter rail project.[165] According to Metro planners, the project is essentially a cost-effective LRT extension in a technologically constrained corridor.[166] Regional planners suggested that the service has already spurred several transit-oriented real estate investments, akin those along MAX light rail lines, in spite of the current operating limitations. They hope to one day expand to all-day service and gradually invest in the corridor (e.g., double tracking) until it can be cost effectively transitioned to MAX LRT technology and provide a one-seat ride to downtown Portland on the existing Westside LRT corridor.

Interviewees suggested that the project's success has not been hampered by technology or the setting of the project but by the frequency of service and the limited hours.[167,168] They believe that improved service could even justify a costly shift in alignment from the existing freight rails over limited distances to provide greater accessibility to certain land uses, particularly a mall that is a major regional trip generator.

Interviewees indicated that they used many of the same rules of thumb for designing WES commuter rail and MAX light rail projects. In general, they believe our proposed indicator-based method could have been applied to WES if it took into account the reduced operating schedules that are typical of commuter rail.

[162] Interviewee AA, in-person conversation, 8/7/12
[163] Interviewee AI, in-person conversation, 8/7/12
[164] Interviewee AM, in-person conversation, 8/7/12
[165] Interviewee AA, in-person conversation, 8/7/12
[166] Interviewee BL, in-person conversation, 8/7/12
[167] Interviewee AI, in-person conversation, 8/7/12
[168] Interviewee AB, in-person conversation, 8/7/12

I.5 University & Medical Center Extensions (Salt Lake City, UT)

The 3.8-mile, seven-station extension of the Salt Lake City, Utah, TRAX light rail system connects the original starter line in downtown Salt Lake City to the University of Utah campus to the east. Though conceived of and planned as part of one larger project, the University and Medical Center extensions represent two subdivisions of that original line. The phased implementation ensured the first phase from downtown to the University of Utah campus, the university extension, was in service when the 2002 Winter Olympic opening ceremonies were held in the University of Utah football stadium. This case study offers insights into the myriad measures of success and indicators of success that can influence transit project proposals, particularly rules of thumb used to define course-grained transit system plans.

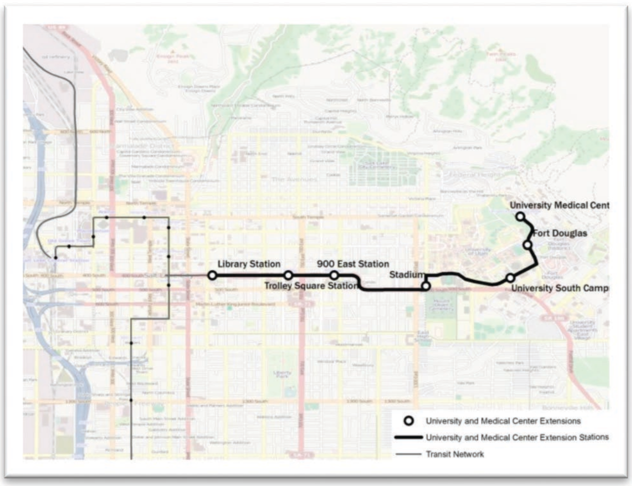


Figure I-7: Route Diagram for Utah Transit Authority (UTA) University and Medical Center Extensions, Salt Lake City, Utah

I.5.1 Expanding Salt Lake City Rail Transit

Initial planning for a light rail system in the Salt Lake City area began in 1983 and, motivated as a mitigation measure for Interstate 15 expansion, the North-South Corridor was identified as the region's initial rail project in 1988. Utah Transit Authority (UTA) utilized a federal grant to acquire and preserve right-of-way in the same time period (FTA 2007). The concept of the 15-mile North-South light rail project was included in a tax funding plan that failed when put before voters in 1992.[169] In spite of the tax measure's failure, planning for an East-West rail project between the Salt Lake City Airport and the University of Utah began in 1993 in anticipation of several major events (FTA 2007). After Salt Lake City won its 1995 bid to host the 2002 Winter Olympics, light rail planning was fast-tracked. A Major Investment Study conducted in 1996 identified a 10.11-mile light rail line from the Salt Lake City International Airport to aid with transportation during the 2002 Olympics.

[169] Interviewee BM, in-person conversation, 8/20/12

Opened in December 1999, the 15-mile starter line from downtown Salt Lake City south to Sandy Civic Center was paid for largely from Interstate 15 reconstruction funds reallocated to the project soon after the Winter Olympic announcement.[170] Ridership on the initial line quickly surpassed projections, and voters passed a quarter-cent sales tax to fund future transit expansion in November 2000, particularly the "West-East Line." Due to federal funding limitations and time constraints related to the 2002 Winter Olympics, the West-East Line was divided into four separate segments in 1999: the Airport Extension, the Downtown Loop, the University Line, and the Medical Center Extension of the University Line (FTA 2007). In spite of dividing the line for funding purposes, by all other measures the lines were considered one project and there was little doubt that all four segments would eventually be constructed.[171]

In early 2000, the FTA approved the final design on the scaled back portion of the West-East alignment that extended from the existing North-South line in downtown to the University of Utah. In mid-2001, UTA received federal approval to begin final designs of the medical center extension as well. Construction commenced on the University Line in the spring of 2000 and a Full-Funding Grant Agreement was signed in August 2000 (FTA 2007).

The relatively fast pace of approvals and construction were based on a desire to open the University Line in time for the 2002 Winter Olympics. Perhaps due to the expedited timeframe, preferred plans for the University and Medical Center projects changed little during the course of planning (Parsons 1999, Parsons 1997).

The first phase of the extension, to the University of Utah football stadium (Stadium Station) was opened on December 15, 2001 (FTA 2007). Construction of the medical center extension followed immediately after construction was completed on the University Line, significantly before a Full-Funding Grant Agreement was signed in May 2002. The second phase, bringing the line to its current terminus at the University Medical Center, was opened on September 29, 2003, a year after the Olympic Games and a full 15 months ahead of schedule (*Salt Lake Tribune* 9/28/03). It is thought that the cost and schedule efficiencies were the product of the seamless construction process between the first and second lines (FTA 2007). UTA reports the cost of the extensions at $148.5 million and $89.4 million, respectively, and roughly 65% ($96.5 million) and 60% ($53.6 million) of the extensions were federally funded (FTA 2000, FTA 2002). The remainder of the projects were funded by local sales tax revenues.

I.5.2 University/Medical Center Operations

UTA's 3.8-mile, two-part extension proceeds east from downtown Salt Lake City in the center lanes of E 400 S (also known as University Boulevard), briefly swinging south onto E 500 S before continuing east and entering the University of Utah campus adjacent to the university's football stadium. The university/medical center extension proceeds east from the stadium and then north to the medical center campus. The first phase of the extension, to the university, included three new stations along 400 S and a station at the University of Utah football stadium. The second project extended the line a further three stations, all of which serve the University of Utah campus, to its current terminus at the University Medical Center.

Under current service patterns, the University/Medical Center extension is part of the Red Line, which shares tracks with the Blue Line (North-South Line) south of downtown Salt Lake City until

[170] Utah Transit Authority; http://www.rideuta.com/uploads/FactSheet_History_2012new.pdf; accessed 10/22/12
[171] Interviewee BN, in-person conversation, 8/20/12

branching to the west at Fashion Place West along the more recently opened Mid-Jordan extension to Daybreak Parkway. The Red Line runs seven days a week, from roughly 5AM to 12AM Monday through Saturday and from 9:30 a.m. to 11:00 p.m. on Sundays. Service is provided at 15-minute headways throughout the day on weekdays, and every 20 minutes on weekends. The vast majority of trains operate the full length of the line, with the exception of several of the earliest and latest trains.

Prior to opening, the University Line corridor was served by multiple UTA bus routes (Chatman 2012). Bus service on the eastern portion of the University Line, along 400 South, was mostly replaced by light rail. Also, the bus routes in the downtown area were modified to facilitate better connectivity between light rail and bus. Significant bus service along 200 South, considered a less-congested and more bus-friendly route than 400 South, continues to operate between downtown and the campus.[172]

According to the TCRP H-42 transit project database, ridership at stations along the two project segments were approximately 7,300 and 3,400 per weekday. This ridership nearly meets forecasts estimated for 2020. In 2020, ridership was expected to be 7,600 weekday boardings on the downtown to university segment of the line, with 3,100 of those expected to be new transit riders (FTA 2000). Also, ridership on the medical center extension was predicted to be 4,100 on an average weekday, with 3,400 new riders (FTA 2002).

I.5.3 Planning a Successful Transit Project

As noted, planning for the University/Medical Center extension was initially included in a larger West-East Line from the Salt Lake City International Airport, due east to downtown, and then further east to the University of Utah campus. The Wasatch Front Regional Council (WFRC), working with UTA, completed environmental studies in 1997 and 1999 on the 10.9-mile West-East Corridor. These documents were required because the project sought funding from FTA, which also influenced the design of the line. A great deal of information about measures of success and indicators of success can be gleaned from planning documents for the West-East Line, the debates that occurred over the alignment, and the after-the-fact assessments of the line that interviewees shared during our conversations about the University and Medical Center extensions.

During early transit system studies, regional planners hired consultants to identify routes that could be viable rail transit projects.[173] The regional evaluation considered three factors sequentially: major regional destinations, origin and destination pairing between major destinations, and existing traffic congestion on corridors linking paired regional destinations. As a regional planner expressed during our interview, "[Automobile congestion] is the reason people will ride transit." The West-East Corridor concept arose out of this form of high-level system planning analysis.

Whereas the region's original North-South alignment had been motivated largely by bus rationalization and availability of right-of-way, the West-East Corridor was identified because it met the primary criteria of the rail transit study because it served the region's primary airport, downtown Salt Lake City, and the University of Utah and congestion between them would only grow worse.[174] In fact, the university was the second biggest generator of traffic in the state, second

[172] Interviewee AE, in-person conversation, 8/20/12
[173] Interviewee BN, in-person conversation, 8/20/12
[174] Interviewee BM, in-person conversation, 8/20/12

only to downtown Salt Lake City.[175] Of particular interest to Utah planners in the early 1990s, the proposed line passed several Olympic venues located in downtown Salt Lake City and on the University of Utah campus, and 47% of Olympic lodging was located within the West-East Corridor. (Parsons 1999)

In addition to those primary destinations, documents claimed that high levels of transit and travel demand existed because of special trip generators along the corridor including: the LDS Church's downtown campus, Utah State Fairpark, Delta Center basketball arena, Salt Lake Arts Center, Abravanel Hall, Salt Palace Convention Center, Capitol Theater, John W. Gallivan Utah Center, Hansen Planetarium, Fine Arts Museum, Museum of Natural History, Pioneer Memorial Theater, Kingsbury Hall, Rice-Eccles Football Stadium, John M. Huntsman Center (Parsons 1999). Planning documents suggested that many of the trips generated by these uses occurred within the corridor as people moved from the airport, campus, and venues to hotels and restaurants also located along the route.

At the behest of the FTA, several transit modes were considered for the service along this destination-rich corridor. Among them were standard bus service, bus lanes, and LRT (Parsons 1999). Bus lanes were motivated by FTA's interest in pursuing bus rapid transit in the mid-1990s.[176] While a feasible and cost-effective option, the region argued that BRT would eventually need to be upgraded to light rail in the corridor at much greater expense and with greater service impacts. Light rail was preferred because of its compatibility with the existing system and the area's aesthetic, the perceived reliability improvements relative to bus service, and the role rail had played in defining the region's long-term land use vision (Parsons 1997). Light rail was also considered superior at the time because of the region's focus on air quality, an argument based on the electric motive power and rail's ability to attract choice riders and reduce regional VMT (Parsons 1997).

There was also a desire to provide a world-class urban transit connection to the University of Utah campus where many Olympic venues were located.[177] The University of Utah was amenable to the light rail transit but argued that it would be best for it to remain on major roadways so that the center of campus could remain a pedestrian-oriented environment. Some planners argued that light rail could be integrated into the heart of the dense campus environment but it was resolved that shuttle services would help move people from rail to the various quadrants of the campus.

Past the main campus area, on the easternmost end of the West-East Corridor, planners considered serving either the medical center to the northeast or a research park to the southeast. They determined that existing and future land uses favored the medical center alignment. As one planner explained, research parks have "long distances between the streets and buildings in a park-like setting: not real transit conditions."[178] Without conducting extensive analysis, the additional trip distance between transit stations and employment destinations in the research park were determined to be indicative of low ridership. Ultimately, it was determined that there was "a much bigger concentration of trips to the medical center."[179] Additionally, transit planners learned that master plans for the University of Utah campus, including the medical center, called for additional facilities within the existing footprint.[180]

[175] Interviewee BN, in-person conversation, 8/20/12
[176] Interviewee BN, in-person conversation, 8/20/12
[177] Interviewee BN, in-person conversation, 8/20/12
[178] Interviewee AE, in-person conversation, 8/20/12
[179] Interviewee BN, in-person conversation, 8/20/12
[180] Interviewee AE, in-person conversation, 8/20/12

Future land use changes were also a consideration when planners evaluated which alignment they would recommend for the connection between downtown and the University of Utah. Planners generally evaluated potential land use changes based on local land use policies, but did not attempt to quantify the scale of real estate development that might have occurred because of the transit project (PBQ&D 1994). Local government staff was adamant that the alignment be located on 400 South because they saw more development potential along that corridor than 200 South, an alternative route along a residential corridor that provided access to the University of Utah's ceremonial campus entrance and was unlikely to experience land use changes.[181] In fact, the city had previously promised the 200 South neighborhood that no density increases would be allowed.

The impetus for the 200 South proposal had been automobile traffic priorities along 400 South. Early transit feasibility studies had identified the 400 South Corridor due to physical constraints on parallel routes and transit planners advocated for the route as planning progressed.[182] The local government agreed to take over maintenance of the roadway, a state route, from Utah DOT to facilitate the implementation of light rail. However, pressure to relocate the project to 200 South or another 400 South alternative came from Utah DOT when their planning process for the Interstate 15 corridor identified 400 South as an interchange. Legislators and others forced a re-evaluation of the light rail route. Ultimately, a compromise solution was developed that retained capacity on the roadway by sharing left turn lanes with light rail tracks. While an operational setback, planners believe the corridor is preferable for a number of reasons.

While planners evaluated a number of measures of success during the planning process, they have found the constructed alignment has been successful for a number of unanticipated reasons. For instance, the transit project was anticipated to influence real estate development on the corridor and a recent UTA study has identified $1 billion in private real estate investment along the corridor.[183] As the UTA's community outreach staff person has stated, "Rail is a big motivator for developers."[184] However, it was not anticipated that the rail would be so successful at allowing for significant public sector real estate investment on the University of Utah campus. Prior to the light rail line, the university had 10,000 occupied parking stalls. In recent years, even with the addition of more occupiable space on campus and more student enrollment, the university experiences demand for approximately 7,000 parking stalls.[185] Development has occurred on several surface parking lots. With the shift in travel patterns the university is able to better utilize its limited land area while avoiding pushing parking demand into neighborhoods. Many donations received by the university will fund new structures but will not pay for parking.[186] Overflow parking into nearby neighborhoods had historically been a major concern and it was difficult to build buildings using donations without identifying additional funding sources to build attendant parking facilities. However, the utilization of transit services by students and staff has allowed the university to grow without adding parking.

In another instance, transit planners anticipated the traffic mitigation benefits of a light rail project but turned their attention to the traffic safety benefits of the transit project only during the later project design phases. West-East Corridor plans focused on the need for a transit alternative in the growing region as vehicle-miles traveled were anticipated to rise faster than population or

---

[181] Interviewee BN, in-person conversation, 8/20/12
[182] Interviewee BN, in-person conversation, 8/20/12
[183] Interviewee AE, in-person conversation, 8/20/12
[184] Interviewee BM, in-person conversation, 8/20/12
[185] Interviewee BO, in-person conversation, 8/20/12
[186] Interviewee AE, in-person conversation, 8/20/12

employment and roadway capacity would not keep pace (Parsons 1999). Yet, highly localized traffic safety benefits were produced as the light rail plan helped to address problem intersections and pedestrian safety issues. The implementation of a roundabout and significant pedestrian infrastructure provided a safer environment, particularly near the University of Utah.[187]

While it was anticipated by planners that connecting regional trip generators would be beneficial for transit, they did not anticipate the operational efficiencies that were gained by serving the University of Utah campus in particular. As one planner explained, students and staff generate significant midday ridership due both to the staggered class schedules of students and the opportunity for students and staff to reach lunch destinations and convenience retail just off campus.[188] While adding significantly to the ridership on the line, this off-peak demand does not require UTA to add additional train cars or increase service frequency.

By almost every measure, the University and Medical Center extensions of the TRAX light rail system were considered a success by interviewees. Success has been defined a number of ways, many of which were not stakeholder priorities during the planning process. This suggests that some of the criteria that informed the conception of these projects—perhaps the density of destinations and the significant barbell trip generators/attractors—may effectively address multiple measures of success simultaneously. The successes have furthered the region's resolve to implement an extensive light rail system. The two extensions were originally envisioned to be part of a West-East Line from the airport to the university and the airport extension of that project is expected to open in 2013. Adding to the University and Medical Center projects, the airport connection will fulfill the complete vision of the late 1990s major investment studies (*Salt Lake Tribune* 5/1/12).

I.5.4 Commuter Rail Insights – FrontRunner North

The Salt Lake City region is also home to FrontRunner commuter rail service. Again, we asked interviewees about their planning of commuter rail service, the differences they see between commuter rail and other fixed-guideway services, and the applicability of our indicator-based method to such transit proposals.

The 44-mile, nine-station FrontRunner North project extends from downtown Salt Lake City to Ogden in the north, cost $551 million to build, and was completed in 2008 (UTA 2005).[189] An expansion of the service is now operational from downtown Salt Lake City to Provo in the south of the region. The project was planned and built cooperatively by regional bodies and UTA. Funding came from the region and FTA.

The service connects northern cities and suburban communities to Salt Lake City along a route that parallels Interstate 15. Service operates from 5:00AM to 11:30AM Monday through Friday and 7:00AM to 11:30AM on Saturday.[190] Trains operate every 30 minutes in the peak and every hour midday and evenings during the week, and every hour and a half on Saturdays except for special services provided for events. Fares vary by distance. UTA buses serve all stations and extensive park-and-ride facilities ranging from 235 stalls to 874 stalls are located at all stations outside of downtown Salt Lake City.

---

[187] Interviewee BN, in-person conversation, 8/20/12

[188] Interviewee BP, in-person conversation, 8/20/12

[189] Utah Transit Authority; http://www.rideuta.com; Accessed 10/19/12

[190] Utah Transit Authority; http://www.rideuta.com; Accessed 10/19/12

Interviewees believed the success of the FrontRunner service is its centrality in the valley, competitive travel times, and high frequency.[191] The route is aligned with the long, linearly-constrained valley geography that has defined the region's urban growth. The rails parallel an Interstate corridor. Stations have both excellent park-and-ride access and bus feeder service along the major arterials that run perpendicular to the North-South Corridor.

Ridership was lower than initially anticipated. Planners attributed this to the Interstate 15 widening that occurred just before opening as well as the economic downturn that has reduced commute travel and roadway congestion in the region.[192] Interestingly, the line was proposed as a mitigation measure for congestion on the adjacent Interstate that was simultaneously widened. The service has been close to ridership forecasts more recently, which planners attribute to the high frequency, economic recovery, and special event services provided at various times during the year.

Interviewees indicated that they used many of the same rules of thumb for selecting the FrontRunner commuter rail alignment as TRAX light rail routes during their regional system planning process.[193] However, they suggested that our proposed indicator-based method would be more reliable if it included multiple commuter rail projects because they felt service characteristics, particularly the limitations of railroad operations related to speed and service frequency, made commuter rail services significantly different from other rail transit modes.

---

[191] Interviewee BN, in-person conversation, 8/20/12
[192] Interviewee AE, in-person conversation, 8/20/12
[193] Interviewee BN, in-person conversation, 8/20/12

I.6 Branch Avenue Extension (Washington, DC, Prince George's County, MD)

The Washington, D.C., region, including the District of Columbia and parts of the states of Maryland, Virginia, and West Virginia, is served by multiple modes of fixed-guideway transit. The primary urban rail transit system serving the District is the Washington Metropolitan Area Transit Authority's (WMATA) 106-mile Metrorail subway system. The Branch Avenue extension—also called the Outer F extension in planning documents—extends from Anacostia Station in Southeast Washington, D.C., to southern Prince George's County, Maryland, at the interchange of the Capital Beltway and Branch Avenue (WRRRTS 1992). The five-station, 6.5-mile-long section of the Green Line was opened on January 13, 2001, after more than 30 years of planning. This Branch Avenue case study suggests that early plans can be very difficult to modify, that transit system plans have been based on indicator-based methods, and that geographic and social equity are critical political considerations for transit planning, so much so that they can outweigh basic measures of success like ridership and project cost.

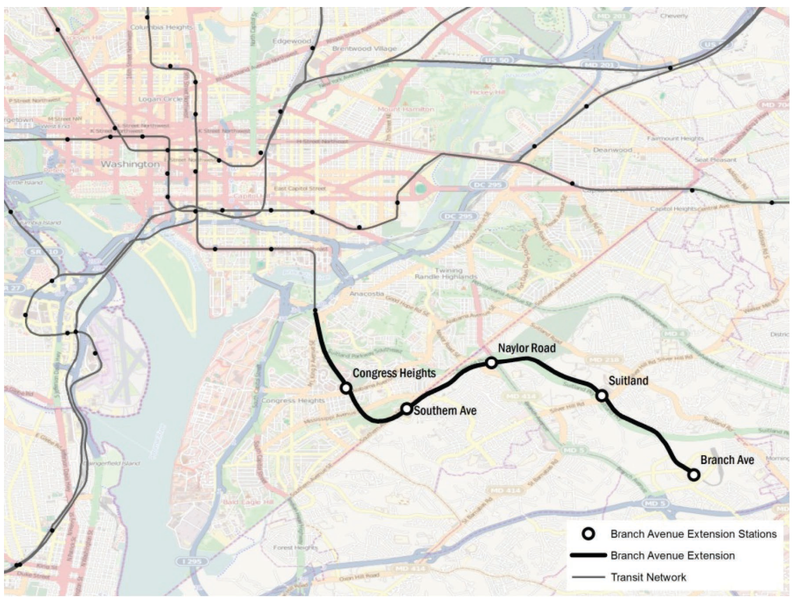


Figure I-8: Route Diagram for Branch Ave. Green Line Extension, Washington, DC

I.6.1 Expanding Washington D.C. Rail Transit

The Washington, D.C., region's subway was initially designed in the 1950s when Congress authorized the National Capital Planning Commission and the National Capital Regional Planning Council to conduct a four-year Mass Transportation Survey (U.S. DOT 1975). In response to 1959 hearings on the planning survey, Congress formed the National Capital Transportation Agency that proposed an 83-mile rail system for the region in 1962. After the formation of the Washington Metropolitan Area Transit Authority in 1967, the region's rail plan was revised to a 98-mile system that included an alignment to the southeast of the U.S. Capitol along Suitland Parkway that would terminate near the Branch Avenue interchange with the Capital Beltway.

As of 1975, schedules called for the entire 98-mile system to be under construction as of July 1981 (U.S. DOT 1975). The Outer F segment of the proposed system, the Branch Avenue corridor, was one of several segments considered worthy of further study and scheduled to be among the last segments constructed (WMATA 1993). Ultimately, system studies lasted into the middle of the 1980s with over 50 Outer F segment alternatives and 20 Outer F station and yard layout alternatives considered.

A primary debate over the Outer F route related to a realignment proposed in 1976 (Peat, Marwick, Michell & Co. 1977). Due to the expense of crossing the Anacostia River and the land takings that would be required, Washington, D.C., officials proposed a new crossing and a corresponding new southerly route through a low-income community within the District.[194] Eyeing an opportunity, landowners and politicians in Prince George's County, Maryland, promoted the District's proposal as well as a new terminus near a horse racing track long slated for redevelopment by the county.[195] The debate led to a change in the officially adopted alignment, a lawsuit, and considerable re-analysis of alternatives. Environmental document experts were hired at WMATA to address some of the issues that had made the agency susceptible to the lawsuits, and a former U.S. Department of Transportation administrator was contracted to negotiate a resolution.[196]

Ultimately, a modified version of the original Branch Avenue route—one that passed through the low-income Congress Heights neighborhood—was selected in 1993 (WMATA 1993). The extension was 6.4 miles long and consisted of approximately equal-length subterranean, surface, and elevated tracks. Construction on the $900 million project began in late 1995 and the line was opened on January 13, 2001 (*Washington Times* 9/24/95, *Washington Post* 1/13/01).

I.6.2 Branch Avenue Operations

The 6.4-mile Branch Avenue extension includes the last five stations built along the 21-station, 23-mile Metrorail Green Line. Service runs the full extent of the line from Branch Avenue in the south to the Greenbelt Station in the north. Along the Green Line, 13 stations are located in the District of Columbia, four stations are located northeast of Washington, D.C., in north Prince George's County, Maryland, and four stations of the Branch Avenue extension are located south of Washington, D.C., also inside Prince George's County. North of L'Enfant Plaza Station, just south of the National Mall, the Green Line and Yellow Line merge and co-operate northward along the remainder of the route.

The Green Line provides connections to the Orange and Blue Lines at L'Enfant Plaza Station and two connections to the Red Line, one at Gallery Place Station in the central business district and the other at Fort Totten Station in the north of the District.

Service is operated throughout regular service hours (Open: 5 a.m. Monday-Friday, 7 a.m. Saturday-Sunday; Close: midnight Sunday-Thursday, 3 a.m. Friday-Saturday nights) and at 12-minute frequencies during most hours except 6-minute frequencies during weekday morning and afternoon peaks.[197]

Upon opening in 2001, the project experienced greater than anticipated ridership (*Washington Post* 1/19/01). Metro anticipated that after six months of service 18,000 daily riders would board at the stations along the new extension. However, on the second day of operations, ridership reached approximately 19,500 boardings. After only two weeks, ridership exceeded 30,000 (*Washington*

[194] Interviewee BQ, telephone conversation, 7/11/12
[195] Interviewee BR, telephone conversation, 7/19/12
[196] Interviewee BQ, telephone conversation, 7/11/12
[197] Metro Pocket Guide <http://www.wmata.com/pdfs/pocket_guides/english.pdf>

Post 1/25/01). Much of the difference in predicted and actual ridership was thought to be driven by free parking that had been offered temporarily at the new Green Line stations. Estimates had suggested 4,000 riders would switch from the Blue Line—where parking costs were $1.75 per day—but the actual number was closer to 12,000 riders. Though the Green Line is still known for its exceptional ridership, after several months and revisions to the parking policy, ridership normalized at levels in line with predictions. As found in the TCRP H-42 database, ridership was just over 25,000 as of 2009.

I.6.3 Planning a Successful Transit Project

The five-station Outer F alignment of the Washington, D.C., Metrorail system was initially proposed by the National Capital Planning Commission and the National Capital Regional Planning Council as part of a high-level rail transit system plan. Specific project plans were developed by National Capital Transportation Agency, predecessor to WMATA, in 1962. More than 30 years of detailed planning was carried out primarily by WMATA and its consultants with construction commencing in 1995. The FTA also played a role in moving the project through the federal environmental review process. The U.S. Congress, State of Maryland, and Prince George's County were the primary government bodies involved in the planning of the project.

The 98-mile system plan adopted in 1967 was motivated by the National Capital Regional Planning Council's 1961 wedges and corridors concept presented in their Year 2000 Policies Plan. (U.S. DOT 1975) The transit services were intended to be competitive with automobile travel to alleviate congestion, address air quality concerns related to vehicle-miles traveled, and provide an enhanced experience relative to existing bus services, which were suffering from competition from private automobile travel. The wedges and corridors plan sought to focus urban growth every few miles at jointly located transit stations and roadway intersections along radial transportation corridors, thus allowing for the preservation of green space wedges between the corridors. A critical element of 1961's Year 2000 Policies Plan was the development of a circumferential freeway that would connect the entire region via interchanges with the radial corridors.

Notably, the plan defined radial corridors emanating in all directions from the central city and transit projects were proposed in each radial corridor to achieve an equitable allocation of benefits.[198] While some corridors were aligned with fast-growing suburbs where it was imagined Metrorail would alleviate growth pains and allow for further economic development, in other corridors—like the Outer F alignment—Metrorail's planners considered the benefit to be largely limited to improved transit performance for transit-dependent populations and the ability to attract middle-class riders that would appreciate central city parking savings.[199] Local governments, like Prince George's County, assumed that the economic development benefits associated with Metrorail were universal and system promoters, including WMATA and its consultants, did little to correct this notion because it benefited their causes.

Early system plans focused on operating cost coverage as a key success metric.[200] Carried out by a firm that has since become a global accounting firm, KPMG, the early plans were essentially financial forecasts based on "customer" patronage assumptions (i.e., ridership forecasts). A primary assumption of those plans was that many Metrorail patrons would access the system by private

[198] Interviewee BQ, telephone conversation, 7/11/12
[199] Interviewee BS, telephone conversation, 7/30/12
[200] Interviewee BS, telephone conversation, 7/30/12

automobile. Surface park-and-ride facilities at each of the outlying stations were sized to accommodate 500 or 1,000 stalls according to the earliest plans (U.S. DOT 1975). During the late stages of system planning, it was determined that the Outer F alignment should reach the circumferential beltway for easy automobile access or not be built.[201] In fact, later studies accommodated 3,000 stalls at the Branch Avenue Station terminus near the Branch Avenue and I-495 interchange because a lack of parking would have dampened ridership forecasts.[202] (Today, 3,074 stalls are located at the Branch Avenue Station and parkers pay a $4.50 daily fee.[203]) Also, in early iterations of the alignment, stations were consistently located at the intersection of the Suitland Parkway and major arterial roadways (e.g., Alabama Avenue) for ease of automobile access into stations without impacting residential streets (U.S. DOT 1975).

Success, defined by system-wide operating cost coverage, was also heavily influenced by the financial windfall generated when system planners assumed long-distance commuter bus routes could be terminated.[204] The bus services, which generally traveled along congested roadways and contributed to central city air quality issues, would be replaced by short-haul bus trips along less-congested suburban roadways that terminated at far-flung Metrorail stations serving as suburban bus transfer hubs. Each of the Outer F stations was originally slated to have between three and seven bus bays to accommodate rail-to-bus transfers (U.S. DOT 1975). Like parking stalls, this capacity was increased further during the planning process (WMATA 1993). (Today, there are 15 bus bays at the Branch Avenue Station.[205])

The concepts put forward by regional plans dictated that the Outer F alignment be co-located with Suitland Parkway, and assumptions made by project planners produced a proposal which relied heavily on travel time competitiveness and central city parking savings as drivers of ridership.[206] A four-step transportation demand model developed by the regional council in the 1970s produced a ridership forecast that confirmed the feasibility of the early system plan (U.S. DOT 1975). With the exception of only a few stations and the route of the Branch Avenue alignment, the current WMATA system reflects the 1967 plan (Schrag 2006).

Detailed studies of the Anacostia River crossing conducted in the mid-1970s led to a discussion of alternative alignments. The original crossing proposal required the line to pass under the Navy Yard between the Waterfront Station and the proposed Downtown Anacostia Station. Because of the cost of environmental cleanup within Navy Yard, the required demolition of several historical structures within Navy Yard, and concerns about construction impacts in Downtown Anacostia (along Good Hope Road) several alternative crossing concept plans were put forward in 1976 (Wallace, McHarg, Roberts and Todd 1976). The alternative that received the greatest attention shifted the Navy Yard Station considerably westward to allow the line to turn south and cross the Anacostia without passing through or under Navy Yard proper. This westward shift in alignment put the crossing on path with a relatively undeveloped linear greenway (as opposed to the Suitland Parkway corridor) that provided a fairly straight shot to a declining horse racing facility, the Rosecroft Racetrack, just south of the Capital Beltway.

Analyses began to consider both a rerouting of the original alignment (still along Suitland Parkway) and the newly proposed route to the Rosecroft Racetrack. In the 1977 EIS, a third

---

[201] Interviewee BS, telephone conversation, 7/30/12
[202] Interviewee BS, telephone conversation, 7/30/12
[203] Washington Metropolitan Area Transit Authority; http://www.wmata.com/rail/parking/; Accessed 10/22/12
[204] Interviewee BT, telephone conversation, 7/24/12
[205] Visual Survey of Satellite Image; Google Maps; Accessed 10/22/12.
[206] Interviewee BQ, telephone conversation, 7/11/12

alignment was proposed that followed the Rosecroft proposal for half its distance and then turned northeastward along Southern Avenue (the border between the District of Columbia and Maryland) to Suitland Parkway where the route followed the original Branch Avenue alignment to its terminus at Branch Avenue Station (S-Curve alignment) (WMATA 1984). While this alternative was heavily studied, political interests in Maryland focused on the redevelopment opportunities at Rosecroft Racetrack.

Proponents of the Rosecroft alternative included Prince George's County officials who saw declining tax revenues from the racetrack and landowners who sought to redevelop the declining horse racing facility and surrounding property into a commercial center at the scale of the emerging Tyson's Corner area or the contemporaneously proposed Reston Town Center development, both in the Virginia suburbs.[207] The arguments were so convincing that the Prince George's County Council approved the Rosecroft alignment and WMATA board, made up of four Virginia, four District, and four Maryland representatives, followed suit in 1978 (Washington Post 5/10/78). Environmental documents produced by WMATA in 1979 still considered the Branch Avenue route as an alternative, partly because of acrimony between Maryland officials over the alignments (WMATA 1979).[208] Members of the Maryland House of Representatives suggested that the route was unduly selected and business owners along the Branch Avenue alignment sued in federal court over economic harm caused by the rerouting (Washington Post 2/27/80, Washington Post 10/14/80). The debate contributed to project delays because ongoing construction of other portions of the Green Line were dependent on decisions regarding the location of the Anacostia River Crossing. Because staff saw no way to resolve the conflict while it was being adjudicated, WMATA board members decided to set strict timetables for the cases to be settled and construction to proceed on the Rosecroft alignment by the end of 1984.[209]

The three viable alternatives—a meandering route following Suitland Parkway, a relatively direct route to Rosecroft Racetrack, and an S-Curve following a portion of the Rosecroft alignment but terminating at Branch Avenue—were the focus of studies and public meetings in the early 1980s.[210] It is in the resolution of the debate that our research found a well-documented debate over definitions of transit project success.

[207] Interviewee BR, telephone conversation, 7/19/12
[208] Interviewee BQ, telephone conversation, 7/11/12
[209] Interviewee BR, telephone conversation, 7/19/12
[210] Interviewee BQ, telephone conversation, 7/11/12

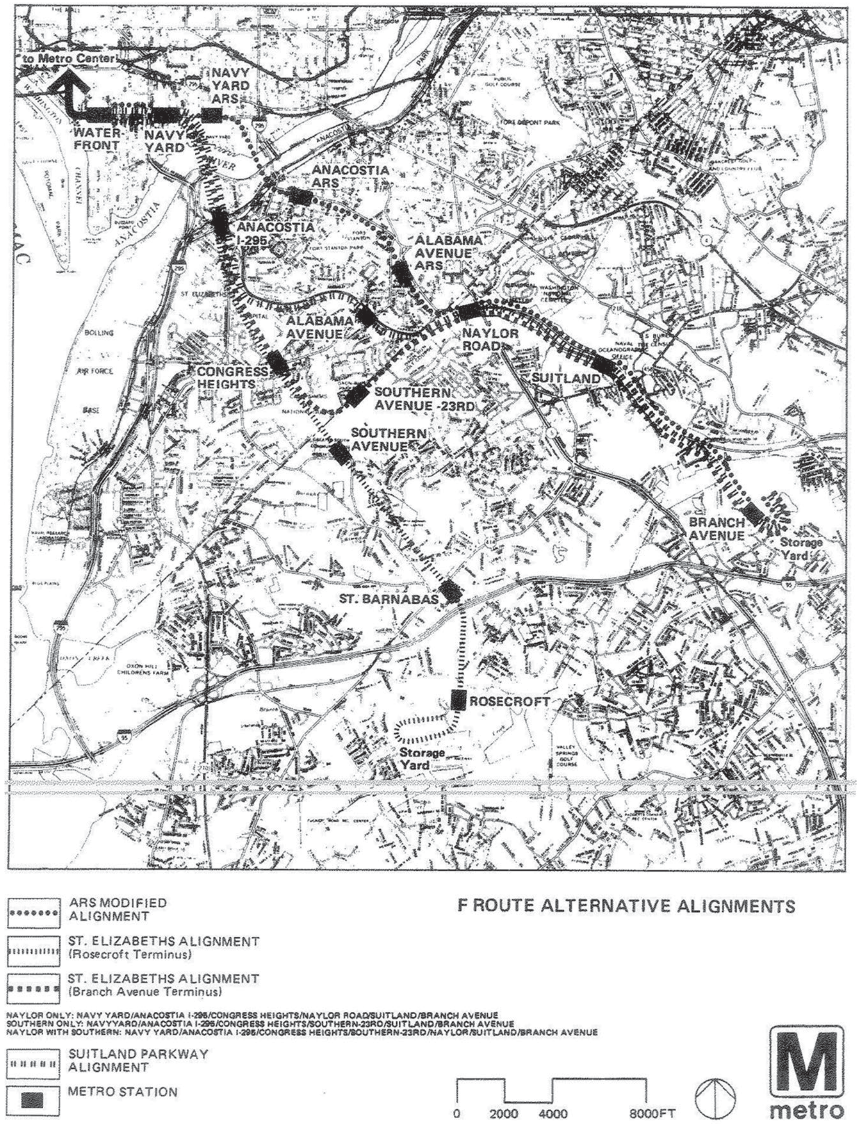


Figure I-9: Alternative Alignments (Easternmost Infeasible Because of Navy Yard Station Location) (WMATA 1984)

According to documents produced after the alignment debate was settled, the S-Curve to Branch Avenue alternative was officially considered preferable due to higher projected ridership, better transit service to transit-dependent populations, fewer displacements, greater secondary development potential, greater reduction in vehicle-miles traveled, and more regional air quality improvement (WMATA 1993). While there were technical analyses to quantify many of these measures of success, project planners found that politicians ignored data that did not corroborate this opinion and relied heavily on simple indicators of success that "ended up playing as much if not more in the final decision than the actual technical data."[211]

[211] Interviewee BS, telephone conversation, 7/30/12

Among all of the issues discussed during the process, one could argue that the environmental and historical impacts were the most influential.[212] The impacts on Navy Yard's historical structures, in addition to the environmental cleanup required at several sites within Navy Yard, were the impetus for discussing alignments outside of that defined by the 1967 plan. Later, when a toxic ash dump was found in the path of construction at the Elizabeth Hospital facility and when local environmental advocates became vocal about impacts to creeks, including Oxen Run Creek, the route was quickly altered again. From a political standpoint, these were indicators of cost, delay, and probable project failure that were to be avoided at all costs.[213]

Another very salient measure of project success was the number of transit-dependent households that would be served by Metrorail stations. Throughout the process, comparisons of alternatives included the number of census tracts in the station service areas that were defined as "very highly transit-dependent" (WMATA 1979). An analysis of 1980 census data determined that between 21,000 and 30,000 highly transit-dependent people would be served by various alignment alternatives. The Rosecroft alignment was projected to serve only 21,100 transit-dependent people, the lowest of any alternative. This was a very powerful political argument used against the Rosecroft alignment.[214]

According to at least one analysis, the Suitland Parkway alignment would have actually served the most transit-dependent people (WMATA 1984). However, District politicians had become wedded to the Congress Heights Station location that was part of the board-approved Rosecroft alignment.[215] Congress Heights became the symbol of a transit-dependent community and any suggestion to not serve the area was considered an injustice. The service to Congress Heights was a strong argument for the Rosecroft or the S-Curve alignments rather than the Suitland Parkway alignment. Later, in spite of the data suggesting that the Suitland Parkway alignment would have stations closer to more transit-dependent individuals, the lack of rail transit in Congress Heights was identified as a "serious problem" because fewer than 40 percent of the adult residents in the Congress Heights area owned an automobile (WMATA 1993). This suggests two things. First, transit plans can be very sticky once a constituency identifies with a proposal. Second, sometimes the most salient indicator of success for a project is whether or not a particular location will be served directly by a station. In fact, this is the essence of the entire Rosecroft debate.

Another social impact that was highly sited in the alignment debate was the number of displacements that would be required. Aside from the Navy's resistance to the alignment passing under its facilities, another argument to move the Anacostia River crossing was the potential impact to businesses along the original route. The original route would have passed through a dense commercial street with predominantly African-American-owned businesses. That portion of the line would have required the taking of numerous commercial properties and the closure of the street for several years as cut-and-cover construction took place. As one planner phrased it, "We had considered putting the Anacostia station in the middle of [the commercial area] and it would have destroyed it."[216]

Comparisons of the other alternatives showed that they would all require fewer takings than the original proposal. While each of the three alternatives would have required approximately the same

[212] Interviewee BQ, telephone conversation, 7/11/12
[213] Interviewee BR, telephone conversation, 7/19/12
[214] Interviewee BQ, telephone conversation, 7/11/12
[215] Interviewee BQ, telephone conversation, 7/11/12
[216] Interviewee BQ, telephone conversation, 7/11/12

number of business and institutional takings, an important differentiator between the alternatives was the number of residential units that would be demolished. While other alignments would have required takings of greater acreage (including existing public parkland), the Rosecroft alternative was considered weakest because it would have required 125 residential units to be taken (versus 93 or 52 for the S-Curve and Suitland, respectively) (WMATA 1984).

One of the strongest arguments for the Rosecroft alignment was the real estate redevelopment potential at the terminus station.[217] However, according to data collected as part of the review process, there was as much or more development potential—defined by developable acres—within 2,000 feet of Prince George's County stations along the S-Curve and Suitland alignments (WMATA 1984). That said, after several experiences with development occurring around stations in the Virginia suburbs and downtown, Metrorail was generally considered a motivation for economic development no matter where stations were built or what land uses surrounded them.[218] Thus, an alignment like the S-Curve, which had one more station than the other alternatives, was perceived to have greater potential economic development impact.[219] The size of developable parcels and the number of stations were statistics used by proponents of the Branch Avenue alignment to neutralize one of the major arguments for the Rosecroft alternative.

Another argument for the Rosecroft alternative was its lower capital cost (WMATA 1984). The route was shorter, straighter, and had fewer points of conflict (e.g., stream crossings, roadway crossings). However, faulty logic was used by advocates of the Branch Avenue terminus to neutralize this argument.[220] According to initial estimates, the Rosecroft and Suitland alignments were within $5 million of capital cost of one another (WMATA 1984). Thus, it was argued that cost was not a differentiator between the Rosecroft and Branch Avenue termini. Yet, the S-Curve alternative—which also terminated at Branch Avenue—was estimated to cost approximately $130 million more than either the Rosecroft or Suitland alternative. Nonetheless, the S-Curve alignment was considered on par with the other options and additional costs were attributed to the additional station at Congress Heights—the cost of serving transit-dependent populations (again, this was based on an argument to serve Congress Heights even though the Suitland alternative would serve more transit-dependent residents).

Our TCRP H-42 research identifies ridership as a prime measure of transit project success. A frequently discussed indicator of ridership in the planning of the Outer F alignment was the existing federal employment centers located along the Suitland and S-Curve alternatives.[221] For instance, the U.S. Census Bureau was located at the Suitland Federal Center. During the alignment debate, this was contrasted with the Rosecroft alignment that provided minimal direct access to any suburban employment.

Likewise, the Rosecroft Racecourse was promoted as a major ridership generator. However, it was determined that transit would achieve little mode share because the horse races typically operated at night during off-peak transit service periods and, based on an informal survey conducted by planning consultants, most patrons owned cars.[222] A recalibrated model produced a lower ridership forecast.

---

[217] Interviewee BQ, telephone conversation, 7/11/12
[218] Interviewee BR, telephone conversation, 7/19/12
[219] Interviewee BS, telephone conversation, 7/30/12
[220] Interviewee BR, telephone conversation, 7/19/12
[221] Interviewee BR, telephone conversation, 7/19/12
[222] Interviewee BT, telephone conversation, 7/24/12

While early ridership estimates had been based on census track-level data and yielded very distinct ridership estimates, subsequent refinements contributed to model outputs that suggested the alternatives would experience similar ridership demand.[223] Travel isochrones overlaid on detailed maps depicting individual single-family homes were used to recalculate the number of residents within stations' service areas. When input into the models, this impacted the Rosecroft alternative because of the limited roadway infrastructure that existed in the area. Because the budget of the transit project could fund only a limited number of roadway improvements and Prince George's County was not willing to commit to roadway construction, lower ridership projections for the Rosecroft alignment were maintained.

Ultimately, ridership projections were not pivotal considerations in the Outer F alignment debates. Estimates conducted in the early 1980s suggested that the S-Curve and Suitland alternatives would have over 70,000 daily riders while the Rosecroft alignment would have just shy of 66,000 (WMATA 1984). As one project consultant noted, "Although the [ridership] data suggested Branch Avenue [was preferable], it was not so compelling a case that you would select Branch Avenue just by the data."[224] In fact, the ridership and operating characteristics of the alignments were so similar that the difference in projected annual net operating deficit of the proposals was less than 7% (WMATA 1984).

In the end, the ridership figures were not used by officials to publish comparison benefit-cost measures of the alignments (WMATA 1984). Neither the operating deficits nor the capital cost figures were considered relative to patronage. Nor were costs considered relative to one of the most noted benefits of the project: rail access for transit-dependent people. Using 1984 comparative statistics to calculate such benefit-cost figures, the results (found in the table below) would have pointed to the Suitland alternative rather than the Rosecroft option (the alternative selected in 1978) or the S-Curve option (the route ultimately constructed).

Table I-2: Benefit-Cost Calculations for Routes Under Consideration in 1984 (WMATA 1984)

Benefit-cost measure	Rosecroft	S-Curve	Suitland
Total capital cost per trip (1990 ridership)	$30.98	$33.89	$29.12
Operating deficit per trip (1990 ridership)	$0.58	$0.54	$0.51
Capital cost per transit-dependent person in station catchments (1980)	$35,180	$34,532	$25,826
Operating deficit (1990) per transit-dependent person in station catchments (1980)	$654	$546	$450

Ultimately, the impasse was broken and the county, District, and WMATA selected the S-Curve alignment through Congress Heights and terminating at Branch Avenue. It met the demands of District politicians to serve a particular transit-dependent neighborhood, passed through major employment centers, avoided further lawsuits by businesses that had relied on the 1967 Metrorail plan to make investment decisions, and provided excellent automobile and bus access without considerable investment in new roadway infrastructure. After WMATA approved the S-Curve route and the court injunction was lifted in late 1984, construction commenced on the portion of the

[223] Interviewee BT, telephone conversation, 7/24/12
[224] Interviewee BS, telephone conversation, 7/30/12

Green Line from L'Enfant Plaza (the intersection with the Yellow/Blue Line) to Anacostia in 1985. Advocates of the Suitland Parkway alignment continued to agitate for shifting the alignment from the S-Curve throughout the late 1980s and early 1990s, but District interest in serving Congress Heights and fears of reopening the debate squelched any further realignment. The extension to Anacostia opened in 1991 and the segment of the Green Line in northern Prince George's County opened in 1993. At that time, final plans were approved for the S-Curve alignment and a construction contract was signed in 1995 with Green Line Metrorail service to Branch Avenue Station commencing in January 2001.

In spite of the difficulties and delays associated with the Outer F portion of the WMATA Green Line, WMATA staff currently considers it one of the most successful segments of the Metrorail system.[225] Unlike the base system that was constructed in the 1970s and 1980s, planners of the Green Line had to prove their case for the line time and time again to Congress, to WMATA's member jurisdictions, and to diverse groups who advocated for alternative alignments and to stop construction altogether. In the end, the line achieved the ridership projections while providing high-quality transit service to one of the most economically depressed parts of the Washington, D.C., metropolitan area.

[225] Interviewee BU, telephone conversation, 8/27/12

I.7 Regional Contexts

The following section provides brief overviews of the regional contexts of each case study.

I.7.1 Charlotte Region

The Charlotte-Gastonia-Rock Hill, NC-SC MSA had an estimated 2011 population of 1.8 million.[226] The region includes five counties in North Carolina and one in South Carolina, and covers almost 3,200 square miles. Centered on the City of Charlotte (population: 751,087), the region is the largest in North Carolina, and 21st largest in the United States.[227] Mecklenburg County, the county in which Charlotte is located, is 523 square miles and has a population of 919,628.[228] The Charlotte region is located in the rolling hills of southwestern North Carolina's Piedmont region just 85 miles southeast of the Appalachian Mountains, and 180 miles northwest of the Atlantic Ocean.

Charlotte is the major banking center of the Southeastern United States and is the nation's second-largest banking and financial hub. Bank of America's headquarters and the east coast operations of Wells Fargo are among the major financial institutions located in Charlotte. The region is home to 273 Fortune 500 Companies, seven of which are headquartered in Mecklenburg County.[229]

Charlotte is served by two main freeways, Interstate 77 and Interstate 85, both of which connect the region to other major southeastern metropolitan areas. Most of the City of Charlotte lies within a beltway, I-485. The city's central business district, Uptown, is encircled by the I-277 freeway. While the central city has a grid-based street pattern, the majority of the region is built around arterial roads that radiate out from the center city.

Transit in the Charlotte region is operated by the Charlotte Area Transit System (CATS). The agency operates over 70 local and express bus routes and paratransit, in addition to the LYNX Blue Line, the Charlotte region's only light rail line. The Charlotte Transportation Center (CTC) in Uptown Charlotte, the northernmost stop on the Blue Line, is the region's multimodal transit hub. Local and express bus routes radiate out of central Charlotte in all directions, some reaching into neighboring South Carolina.

Of the 344,436 workers commuting to work in 2010, 77.6% drove alone, 10.6% carpooled, 3.7% took public transportation, 2.2% walked, 0.8% used other means, and 5.2% worked at home.[230]

I.7.2 Dallas Region

The Dallas-Fort Worth-Arlington, Texas MSA covers 9,286 square miles in 12 counties.[231] The MSA, also called the Dallas-Fort Worth Metroplex, is the largest MSA in Texas, and the fourth-largest in the United States. It is also the 12th largest metropolitan economy (global scale) by 2005

---

[226] Annual Estimates of the Population of Metropolitan and Micropolitan Statistical Areas: April 1, 2010 to July 1, 2011 <http://www.census.gov/popest/data/metro/totals/2011/tables/CBSA-EST2011-01.xls

[227] U.S. Census – State & County Quick Facts

[228] 2010 U.S. Census

[229] Chamber of Commerce; http://charlottechamber.com/eco-dev/charlotte-s-economy-demographics/

[230] U.S. Census Bureau – 2010 American Community Survey 1-Year Estimates, "Selected Economic Characteristics"

[231] http://www.census.gov/popest/data/metro/totals/2011/tables/CBSA-EST2011-01.xls

GDP$[232] and its 2011 population was estimated to be 6.56 million. The Dallas-Fort Worth-Arlington MSA contained 2,968,500 jobs in April 2012.[233] The MSA includes the Dallas-Plano-Irving and Fort Worth-Arlington Metropolitan divisions and the Dallas-Plano-Irving MD contains 70% of the areas workforce. The MSA's largest employment sector is trade, transportation and utilities.[234]

The Dallas-Fort Worth-Arlington MSA is characterized mostly by prairie land. Around Dallas is the blackland prairie—named for the fertile black soil and historically used to grow cotton.[235] Around Fort Worth is the Fort Worth Prairie, which contains low fertility soil. Traditionally it was used for ranchland, but it is now the primary regional location for oil refining.

The north-Dallas area suburbs are coined the "Silicon Prairie" because of the high number of technology firms and corporate offices in the region (AT&T, HP, Microsoft, etc.). The Richardson Chamber of Commerce went so far as to trademark "Telecom Corridor" to refer to their high-tech business community.[236]

The Dallas-Fort Worth region is served by two rail transit systems and a variety of bus and other transit services. DART operates the light rail system, and jointly (with the Fort Worth Transportation Authority) runs the area's commuter rail service, the Trinity Railway Express (TRE). The DART light rail system consists of three color-coded lines totaling 58 stations and 77 miles of track, now the longest light rail system in the country.[237] The TRE system adds another 10 stations and 34 miles. DART light rail serves over 71,000 passenger trips each weekday, while TRE serves 8,500 daily trips. The DART system also includes bus service on over 100 routes, serving over 125,000 weekday boardings.

DART light rail is operated with modern light rail vehicles called Super Light Rail Vehicles, featuring level boarding and increased passenger capacity. DART light rail headways average about 15 minutes system-wide, but the Red Line and Blue Line have supplemental Orange Line service that increases frequency during peak hours to about 7 minutes.

Of the 2,999,949 estimated workers in the DFW MSA, 81% commuted alone by auto, 10% carpooled, 1% took transit, 1% walked, 2% took a taxicab, motorcycle, bicycle, or other means, while 5% worked at home.[238]

I.7.3 Eugene Region

The Eugene-Springfield, OR, MSA, which covers 4,722 square miles in one county (Lane), had an estimated 2011 population of 353,416.[239] The region, centered on the cities of Eugene (population: 156,185) and Springfield (population: 59,403), is the third-largest in Oregon, and 144th-largest in the United States. Lane County's population grew almost 9% between 2000 and 2010.

Lane County stretches from the Pacific Ocean to the Cascade Mountain range in central Oregon. The center of the metropolitan area is located in the middle of the county, in the Willamette Valley.

---

[232] Kessler, Dan. "Metropolian Transportation Update – International Right of Way Association North Texas Chapter." North Central Texas Council of Governments. June 09 2009.
[233] Work Area Profile Analysis. LEHD. On the Map. Census Bureau; http://onthemap.ces.census.gov/
[234] BLS "Dallas-Fort Worth Area Employment – April 2012." Southwest Information Office. News Release April 2012.
[235] Dallas Fort Worth Tourism; http://dfwtourism.com/demo/
[236] http://www.telecomcorridor.com/about-us/telecom-corridor-geneaology-project-1
[237] http://www.dart.org/about/dartfacts.asp; Accessed 10/22/12
[238] U.S. Census Bureau. "Means of Transportation to Work by Age." 2010 ACS 1 year estimates.
[239] http://www.census.gov/popest/data/metro/totals/2011/tables/CBSA-EST2011-01.xls; Accessed 7/28/12

Eugene and Springfield, the MSA's two primary cities, are located on opposite sides of the Willamette River, in the southernmost corner of the valley, surrounded by mountains on three sides. The centers of the two cities are separated by only four miles.

Eugene has the region's largest central business district, and is home to the University of Oregon, which had nearly 25,000 students in 2011.[240] Just across the Willamette River is Springfield, the region's second-largest city, which has a smaller downtown. Much of the recent growth in employment has occurred at the fringe of the urban area, notably in office parks in the northwest portion of Springfield near the I-5/Randy Pape Beltline interchange. The region's economy, originally heavily timber-based, has since diversified and now consists of manufacturing, high-tech and healthcare sectors.

Interstate-5 bisects the Eugene-Springfield MSA, forming the border between the two cities but not serving either downtown. A spur, I-105 connects downtown Eugene to I-5 and areas east, but not directly to downtown Springfield. An incomplete Outer Loop (OR-569) and a short North-South freeway (Delta Highway) comprise the rest of the region's limited access highway network.

The Eugene-Springfield region is served by the Lane Transit District (LTD), which carries almost 39,000 weekday riders on 34 standard bus routes and its EmX BRT route.[241] The network is, for the most part, a radial one, with the majority of routes fanning out from Eugene Station, a transit center in downtown Eugene. A handful of routes radiate out from Springfield Station in downtown Springfield. The system also features several outlying transit centers and almost 20 park-and-ride lots.

According to 2006-2010 ACS estimates, just over 80% of Lane County residents commuted to work by auto. The next largest share of workers (8%) worked from home. Transit, cycling, and walking each captured roughly 4% of the commute share.

I.7.4 Portland Region

The Portland-Vancouver-Hillsboro, OR-WA MSA, which covers 6,684 square miles in six counties (four in Oregon and two in Washington), had an estimated 2011 population of 2.26 million.[242] The region, centered on the city of Portland (population: 583,776), is the largest in Oregon, and 23rd-largest in the United States.

The Portland region has an elected government body, Metro, that oversees long-range land use and transportation planning. Metro's own analysis shows that employment in the region grew by 7.4% overall between 1996 and 2005, with the vast majority of that growth occurring in outlying Washington and Clark (WA) counties. Multnomah County, which contains Portland and its eastern suburbs, now holds roughly 36% of the region's jobs.[243]

Portland centers on the Willamette River near its terminus at the Columbia River—which drains into the Pacific—and was the site of a 19th century seaport. Hydraulic power and wartime shipbuilding propelled growth in the 20th century. Today, Portland sits at the junction of two Interstate highways, I-84 (East-West) and I-5 (North-South). In addition to these trunk routes, the metropolitan area is served by two auxiliary routes, I-405, which forms half of a loop around Portland's CBD, and I-205, an eastern bypass, as well as several shorter connecting limited access

240 http://admissions.uoregon.edu/profile.html; Accessed 10/22/12
241 http://www.ltd.org/about/history.html?SESSIONID=2177f5ac0d3a59aeab899b7df2c2bb81
242 http://www.census.gov/popest/data/metro/totals/2011/tables/CBSA-EST2011-01.xls
243 http://library.oregonmetro.gov/files/regionaltrendstravelfinal.pdf

highways. Portland was the first American city to tear down an existing limited access freeway when, in 1974, Harbor Drive was demolished and replaced with a park, reconnecting the central business district with the riverfront.

The Portland region has a relatively extensive and well-developed bus-, light rail-, and streetcar-based transit system, operated by TriMet. The system includes the MAX light rail network, which started with the opening of Eastside MAX to Gresham in 1986. TriMet has consistently expanded the system, which now consists of four lines (Red, Blue, Green, and Yellow) radiating out of two dedicated alignments that cross one another perpendicularly in downtown Portland. In addition to the ever-expanding light rail system, TriMet operates a grid of frequent bus service throughout the metropolitan area. TriMet also participates in the operations of Portland's downtown streetcar facilities which expanded outside of the downtown as of 2012.

In 2000, 84% of Portland area workers commuted by auto, down from almost 90% in 1990. During that same period, public transportation's share rose from 5.8% to 6.7%. 2010 ACS five-year estimates show transit's share remaining flat, at 6.6%.[244] According to TriMet, between 1990 and 2000, transit ridership "increased (58%) faster than population growth (24%) and overall growth in vehicle-miles traveled (35%)." The Portland region averages roughly 80 annual transit trips per capita, second only to New Orleans among American metropolitan regions of similar sizes.[245]

I.7.5 Salt Lake City Region

The Salt Lake City-Ogden, UT, MSA has approximately 1.15 million[246] residents. The region, centered on Salt Lake City, is the most populous in Utah and 48th-largest in the United States. A related larger regional geography is referred to as the Wasatch Front and consists of two MSAs (SLC-Ogden and Provo, UT) and has a combined population of over two million.

Salt Lake City is the most populous city in the region, and its 109-square-mile area is bounded on two sides by mountain ranges and on a third side by the Great Salt Lake. The city lies at the junction of two cross-country Interstate highways, I-80 (extending east to New York City and west to San Francisco) and I-15 (extending north to Canada and south to Mexico). An incomplete belt route, I-215, and a spur (Highway 201) comprise the rest of the highway network of the central metropolitan region. A grid of wide, regularly spaced arterial surface roads blanket the region. The Salt Lake City International Airport is five miles from downtown Salt Lake City and, as a hub for Delta airlines, is the 23rd-busiest airport in the nation.[247]

The top three employers in Salt Lake County are the University of Utah, Intermountain Health Care, and the State of Utah.[248] The top employer in Weber County is the Internal Revenue Service, while the largest employer in Davis County is Hill Air Force Base.[249,250] Salt Lake City has become an attractive location for technology sector firms. Forbes listed Salt Lake City as the fourth-best city in the nation for tech jobs, citing Adobe, Electronic Arts, and Twitter.[251]

---

244 2006-2010 American Community Survey 5-Year Estimates
245 http://library.oregonmetro.gov/files/regionaltrendstravelfinal.pdf
246 Annual Estimates of the Population of Metropolitan and Micropolitan Statistical Areas: April 1, 2010 to July 1, 2011 <http://www.census.gov/popest/data/metro/totals/2011/tables/CBSA-EST2011-01.xls
247 Utah at a glance <http://www.edcutah.org/documents/Utah-At-A-Glance_000.pdf>
248 Salt Lake County Profile <http://www.edcutah.org/documents/SaltLakeCounty.pdf>
249 Weber County Profile <http://www.edcutah.org/documents/WeberCounty.pdf>
250 Davis County Profile < http://www.edcutah.org/documents/WeberCounty.pdf>
251 SLC ranks High as tech job hot spot <http://www.edcutah.org/documents/SLCTechJobHotSpot.pdf>

Public transportation in the Salt Lake City region is provided by the Utah Transit Authority (UTA), which operates bus, light rail and commuter rail routes throughout the entire region. UTA's system averages over 150,000 daily boardings on 131 routes in six counties. The relatively new light rail network, TRAX, opened in 1999 with the Salt Lake City to Sandy (now Blue) line. The light rail system consists of three color-coded lines (Red, Blue and Green) with a new extension from downtown Salt Lake City to the airport slated to open in early 2013 and a 3.8-mile extension south from the current Sandy Blue Line terminus to open in 2014. A streetcar line in South Salt Lake is also anticipated to open in 2013 and will connect with the Blue, Red, and Green Lines at Central Pointe station—where the West Valley segment of the Green Line intersects with the North-South TRAX trunk line. The streetcar provides rail access to neighborhoods to the east of the trunk line and I-15 and just north of I-80. FrontRunner, a commuter rail line currently serving Ogden and points north of Salt Lake City, opened in 2008, and connects to the TRAX network at the Salt Lake City Intermodal Center. The FrontRunner will extend 45 miles south from the Salt Lake City Intermodal Center to Provo starting in late 2012. UTA's total system ridership in 2011 reached 41,553,315 with more than 22.6 million on UTA buses, 15.2 million on TRAX, and 1.6 million on FrontRunner.[252]

Of the 522,765 people commuting to work in the Salt Lake City, UT, MSA in 2010, 77.7% drove alone, 11.3% carpooled, 2.9% took public transportation, 2.3% walked, 1.9% arrived by other means, and 4.0% worked from home.[253]

I.7.6 Washington, D.C., Region

The Washington-Arlington-Alexandria DC-VA-MD-WV MSA, which covers 5,564 square miles surrounding the nation's capital, had an estimated 2011 population of 5.58 million.[254] In addition to the District of Columbia, the MSA includes five counties in Maryland, nine counties in Virginia, and one county in West Virginia.[255] The Washington, D.C., region is centered on the District of Columbia. The District is approximately 60 square miles with a 2010 population of approximately 600,000 people.[256]

As of January 2012, the region's labor force comprised 3,174,984 people.[257] The five largest employers were the U.S. Department of Defense, Fairfax County Public Schools, County of Fairfax, Prince William County School Board, and Booz, Allen and Hamilton.[258] The technical services sector has historically been the largest employer in the region.[259]

The District of Columbia lies at the confluence of the Potomac and Anacostia rivers. Encircling the District, the I-495 Capital Beltway passes through Virginia and Maryland and intersects with I-95 to the north and south, I-66 to the west, and I-270 to the northwest. A loop consisting of I-395, I-695, and I-295 are the only direct Interstate connections inside the District, though five limited access parkways also enter the District's borders.

---

[252] UTA – 2011 Year in Review <http://www.rideuta.com/uploads/2011inreview.pdf>
[253] 2010 American Community Survey 1-Year Estimates – "Selected Economic Characteristics"
[254] Annual Estimates of the Population of Metropolitan and Micropolitan Statistical Areas: April 1, 2010 to July 1, 2011<http://www.census.gov/popest/data/metro/totals/2011/tables/CBSA-EST2011-01.xls>
[255] Economic Census Local Business Snapshot <http://www.census.gov/econ/census/snapshots_center/dc.html>
[256] www.dc.gov
[257] Bureau of Labor Statistics <http://www.bls.gov/xg_shells/ro3fx9512.htm>
[258] Page 20 <http://virginialmi.com/report_center/community_profiles/5121S47890.pdf>
[259] Economic Census: Local Snapshot <http://www.census.gov/econ/census/pdf/dc.pdf>

The Washington Metropolitan Area Transit Authority (WMATA) is the region's dominant transit provider. In addition to its substantial Metrobus fleet, WMATA's Metrorail serves 86 stations along 106 miles of track.[260] During rush periods, the Green Line operates in intervals of 6 minutes between trains with a train size of 6-8 cars. The midday intervals between trains is 12 minutes and the evening intervals between trains is 20 minutes with a train size of six cars. Residents of the eight WMATA compact jurisdictions in D.C., Maryland, and Virginia generate 88% of weekday ridership.[261] Riders outside of the WMATA service area have transit alternatives. In addition to the Metrobus and Metrorail, the Washington-Arlington-Alexandria region is served by several other bus services and two other commuter rails (MARC and VRE).[262]

Of the 2,931,890 commuters in 2010, 65.6% drove to work alone, 10.6% carpooled, 14% used public transportation, 3.5% walked, 1.5% arrived by other means, and 4.9% worked from home.[263]

[260] Metro Facts <http://www.wmata.com/about_metro/docs/metrofacts.pdf>
[261] Regional Transportation <http://www.wmata.com/getting_around/regional_transit.cfm>
[262] Regional Transportation <http://www.wmata.com/getting_around/regional_transit.cfm>
[263] U.S. Census Bureau "Commuting to Work" 2010 ACS 1 year estimates

APPENDIX J: Data Sources

Attribute	Source	Provider	Measure / Predictor	Year	Coverage	Smallest Unit
1. Costs						
1a. Capital and Operation Costs						
	Public Transportation Factbook (PTFB)	American Public Transportation Association (APTA) (non-profit transit agency industry organization)	Capital and operating expenses	2010 (2008 data), and annually (2003-2010 available online). Some historical tables date to as early as 1902.	National and Canada	Transit agency
	National Transit Database (NTD)	U.S. DOT, Federal Transit Administration (FTA)	Operating expenses	Annual summaries available from 1996 to 2009. Time-series data files contain agency summaries from 1991 to 2009.	National	Transit agency
1b. Discount Rates						
	Statistics & Historical Data on H.15 Selected Interest Rates	The Board of Governors of the Federal Reserve System	Interest rates	Daily 1954-present.	National	National
2. System and Financial						
2a. Service Supplies						
	TOD Database	Center for Transit-Oriented Development; Center for Neighborhood Technology	Locations of U.S. fixed-guideway stations	2000 (employment 2002-2008).	Nationwide where fixed-guideway transit is present	Fixed-guideway transit stations and surrounding area

Attribute	Source	Provider	Measure / Predictor	Year	Coverage	Smallest Unit
	National Transportation Atlas Database (NTAD)	U.S. DOT, Bureau of Transportation Statistics (BTS), Research and Innovative Technology Administration (RITA),	Presents locations of fixed-guideway transit facilities	2010, 2009, 2008, etc.	National	Facilities, stations and links
	Google General Transit Feed Specification (GTFS) Data	Various transit operators	Service information can be derived from station information	Varies by agency	Numerous U.S. and Canadian transit systems	Transit station
	Public Transportation Factbook (PTFB)	American Public Transportation Association (APTA) (non-profit transit agency industry organization)	Public transit revenue miles and hours	2010 (2008 data), and annually (2003-2010 available online). Historical tables date to as early as 1902 depending on statistic. Most figures available for at least 10 years.	National (and some Canadian data)	Transit agency
	National Transit Database (NTD)	U.S. DOT, Federal Transit Administration (FTA)	Transit vehicle revenue miles and hours and vehicle counts	Annual summaries available from 1996 to 2009. Time-series data files contain agency summaries from 1991 to 2009.	National	Transit agency
2b. Passenger Demands						
	TOD Database	Center for Transit-Oriented Development; Center for Neighborhood Technology	Demographics surrounding fixed-guideway transit stations	2000 (employment 2002-2008)	Nationwide fixed-guideway transit system station locations	Fixed-guideway transit stations and surrounding area
	Longitudinal Employer-Household Dynamics (LEHD)	U.S. Census Bureau	Employee home and work OD pairs	2002-2008	47 States	Census Block
	Census Transportation Planning Package (CTPP)	U.S. Census Bureau / American Association of State Highway and Transportation Officials (AASHTO)	Origin-destination tables of employees	Decennial Census: 1990, 2000. ACS: 2006-2008	National	Census Block Group

Attribute	Source	Provider	Measure / Predictor	Year	Coverage	Smallest Unit
	Public Transportation Factbook (PTFB)	American Public Transportation Association (APTA) (non-profit transit agency industry organization)	Unlinked transit trip summaries and passenger miles	2010 (2008 data), and annually (2003-2010 available online). Historical tables date to as early as 1902 depending on statistic. Most figures available for at least 10 years.	National and Canada	Transit agency
	National Transit Database (NTD)	U.S. DOT, Federal Transit Administration (FTA)	Unlinked passenger trips and passenger miles traveled	Annual summaries available from 1996 to 2009. Time-series data files contain agency summaries from 1991 to 2009.	National	Transit agency
	National Household Travel Survey (NHTS) and Nationwide Personal Transportation Survey (NPTS)	U.S. Department of Transportation (DOT), Bureau of Transportation Statistics (BTS), Federal Highway Administration (FHWA)	Comprehensive travel survey	NHTS: 2009, 2001-2002, 2009; NPTS: 1995, 1990, 1983, 1977, 1969	National	Census Block Group & Household
2c. Revenues and Cross-Subsidies						
	Public Transportation Factbook (PTFB)	American Public Transportation Association (APTA)	Fare collection summaries	2010 (2008 data), and annually (2003-2010 available online). Historical tables date to as early as 1902 depending on statistic. Most figures available for at least 10 years.	National (and some Canadian data)	Transit agency
	National Transit Database (NTD)	U.S. DOT, Federal Transit Administration (FTA)	Revenue by mode and service type, public resources for cross-subsidies	Annual summaries available from 1996 to 2009. Time-series data files contain agency summaries from 1991 to 2009.	National	Transit agency
3. Social Characteristics						
3a. Transportation and Housing Affordability						
	Housing +Transportation (H+T) Affordability Index	Center for Neighborhood Technology	Housing and transportation affordability indices	2008, 2000	National (337 MSAs)	Census Block Group

Attribute	Source	Provider	Measure / Predictor	Year	Coverage	Smallest Unit
	American Community Survey (ACS)	U.S. Census Bureau	Includes income and housing costs	1996-2009	National	Census Place
	American Housing Survey (AHS)	U.S. Department of Housing and Urban Development (HUD)	Includes income and housing costs	1973-2009	National	Census Tract
	ESRI Updated Demographics	ESRI	Estimates income and home valuations	Updated annually	National	Census Block Group
	Regional, State, and City House Price Index (HPI) Data	Federal Housing Finance Age (public)		1975-Present Year, Quarterly	National	State & MSAs
3b. Public Health and Safety						
	American Housing Survey (AHS)	U.S. Department of Housing and Urban Development (HUD)	Housing with lead paint information	1973-2009	National	Census Tract
	Public Transportation Factbook (PTFB)	American Public Transportation Association (APTA)	Includes transit fuel and energy use	2010 (2008 data), and annually (2003-2010 available online). Historical tables date to as early as 1902 depending on statistic. Most figures available for at least 10 years.	National (and some Canadian data)	Transit agency
	Behavioral Risk Factor Surveillance System (BRFSS)	U.S. Centers for Disease Control and Prevention (CDC)	Various indicators of public health	Annual Survey (1984-Present Year); ArcGIS (2002-Present Year)	National	State & some MSAs
	National Health Interview Survey (NHIS)	U.S. National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention (CDC)	Survey of health conditions	1963-2009	National	Households
	Fatality Analysis Reporting System (FARS) and National Automotive Sampling System General Estimates System (NASS GES)	U.S. Department of Transportation (DOT), National Highway Traffic Safety Administration (NHTSA)	Traffic related fatalities	Annual 1975-Present (FARS) & 1998-Present Year (NHTSA)	National	County City & Class Trafficway (FARS), Geographic Region

Attribute	Source	Provider	Measure / Predictor	Year	Coverage	Smallest Unit
3c. Socioeconomic Diversity						
	TOD Database	Center for Transit-Oriented Development; Center for Neighborhood Technology	Includes demographic information near transit stations	2000 (employment 2002-2008)	Nationwide fixed-guideway transit system station locations	Transit station and surrounding area
	Decennial Population and Housing Census	U.S. Census Bureau	Most complete source of demographic information	2000, 1990, 1980, etc.	National	Census Block
	American Community Survey (ACS)	U.S. Census Bureau	Detailed population information at coarse units of analysis	1996-2009	National	Census Place
	GeoLytics 2001-2008 Demographic Data	GeoLytics	Annual demographic and socioeconomic information	2001-2008	National	Census Block Group
	ESRI Updated Demographics	ESRI	Estimates of demographic and socioeconomic characteristics	Updated annually	National	Census Block Group
3d. Geographic Accessibility						
	TOD Database	Center for Transit-Oriented Development, Center for Neighborhood Technology	Land use near stations indicates quantity of transit accessible land uses	2000 (employment 2002-2008)	Nationwide fixed-guideway transit system station locations	Transit station and surrounding area
	Housing +Transportation (H+T) Affordability Index	Center for Neighborhood Technology	Includes measures of auto and transit usage	2008, 2000	National (337 MSAs)	Census Block Group
	Longitudinal Employer-Household Dynamics (LEHD)	U.S. Census Bureau	Employee home and work OD pairs	2002-2008	47 States	Census Block

Attribute	Source	Provider	Measure / Predictor	Year	Coverage	Smallest Unit
	National Dataset for Location Sustainability and Urban Form (5Ds & SLIs)	Natural Resource Ecology Laboratory, Colorado State University	Accessibility measures for auto and transit travel	2009	National	Census Block Group
	Census Transportation Planning Package (CTPP)	U.S. Census Bureau / American Association of State Highway and Transportation Officials (AASHTO)	Includes origin-destination information for U.S. workers and related travel times	Decennial Census: 1990, 2000. ACS: 2006-2008	National	Census Block Group
	Google General Transit Feed Specification (GTFS) Data	Various transit operators	GTFS information is the building block for transit trip routing	Varies by agency	Numerous U.S. and Canadian transit systems	Station and transit route
	National Household Travel Survey (NHTS) and Nationwide Personal Transportation Survey (NPTS)	U.S. Department of Transportation (DOT), Bureau of Transportation Statistics (BTS), Federal Highway Administration (FHWA)	Comprehensive travel survey	NHTS: 2009, 2001-2002, 2009; NPTS: 1995, 1990, 1983, 1977, 1969	National	Census Block Group & Household
4. GIS and Network						
	National Transportation Atlas Database (NTAD)	U.S. DOT, Bureau of Transportation Statistics (BTS), Research and Innovative Technology Administration (RITA),	Includes GIS layers of transit stations and facilities	2010 (online or DVD), 2009 (DVD), 2008 (DVD)	National	Facilities, stations and links
	Google General Transit Feed Specification (GTFS) Data	Various transit operators	Includes lat/long locations of transit stations and service information	Varies by agency	Numerous U.S. and Canadian transit systems	Station and transit route
	U.S. Census Topologically Integrated Geographic Encoding and Referencing system (TIGER/Line) Shapefiles	U.S. Census Bureau	Census zones, streets, and other geographic features	2010, 2009, 2008, 2007, 2000, etc.	National	Census block, streets, and point places

Attribute	Source	Provider	Measure / Predictor	Year	Coverage	Smallest Unit
	ESRI Updated Demographics	ESRI	Up-to-date demographic and household economic condition estimates	Updated annually	National	Census Block Group
5. Intermodal Characteristics						
5a. Urban Mobility on Roadway						
	Urban Mobility Report (UMR)	Texas Transportation Institute (TTI)	Regional traffic congestion measurements	1982-2010	National (selected MSAs)	Metropolitan region
	Highway Statistics	U.S. Department of Transportation (DOT), Federal Highway Administration (FHWA)	Quantifies vehicle-miles of travel	1992-2009	National	Urbanized Areas
5b. Modal Competitiveness						
	National Dataset for Location Sustainability and Urban Form (5Ds & SLIs)	Natural Resource Ecology Laboratory, Colorado State University (Academic Institute)	Accessibility measures for auto and transit	2009	National	Census Block Group
	Census Transportation Planning Package (CTPP)	U.S. Census Bureau / American Association of State Highway and Transportation Officials (AASHTO)	Includes mode and travel time for work trips	Decennial Census: 1990, 2000. ACS: 2006-2008	National	Census Block Group
	National Household Travel Survey (NHTS) and Nationwide Personal Transportation Survey (NPTS)	U.S. Department of Transportation (DOT), Bureau of Transportation Statistics (BTS), Federal Highway Administration (FHWA)	Mode and travel times for household travel	NHTS: 2009, 2001-2002, 2009; NPTS: 1995, 1990, 1983, 1977, 1969	National	Census Block Group & Household
	Urban Mobility Report (UMR)	Texas Transportation Institute (TTI)	Indication of regional auto travel inconvenience	1982-2010	National (selected MSAs)	Metropolitan region
5c. Intermodal Connectivity						
	Intermodal Passenger Connectivity Database	Research and Innovative Technology Administration (RITA)/Bureau of Transportation Statistics (BTS)	Intermodal facilities and relevant information	2011	National	Census Block Group and Facilities

Attribute	Source	Provider	Measure / Predictor	Year	Coverage	Smallest Unit
	National Transportation Atlas Database (NTAD)	U.S. DOT, Bureau of Transportation Statistics (BTS), Research and Innovative Technology Administration (RITA),	Intermodal facilities are included among other transportation facilities	2010 (online or DVD), 2009 (DVD), 2008 (DVD)	National	Facilities, stations and links
5d. Local Access Availability						
	Google General Transit Feed Specification (GTFS) Data	Various transit operators	GTFS feeds are available for some U.S. BRT systems	Varies by agency	Numerous U.S. and Canadian transit systems	Station and transit route
6. Bus Rapid Transit (BRT)						
	National Transportation Atlas Database (NTAD)	U.S. DOT, Bureau of Transportation Statistics (BTS), Research and Innovative Technology Administration (RITA),	Includes fixed-guideway transit facilities	2010 (online or DVD), 2009 (DVD), 2008 (DVD)	National	Facilities, stations and links
	Google General Transit Feed Specification (GTFS) Data	Various transit operators	GTFS feeds are available for some U.S. BRT systems	Varies by agency	Numerous U.S. and Canadian transit systems	Station and transit route
7. Parking						
	North America Central Business District Parking Rate Survey	Colliers International	Survey of center city parking prices in major MSAs	2001-2010	National, selected cities	Central business district
	"Parking in America" report	National Parking Association	Survey of center city parking prices in major MSAs	2008-2010	National, selected cities	Central business district

Attribute	Source	Provider	Measure / Predictor	Year	Coverage	Smallest Unit
8. Urban Design						
8a. Street Connectivity						
	National Dataset for Location Sustainability and Urban Form (5Ds & SLIs)	Natural Resource Ecology Laboratory, Colorado State University	Intersection density	2009	National	Census Block Group
	National Transportation Atlas Database (NTAD)	U.S. DOT, Bureau of Transportation Statistics (BTS), Research and Innovative Technology Administration (RITA),	Street network GIS Shapefile	2010 (online or DVD), 2009 (DVD), 2008 (DVD)	National	Street
9. Urban Development						
9a. Residential Location						
	TOD Database	Center for Transit-Oriented Development, Center for Neighborhood Technology	Residential occupation in areas near transit stations	2000 (employment 2002-2008)	Nationwide fixed-guideway transit system station locations	Transit station and surrounding area
	Decennial Population and Housing Census	U.S. Census Bureau	Residential demographic information	2000, 1990, 1980, etc.	National	Census Block
	American Community Survey (ACS)	U.S. Census Bureau	Detailed population information at coarse units of analysis	1996-2009	National	Census Place
	GeoLytics 2001-2008 Demographic Data	GeoLytics	Private demographic data source	2001-2008	National	Census Block Group
	ESRI Updated Demographics	ESRI	Estimates of demographic and socioeconomic characteristics	Updated annually	National	Census Block Group

Attribute	Source	Provider	Measure / Predictor	Year	Coverage	Smallest Unit
9b. Business Location						
	TOD Database	Center for Transit-Oriented Development, Center for Neighborhood Technology	Employment indicates business activity near transit stations	2000 (employment 2002-2008)	Nationwide fixed-guideway transit system station locations	Transit station and surrounding area
	County; Metro; & ZIP Code Business Patterns (CBP; MBP; & ZBP)	U.S. Census Bureau	Number of establishments, payroll, and employee counts	1986-2008	National	ZIP Code (from 1994)
	Longitudinal Employer-Household Dynamics (LEHD)	U.S. Census Bureau	Employees, age, earnings, and industry by work location	2002-2008	47 States	Census Block
	Economic Census	U.S. Census Bureau	Business activity and trade by geography	2007, 2002, 1997	National	ZIP Code
9c. Multiple Integration						
	National Dataset for Location Sustainability and Urban Form (5Ds & SLIs)	Natural Resource Ecology Laboratory, Colorado State University	Includes various information on factors theoretically related to residential location and transport mode share	2009	National	Census Block Group
	TOD Database	Center for Transit-Oriented Development, Center for Neighborhood Technology	Employment indicates business activity near transit stations	2000 (employment 2002-2008)	Nationwide fixed-guideway transit system station locations	Transit station and surrounding area

<u>**Attribute**</u>	<u>**Source**</u>	<u>**Provider**</u>	<u>**Measure / Predictor**</u>	<u>**Year**</u>	<u>**Coverage**</u>	<u>**Smallest Unit**</u>
9d. Property Transaction						
	RealQuest Professional	The FirstAmerica CoreLogic	All property transaction prices and other attributes	Long-term (custom order)	National	Transaction Address
	DataQuick	DataQuick	All property transaction prices and other attributes	Long-term (custom order)	National	Transaction Address
	Zillow.com	Zillow, Inc.	Housing property transaction prices and other attributes	Last few years	National	Transaction Address
	HUD Aggregated USPS Administrative Data On Address Vacancies	U.S. Department of Housing and Urban Development (HUD)	Business, residential, and other property vacancy rates and absorption days	Quarterly Dec.2005 to Sep.2010.	National	Census Tract
	Regional, State, and City House Price Index (HPI) Data	Federal Housing Finance Agency (FHFA)	Standardized housing price data	1975-Present Year, Quarterly	National	State & MSAs

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation