Benefit/Cost Analysis of Converting a Lane for Bus Rapid Transit

DETAILS

27 pages | | PAPERBACK
ISBN 978-0-309-42975-7 | DOI 10.17226/23025

AUTHORS

June 2009

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Subject Areas: IA Planning and Administration; IVA Highway Operations, Capacity, and Traffic Control; VI Public Transit

Responsible Senior Program Officer: Gwen Chisholm-Smith

Research Results Digest 336

BENEFIT/COST ANALYSIS OF CONVERTING A LANE FOR BUS RAPID TRANSIT

This digest presents the results of NCHRP Project 20-65, Task 21, "Cost/Benefit Analysis of Converting a Lane for Bus Rapid Transit." The research was conducted by ICF International, with Karen Jones Savage as the Principal Investigator and Project Director.

CONTENTS

INTRODUCTION

This report presents the results of a study of the cost benefit of converting a mixed-flow travel lane to exclusive bus rapid transit (BRT) use. This research included a comprehensive literature review of BRT projects in operation in the United States and several other countries, identification of potential locations where BRT implementation involved taking or converting an existing mixed-flow traffic lane for exclusive BRT use, interviews with representatives of these projects, and preparation of this report summarizing the findings of the research. In addition, research team members conducted research on level of service (LOS) and other evaluation criteria used for the evaluation of BRT proposals, benefit/cost approaches, and evaluation criteria for the Federal Small Starts program—a major source of federal funding for BRT implementation.

SUMMARY

Urbanized areas throughout the United States continue to face considerable challenges in meeting today's transportation needs. Many areas have experienced significant population growth that has outpaced the capacity of the transportation infrastructure. Growth in urban areas has resulted in increased vehicle congestion, longer travel times, and increased travel distances for the majority of the traveling public. Adding highway capacity to address congestion may be cost prohibitive, and, in many cases, the prospect is nearly infeasible due to environmental impacts and community opposition. Thus, attention has turned to enhancing the capacity and efficient operation of the existing transportation system. One option to expand transportation system capacity to move people (as opposed to moving vehicles) is BRT. BRT systems vary from one system to another, but all provide a higher level of transit service than traditional bus transportation. As a result, BRT has become increasingly popular around the United States, with dozens of new lines opening within the past several years and others in planning stages. BRT lines have recently opened in Boston, MA; Denver, CO; and Las Vegas, NV. New lines or expansions of service are planned for Austin, TX; New York, NY; and Seattle, WA; and plans in Los Angeles, CA, include as many as 28 total BRT lines.

While state departments of transportation (DOTs) and local jurisdictions prefer to implement BRT lanes through the provision of additional capacity, it is not always possible, and conversion of existing mixed-flow travel lanes should be considered. Local

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

entities want BRT, even if it means taking a lane. The state, relying on existing design and operations standards, opposes taking a lane. To minimize the prospect of strained relationships with local partners, state DOTs need a tool to help practitioners analyze the effectiveness and benefits of converting existing mixed-flow travel lanes to BRT or other high occupancy vehicle (HOV) lanes. Establishing objective criteria to determine when it is appropriate to take a lane for BRT use would provide value to state DOTs and local jurisdictions alike. A benefit/cost analysis of converting a mixed-flow travel lane for exclusive BRT use would enable state DOTS to examine proposed BRT projects with local partners and the public. In addition, identifying best practices for converting a lane for BRT or HOV use would speed the project delivery process, ultimately benefiting all stakeholders.

RESEARCH OBJECTIVE

The objectives of this research were to (1) locate and assemble documented information on best practices, (2) learn what practice has been used for solving or alleviating the problems, and (3) learn what problems remain largely unsolved.

The effort was broken into two phases. Phase I identified best practices of analysis for converting an existing lane to BRT, including data collection, organization and analysis. Phase II will develop some type of benefit/cost tool to use in analyzing conversion of an existing lane to BRT, including the evaluation requirements and methodology. This effort may include redefining benefit. This digest presents the results of Phase I of the research.

Literature Review

The researchers completed a review of BRT systems around the world (focusing primarily on the United States) to identify locations where it was possible that an existing mixed-flow travel lane had been converted to a designated BRT lane. This review included a focused literature review as well as an online review. Thirty-eight BRT projects were identified where BRT had occurred on a significant level. While there are numerous BRT systems, it is rare that implementation involves converting mixed-flow travel lanes for exclusive BRT or HOV use. The initial list was reviewed and reduced to a list of six locations where the information indicated that a mixed-flow travel lane might have been converted for BRT use. These six locations were the East Bay (Berkeley, Oakland, and San Leandro, CA); Cleveland, OH; Eugene, OR; Los Angeles, CA; Vancouver, BC; and Boston, MA.

Agency Interviews

Research team members conducted interviews with representatives of these six projects to obtain information about the BRT systems, whether implementation involved conversion of a mixed-flow travel lane, and the criteria used to evaluate the BRT projects. Key topics for the interviews included general project background information, barriers or obstacles to project implementation, specific characteristics of the projects, information about project costs and benefits, and lessons that the interviewees learned through implementation of their projects. Interviewees were also asked to provide any additional relevant documentation related to the decision-making process for their projects.

SUMMARY OF FINDINGS

While BRT operations in these six study locations may be operated in exclusive lanes (or separate lanes during the peak travel periods), only two locations involved the conversion of a mixed-flow travel lane. These locations were Cleveland, OH, and Lane County, OR. Other BRT systems have either added new lanes for BRT operation, or used parking lanes during the peak travel hours. BRT in these two locations is operated on arterials. The team did not find any locations where a freeway lane was converted to exclusive BRT or other HOV use.

Benefit/Cost Analysis

None of the six systems studied for this research used a formal benefit/cost analysis or a benefit/cost model. Many of the evaluation criteria used by these agencies to evaluate potential BRT systems are common for multiple systems. This is due in part to the evaluation requirements to receive funding under the Federal Small Starts program, which is a major source of funding for implementation of BRT. The most common evaluation criteria used for the six study locations included travel time, service reliability, system capacity, and cost savings.

Numerous models and strategies have been developed for project evaluation. Some of these include financial evaluations and elements of benefit/cost evaluation. Others use the Federal Transit Administration (FTA) Small Starts process to assess cost-effectiveness rather than a benefit/cost ratio or other specific benefit/cost measures. Some of these models include the California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C), FTA's Transit Investment Analysis Methodology, and FHWA's Highway Economic Requirements System State Version (HERS-ST) model.

Level of Service

An important consideration for BRT implementation is the impact that the BRT lane will have on traffic operations in adjacent mixed-flow travel lanes. The level of traffic congestion typically is expressed as a level of service (LOS) category ranging from LOS A (best conditions) to LOS F (failing). The most commonly accepted definition of LOS is given in the *Highway Capacity Manual* (HCM) published by the TRB. Although the HCM provides operational definitions for LOS for transit, references to LOS generally mean LOS for vehicles on roadways.

While the HCM includes LOS measures for modes other than vehicles on roadways, these LOS measures are based on the amount of facilities and services provided, rather than speed and delay criteria. Transit LOS typically is expressed as a measure of capacity or accessibility (e.g., the number of people residing within walking distance to bus routes or service frequency on a particular street, rather than the operating conditions for transit vehicles such as bus travel speeds, or waiting times for passengers).

In urban areas, transportation agencies have recognized their inability to provide good levels of service for single occupant vehicles on all major routes and, in many cases, have turned to a multimodal approach to defining and measuring LOS. This approach emphasizes person throughput over vehicle throughput. The traditional definition and method of calculation of LOS for a facility is based on the speed or delay for individual vehicles, regardless of the capacity or occupancy of each vehicle. Consequently, a vehicle with one occupant receives just as much priority as a vehicle with 50 occupants in the analysis of present or future traffic conditions. A more important measure for LOS would be the person throughput versus the vehicle throughput for a facility, which would recognize the far greater capacity of transit vehicles.

Lessons Learned

The research team conducted telephone interviews with representatives from organizations and/or departments associated with each of the six selected locations, including representatives from the area's transit agency who were most closely associated with each project. The interviews revealed a number of important lessons that these agencies learned from implementation of their respective systems.

A number of interviewees mentioned encountering economic issues during implementation. They specifically mentioned problems with general financing of their projects, as well as concerns of business owners who did not want to locate their businesses along a BRT route due to a perceived financial risk. Many business owners were concerned that a BRT line would not generate returns on investment similar to that along rail lines. Many places had to contend with public opposition to the system, especially in those areas where they planned to convert travel lanes to exclusive BRT use. The public was concerned about congestion levels worsening and were largely opposed to implementing BRT. In these locations, the agencies increased their public education and public involvement campaigns. They indicated that when the agency took time to explain the minimal negative effects anticipated by implementation of the BRT system, as well as the benefits of the system, public opinion generally changed.

Several of the agencies mentioned the importance of incorporating up-to-date technology, such as light-emitting diode (LED) real-time displays, and the importance of consistent, reliable, and convenient service. Interviewees commented that agencies should keep in mind that BRT systems have been most successful when planned in the context of their surrounding environment rather than independent of it. This lesson applies to the corridor selection, the level of on-street parking that is retained, and where the route operates within the street right of way.

Circumstances When It Is Desirable to Convert a Lane for BRT

One of the most critical evaluation factors in considering conversion of a mixed-flow traffic lane for exclusive BRT use is the potential benefits and dis-benefits that will accrue to all corridor users. Perceived dis-benefits for drivers may be more than offset by improvements for transit users, especially if there is a substantial mode shift from private automobiles to transit. Increasing transit capacity and transit utilization in the corridor will result in an increased person throughput for the entire corridor.

In addition, Intelligent Transportation (IT) improvement on the facility, and on parallel and intersecting facilities, may offset the traffic impacts of converting a mixed-flow travel lane for exclusive BRT use and actually improve travel conditions for all vehicles. It is critical that all of these factors are taken into account in the evaluation of a proposed lane conversion to determine the net benefit of the proposed action and the cost-effectiveness of the potential investment.

SUMMARY OF SUGGESTED RESEARCH

The Phase II research will develop a tool to help practitioners analyze the cost-effectiveness and public feasibility of converting an existing mixed-flow travel lane to a BRT lane or other means of providing increased people throughput for specific transportation facilities. The research will address four areas: (1) identification and evaluation of information sources related to existing benefit/cost models, evaluation criteria for projects requesting funds under the FTA's Small Starts program, and alternative methods to address LOS issues associated with lane conversion; (2) development of a framework for the benefit/cost tool and identification of data elements needed for the model; (3) development of the benefit/cost model itself, testing of the preliminary model, and development of a web interface for the model; and (4) preparation of a comprehensive User's Guide for the model that can be used by a variety of practitioners.

CHAPTER 1 BACKGROUND

PROBLEM STATEMENT

Urbanized areas throughout the United States continue to face considerable challenges in meeting today's transportation needs. Many areas have experienced significant population growth that has outpaced the capacity of the transportation infrastructure. Growth in urban areas has resulted in increased vehicle congestion, longer travel times, and increased travel distances for the majority of the traveling public. In its 2007 *Urban Mobility Report,* the Texas Transportation Institute reported that traffic congestion continues to worsen in all 437 of the nation's urban areas and estimates this is a $78 billion annual drain on the U.S. economy in the form of 4.2 billion lost hours and 2.9 billion gallons of wasted fuel (*1*).

Adding highway capacity to address congestion may be cost prohibitive; often, the prospect is nearly infeasible due to environmental impacts and community opposition. Thus, attention has turned to enhancing the capacity of the existing transportation system. One option to expand system capacity to move people (as opposed to vehicles) is Bus Rapid Transit (BRT). BRT systems vary from one to another, but all provide a higher level of transit service than traditional bus transportation. Usual features include restricted-use lanes, special buses and stations, traffic signal prioritization, prepaid fare systems, real-time passenger information, and some application of Intelligent Transportation Systems (ITS) such as wireless communications, automatic vehicle location, signal priority for buses, and closed-circuit television.

Service on BRT systems is generally faster than regular bus service because the BRT buses make fewer stops and may run as often as comparable rail systems during peak travel times. Many transit agencies now see BRT as an attractive way to get drivers out of their cars and into transit to relieve traffic congestion pressure. The initial cost to implement BRT is typically much less than rail; and in the right conditions, BRT lines can transport large numbers of people efficiently and cost-effectively. Many BRT lines mimic modern rail systems in ease of use, intermodal connectivity, and passenger comfort.

Moreover, many argue that since the right-of-way requirements for BRT and light rail are comparable, BRT facilities may allow for the possibility of conversion to a light rail facility if that is warranted in the future. While examples of this conversion are rare, design adaptability is an additional selling point for BRT proponents. Because many state highway systems already have extensive networks of HOV lanes that can be used for BRT service, it can be implemented relatively quickly. For instance, California's HOV system comprises nearly 1,200 lane-miles. With limited improvements, BRT systems can take advantage of this built-in infrastructure.

As a result, BRT has become increasingly popular around the country with dozens of new lines opening within the past several years and others in planning stages. Lines have recently opened in Boston, Denver, and Las Vegas. New lines are planned for Austin, New York City, and Seattle; and plans in Los Angeles include as many as 28 total BRT lines.

To support the development of these projects, and to expedite their delivery, state DOTs are working more closely with local transit planning and development organizations. For example, the California Department of Transportation (Caltrans) formally recognized the importance of local partnerships when it issued its BRT implementation support policy in 2007.

BRT does not come without controversy. Despite the enthusiasm it engenders, implementing BRT may still be problematic, especially if proposals rely on conversion of mixed-flow travel lanes to BRT lanes. Despite the difficulties, local entities in some areas desire BRT even at the cost of "taking a lane." In San Francisco, local authorities are looking at BRT to alleviate congestion in several corridors, including along Geary Boulevard—one of the city's most popular bus routes. Authorities have proposed various configurations of the new system, including dedicated bus lanes in the center of the corridor or on the sides of the boulevard. This has sparked opposition from local business owners concerned about the elimination of parking and worsening of overall traffic congestion.

Transportation departments, relying on existing design and operations standards, typically oppose the idea of taking a lane for BRT or other HOV use, especially when it involves a full-time taking (rather than peak periods only), or where it causes increased congestion of vehicles in the remaining mixed-flow travel lanes. Generally, the public opposes "take-a-lane" strategies such as this. When Caltrans converted general-purpose lanes to HOV lanes in 1976 on the Santa Monica Freeway (the westernmost segment of Interstate 10), public outcry led to termination of the project and significantly set back other HOV lane development in the Los Angeles area. HOV projects implemented in Los Angeles since then have involved "add-a-lane." A similar situation occurred in 1992 when HOV lanes were created along the Dulles Toll Road, outside of Washington, DC. After several weeks of unrestricted access to the HOV lanes, it became politically infeasible to restrict general traffic from using the lanes. After only a month of operation with restricted lanes, the lanes were re-opened to all vehicles. The Santa Monica and Dulles examples indicate that once lanes are available to general traffic, converting them to exclusive BRT or HOV use is, at a minimum, very contentious.

While state DOTs and local jurisdictions prefer to implement HOV or BRT lanes through the provision of additional capacity, it is not always possible, and lane conversion must be considered. To minimize the prospect of strained relationships with local partners, state DOTs need a tool to help practitioners analyze the effectiveness and benefits of converting existing mixed-flow traffic lanes to BRT or other HOV lanes. Establishing objective criteria to determine when it is appropriate to take a lane for BRT use would provide value to state DOTs and local jurisdictions alike. A benefit/cost analysis of converting a lane for BRT use would enable state DOTs to examine proposed BRT projects with local partners and the public. In addition, identifying best practices for converting a lane for BRT or HOV use would speed the project delivery process, ultimately benefiting all stakeholders.

CHAPTER 2 RESEARCH APPROACH

Literature Review and Selection of Candidate BRT Lane Conversion Projects

The researchers completed a review of BRT systems around the world (focusing primarily on the United States) to identify locations where it was possible that an existing mixed-flow traffic lane had been converted to a designated BRT lane. This review included a focused literature review as well as an online review. The team identified 38 projects where BRT had occurred on a significant level. This list was reviewed and reduced to a list of six locations and two alternates where the information indicated that a mixed-flow traffic lane might have been converted for BRT use. The interview list included BRT routes that operate primarily along arterials rather than highways because the literature survey did not identify locations where a lane conversion occurred on a highway.

Candidate locations were selected for interviews based on (1) the likelihood of lane conversion for project implementation and (2) potential consideration of person throughput (as opposed to more traditional LOS measures) as a performance measure or evaluation criterion for the BRT project. The list of interview candidates is included in Table 1, along with summary information about each location. Detailed information for the 38 projects identified through the literature review is available online as Appendix A.

Table 1 Summary of BRT locations selected for interviews

Interview Locations	System Characteristics
Berkeley, Oakland, and San Leandro, CA East Bay BRT Rapid Transit	• Operating in mixed traffic on four-lane arterials • When complete 90% of the operation will use exclusive, dedicated median lanes • Final implementation of the BRT will use bus-only lanes on arterials, with special pavement delineation and mountable curbs • Enhanced stops, designated stations, intermodal terminals, pedestrian-friendly areas • Articulated low-floor vehicles with enhanced aesthetics and passenger amenities • Off-board, self-service fare collection, smart cards • Hybrid-electric, clean diesel vehicles • Signal manipulation, precision docking, vehicle tracking, passenger information, voice annunciation and security
Cleveland, OH Euclid Corridor BRT	• Operating on mixed-flow arterials with dedicated lanes for BRT • Exclusive BRT lanes (one in each direction) • Enhanced stops, designated stations, intermodal terminals, pedestrian-friendly areas • Low-floor vehicles with enhanced aesthetics • On-board fare collection, cash or smart card • Hybrid-electric vehicles • Vehicle tracking, passenger information, security
Lane Transit District, Eugene, OR Franklin EmX BRT	• Mixed-flow arterials, dedicated arterial, at-grade running ways • Designated stations, land use policies, pedestrian-friendly areas • Articulated low-floor vehicles, enhanced aesthetics, passenger amenities, added doors, quieter operation • Off-board, self-service, fare collection, fare-free initially • Hybrid-electric vehicles • Signal manipulation, vehicle tracking, passenger information, voice annunciation, security
Los Angeles, CA Metro Rapid, Wilshire Boulevard BRT	• Mixed-flow arterials • Designated stations, pedestrian-friendly areas • Conventional, articulated, low-floor vehicles • On-board fare collection • CNG vehicles • Signal manipulation, vehicle tracking, passenger information, and voice annunciation
Vancouver, BC 97 B Line	• Mixed-flow arterials • Basic stops/shelters, enhanced stops, pedestrian-friendly areas • Conventional, low-floor vehicles • On-board fare collection, cash and card • Clean diesel vehicles
Boston, MA Silver Line (Phases I, II, and III)	• Mixed-flow arterials and freeways • At-grade transitways, subways • Basic stops/shelters • Designated stations • Intermodal terminals • Articulated low-floor vehicles, passenger amenities, added doors • Off-board and on-board fare collection • Clean diesel, dual-mode trolley • Passenger information, voice annunciation

Table 1 (Continued)

Alternative Locations	System Characteristics
Minneapolis, MN, Northwest Corridor	• Mixed-flow arterials, dedicated arterials, HOV lanes • Enhanced stops, designated stations, pedestrian-friendly areas • Low-floor vehicles, enhanced aesthetics, added doors, quieter operation • Off-board, self-service fare collection • Hybrid-electric vehicles • Signal manipulation, vehicle tracking, passenger information
San Juan, PR, Rio Hondo Corridor	• Mixed-flow arterials, dedicated arterials, HOV lanes • Enhanced stops, intermodal terminals, pedestrian-friendly areas • Conventional low-floor vehicles • Off-board fare collection, magnetic strip • Clean diesel vehicles • Signal manipulation, vehicle tracking, security

SOURCE: *METRO Magazine,* 2006, 2007, 2008 (*2*).

Agency Interviews

Research team members conducted interviews with representatives of the six projects described in Table 1. Key topics for the interviews included general project background information, barriers or obstacles to project implementation, specific characteristics of projects, information about project costs and benefits, and lessons learned through implementation of projects. Interviewees also were asked to provide additional relevant documentation related to the decision-making process for the project. The results of the interviews are included in Table 9 (Lessons Learned) and in Appendix B, which is available online.

BENEFIT/COST ANALYSIS

The purpose of a benefit/cost analysis is to determine the project alternative that would provide the greatest net benefit, by comparing the monetary value of benefits and costs of each alternative (*3*). The benefits and costs will depend on the features of the project, estimates of future travel demand, and characteristics of the local area or region, such as the local economic and transportation conditions. Transportation agencies may be required to do a detailed benefit/cost analysis to justify investment in a particular project.

Benefit/Cost Analysis (BCA) is one of many tools used over the last four decades to evaluate transportation improvement projects. In the 1990s several financial models were developed, including StratBenCost, NET_BC, CAL/B-C, and STEAM. These tools allow decisionmakers to systematically evaluate and compare the relative advantages (benefits) and disadvantages (costs) of different transportation investment alternatives to a base case and to each other.

BCA is not the same thing as financial analysis. Financial analysis is concerned with how to fund a project over its lifespan and measures the adequacy of current and future funds and revenues to cover the cost of building, operating, and maintaining the project. While financial analysis is an important part of project analysis and management, the economic merit of the project as measured by BCA is generally not affected by how the project is financed.

To complete a "quantitative" analysis, it is necessary to translate all costs and benefits into dollar values. BCA attempts to capture all benefits and costs accruing to society from a project or course of action, regardless of which particular party realizes the benefits or costs, or the form these benefits and costs take. How particular parties will bear various benefits and costs is taken into account since benefits and costs may vary by group. For example, if the value of time savings is considered as one-half the wage rate (often used as an assumption), lower income groups receive proportionately lower benefits than members of higher income groups. In cases of environmental justice issues, disadvantaged groups may face higher costs than other parties, depending on the characteristics of proposed actions. Used properly, BCA reveals the economically efficient investment alternative, i.e., the one that maximizes the net benefits to the public from an allocation of resources.

In general, costs (e.g., capital costs of construction, operating and maintenance costs) are easier to quantify because they are more "concrete" or tangible. However, some costs such as environmental costs and safety may be difficult to measure or quantify. Benefits are more difficult to quantify due to intangible as well as tangible benefits. Potential categories of benefits and dis-benefits (e.g., user impact measures) include travel time (decreases or potential increases for some members of the traveling public), travel costs (including out-of-pocket and other travel costs), travel safety, and emissions.

Since costs and benefits occur over extended time periods, the BCA must take this into account. Typically, this involves conversion of annualized benefit and cost data into a multi-year net benefit analysis. In BCA, the analyst applies a discount rate to the benefits and costs incurred in each year of the project's life cycle.

The BCA process begins with the establishment of objectives for a transportation improvement, such as reducing transportation congestion or improving safety. A clear statement of the objective(s) is essential to reduce the number of alternatives considered and guide the development of evaluation criteria and measures.

To enable comparison of alternatives, it is necessary to standardize the categories of benefits and costs that are considered and the methodology used to calculate them. Direct benefits to users of the transportation system (including travel time savings, reduced trip costs, and reduced accident costs) and the direct benefits that accrue to users and non-users (such as reductions in emissions, noise, and other environmental impacts) are relatively simple to estimate. However, much variation exists in how these benefits are monetized. Indirect benefits arising from increased economic development and land development are often difficult to estimate and, for this reason, may be omitted by agencies. The costs against which benefits are weighed are also similarly varied. The construction, operation, and maintenance costs of a project are easier to estimate than the costs of traffic delays during construction or the costs of long-term environmental impacts. Table 2 summarizes example benefits and costs.

Once the analyst has calculated all of the benefits and costs of alternatives and discounted them, several measures could be used to compare benefits to costs in BCA. The two most widely used measures are Net Present Value (NPV) and Benefit/Cost Ratio (BCR).

Net Present Value

NPV is perhaps the most straightforward BCA measure. All benefits and costs over an alternative's life cycle are discounted to the present, and the costs are subtracted from the benefits to yield an NPV. If benefits exceed costs, the NPV is positive and the project is worth pursuing. Where two or more alternatives for a project exist, the one with the highest NPV over an equivalent analysis period should usually be pursued. New approaches have been developed recently to deal with a primary criticism of discounting—that benefits to future generations appear too insignificant when seen in terms of present value, while costs seem relatively higher because they are required in the short term. Therefore, projects with seemingly lower NPV may actually be worth pursuing because the benefits will be in the future rather than the present. Policy issues, perceived risk, and funding availability, however, may lead to the selection of an alternative with a lower NPV.

Benefit/Cost Ratio

The BCR is frequently used to select among projects when funding restrictions apply. In this measure, the present value of benefits (including any negative benefits) is placed in the numerator of the ratio and the present value of the initial agency investment cost is placed in the denominator. For a given budget, projects with the highest BCRs can be selected to form a package of projects that yields the greatest multiple of benefits to costs.

DEFINING BRT

There is a range of characteristics associated with BRT operations in the United States and around the world. "Bus Rapid Transit can best be described as a combination of facility, systems, and vehicle investments that convert conventional bus services into a fixed facility transit service, greatly increasing their efficiency and effectiveness to the end user" (*4*).

BRT is also defined as "a flexible rubber-tired rapid transit mode that combines stations, vehicles, services, running ways, and Intelligent Transportation System (ITS) elements into an integrated system with a strong positive identity that evokes a unique image. BRT applications are designed to be appropriate to the market they serve and their physical surroundings, and can be incrementally implemented in a variety of environments" (*5*).

Table 2 Example benefits and costs of converting a lane for BRT

	Benefits
Direct Benefits	• Travel time savings for transit users • Vehicle operating cost, parking cost, and insurance savings for people who switch from private auto to transit • Improved access to jobs and amenities for certain population groups, especially transit-dependent travelers • Potential reduction in accident costs • Benefits from reduced emissions* • Lower costs for transit per passenger due to improved operating efficiencies and higher ridership for transit • Benefits from reduced environmental damage
Indirect Benefits	• Benefits from increased economic activity and/or agglomeration of businesses • Benefits from property development owing to transit investment+ • Growth in employment in transit service area+ • Benefits to government from increased taxes generated by new development
	Costs
Direct Costs	• Capital costs of materials and equipment • Delay for travelers in mixed-flow travel lanes • Infrastructure construction costs (including roadway improvements, bus shelters, IT) • Capital costs for new buses • Operations and maintenance costs • Overhead expenses of business, commercial and government fleets using mixed-flow travel lanes resulting from traffic delays in mixed-flow lanes • Enforcement costs to government to prohibit use of dedicated lanes by general-purpose traffic
Social Costs	• Costs of traffic delays during construction • Costs of noise pollution • Costs of emissions if congestion on remaining lanes of highway increases • Costs of travel delay to others if congestion on remaining lanes of highway increases

* This benefit accrues to both users and non-users and would vary over the life of the project with changes in the level of service on the roadway for transit and for general-purpose traffic.
+ Although these are indirect benefits, they are not included in calculations because they are considered a transfer from other regions.

Systems usually are described in relation to six major categories as summarized in Table 3. Specific characteristics may differ substantially from one location to another within each of these major categories.

While it is not necessary that BRT projects meet all of the elements described above, there is a minimum set of characteristics needed to qualify for funding under the Federal Small Starts program. In order to qualify for federal funding, the system must include the following features:

- Substantial transit stations;
- Traffic signal priority/pre-emption, to the extent, if any, that there are traffic signals on the corridor;
- Low-floor vehicles or level boarding;
- Branding of the proposed service; and
- 10-min peak/15-min off-peak headways or better while operating at least 14 hr on weekdays.

Lane Conversion for BRT

Given the problems associated with adding lanes to existing freeway and arterial facilities, some transportation agencies have proposed “taking” a mixed-flow traffic lane serving general-purpose traffic and converting it to exclusive bus or HOV use. This would allow transit vehicles and HOVs to travel more quickly and with more reliable travel times and speeds on these facilities. In some locations, BRT lanes have been

Table 3 BRT characteristics

Element	Definition
Running Way	Dedicated running ways, exclusive bus lanes Distinctive pavement treatment "Branded," consistent with appearance of BRT vehicles High-quality, attractive, functional amenities
Vehicles	Easy-to-board (level with platform) Multiple-door boarding and alighting "Branded" exteriors that are distinctive and consistent with appearance of stations High capacity, level boarding and alighting Pleasant interior conveniences, quiet Low or zero emissions
Service	Frequent all-day service with short headways (10 min or better) Wide station stop spacing
Route Structure	Simple route layout Convenient transfers Station locations coordinated with land use plans Service to major activity centers
Fare Collection	Off-vehicle fare collection Emphasis on prepaid fares
Intelligent Transportation Systems (ITS) and Technology	ITS technologies (for example, real-time "next bus" arrival information signs at stations, "next stop" signs on board buses, smart fare payment media and technology, traffic signal prioritization and traffic management) Automated guidance features for precision operations and docking

SOURCE: TCRP Project A-23, 2001 (*6*).

created by eliminating on-street parking during peak travel periods. In other locations, BRT lanes have been created by using the shoulders or medians on existing facilities or by adding new lanes to existing facilities; in some locations BRT lanes have been created by converting a mixed-flow traffic lane. Several potential issues are associated with conversion of existing travel lanes for exclusive bus or HOV use, including

- Potential degradation of the LOS for general-purpose traffic using the remaining mixed-flow travel lanes;
- Operational issues including potential conflicts for use of the curb lanes on arterials (parking, vehicles turning at intersections or entering/exiting on freeways ramps, bicycles) and issues associated with passenger access to BRT for lanes operating in the medians of facilities; and
- Cost-effectiveness of converting a mixed-flow traffic lane to exclusive transit use.

However, there are some examples of locations where an existing mixed-flow travel lane(s) has been converted for exclusive BRT use, including the Euclid Line in Cleveland, OH; the EmX lane in Eugene, OR; and the proposed lane for AC Transit's East Bay BRT. In other locations on-street parking has been converted for BRT use (e.g., Los Angeles, CA); and in some instances turn lanes were converted to BRT use (Vancouver, BC, B Lines).

Supporting Actions to Minimize Impacts of Lane Conversion

When deciding whether or not to convert an existing mixed-flow travel lane to exclusive BRT, it is useful to evaluate the potential impacts of supportive actions on conditions in the travel corridor, as well as parallel and intersecting facilities. Communities can use several strategies to minimize potentially negative impacts of the proposed lane conversion and improve the operating environment for the BRT system, as well as traffic in general. Supporting actions that can be used to mitigate potential negative impacts of a lane conversion fall into three major categories, as described below:

- Implement ITS strategies on the facility for all travel lanes and on parallel and intersecting routes. Advanced signal synchronization and signal priorities for BRT vehicles can improve the traffic conditions in the BRT lane, as well as the overall flow and capacity of the facility. It is possible that traffic conditions could actually improve in the remaining mixed-flow traffic lanes if buses are removed from the traffic mix and appropriate ITS improvements are implemented. In addition to making ITS improvements on the facility with the BRT lane, communities can make ITS improvements on parallel and intersecting facilities to accommodate traffic that may be diverted to other facilities and to improve the traffic flow in a larger area.
- Implement Smart Growth land use policies and plans. Smart Growth strategies that call for increased density of development, mixed-use development, infill development, and improved conditions for pedestrians all help to create a better environment for successful transit operations.
- Implement a comprehensive Travel Demand Management (TDM) program. The TDM program would include strategies/policies related to parking management, employer incentive programs, and increased transit services in the BRT corridor, as well as on parallel and intersecting facilities. It is also important to ensure that the BRT lanes link key locations and provide convenient access to them through multiple access modes (e.g., provision of a park-and-ride lot at the end of a BRT corridor and/or feeder bus service to key nodes/stations on the BRT corridor). Together, these actions would help to improve the operating environment for transit and increase the demand for transit use relative to driving alone.

CHAPTER 3 FINDINGS AND APPLICATIONS

EVALUATION CRITERIA FOR BRT

Many of the evaluation criteria used to evaluate potential BRT systems are common for multiple systems. This is due in part to the requirements for funding under the Federal Small Starts program, which is described in more detail later in this chapter. Table 4 summarizes the criteria used for evaluation of alternatives for the case study locations selected for this project.

Three of the six sites selected for interviews did, or are planning to, convert an existing mixed-flow traffic lane for dedicated BRT use. These include the East Bay BRT in Oakland, CA; the Euclid Corridor in Cleveland, OH; and the EmX Franklin Corridor in Eugene, OR. These three locations used different processes and criteria to evaluate their proposed projects. However, there are similarities because all three involved the use of federal funds for project implementation. The evaluation processes were designed to address the criteria included in the FTA New Starts or Small Starts funding programs. A brief summary of these three projects is provided below.

East Bay BRT, Oakland, CA

The proposed bus lane project is currently under evaluation. A Draft Environmental Impact Statement (EIS) was completed in May 2008 and was released for public review and comment. Currently AC Transit is working with local jurisdictions to obtain permission to convert a lane for exclusive BRT operation along the 17-mile route on State Route 185. They are identifying necessary mitigation and refinements in the design to address local concerns and situations. AC Transit submitted their application for Federal Small Starts funding in December of 2008 and received a high rating; and they are on the list for funding in 2010.

A Major Investment Study (MIS) was done for the corridor to evaluate alternative transit improvements for the corridor. The corridor alternatives included light rail transit and different levels of BRT operation. Due to the urban nature of the corridor, with buildings fronting on the roadway, it was determined that roadway widening was not an option. Concern expressed by property owners and the public about the loss of parking led to evaluation of the option of converting two mixed-flow traffic lanes on this four-lane facility.

The analysis for the project did not include a standard benefit/cost analysis. Since they have applied for Federal Small Starts funding they conducted their analysis in conformance with the Small Starts criteria, which is based on evaluating the cost-effectiveness of the investment, rather than a more traditional benefit/cost ratio. They used the FTA SUMMIT model to analyze person travel time before and after implementation of the proposed project. The analysis includes

Table 4 Evaluation criteria used for BRT projects

Criteria Used	Boston Silver Line	Cleveland Euclid	EmX Eugene, OR	AC Transit	Los Angeles Wilshire Line	B Line Vancouver, B.C.
Travel Time (minutes)	X	X	X	X	X	X
Reliability (poor to excellent)	X		X	X	X	X
Bus Boardings in Corridor, Change in Weekday Boardings		X	X	X		
Transit Ridership (new weekday transit trips)		X	X	X	X	
Image & Identity	X				X	X
Passenger Safety & Security	X					
System Capacity (# of riders/hour)	X		X	X	X	X
Transit System User Benefits		X		X		
Energy Savings		X	X			
Cost Savings (incremental cost per incremental rider), Net Operating Costs		X		X	X	X
Auto Travel, Change in Alameda Co. Weekday VMT				X		
Express Bus Frequency				X		
Roadway Auto Capacity				X		
Roadway Person Trip Capacity				X		
Potential for Transit-Oriented Development		X		X	X	X
Construction Cost				X		X
Total Cost/New Transit Trip		X		X		X
Parking Displaced		X		X		
Intersection Delay		X		X		
Construction Impacts				X		
Environmental Justice				X		
Other Environmental Effects (air quality, noise, energy, cultural resources, etc.)		X	X	X		X

SOURCE: FTA, 2008 (*7*).

the assessment of annual cost (operating and capital) divided by the travel time savings for transit users. In this case FTA had them factor in delays that would be encountered by motorists using the remaining two lanes to determine the net improvements in travel time for all corridor users.

Key criteria used for the evaluation were oriented around achievement of service objectives developed for the project and included improvements in travel time for transit users, impacts on traffic on State Route 185 and parallel facilities, encouragement of Transit Oriented Development (TOD) in the corridor, air quality, mode shift to transit, and other considerations required by the Small Starts program.

Euclid Corridor, Cleveland, OH

There is a long history of transit planning for the Euclid Corridor, stretching back over 50 years when a subway line was studied for the corridor. More recently, they completed an Alternatives Analysis for the corridor to evaluate options, including light rail, electric trolley, and BRT. Rather than using a formal benefit/cost model, they relied on the evaluation criteria and process required for FTA New Starts funding. This is the only BRT system in the United States that received funding through the New Starts program; others have received federal funding through the Small Starts program.

They began work on implementation of the lane conversion in the spring of 2006, and it became fully operational in October 2008. The BRT lane was developed in coordination with the implementation of a Transit Zone in downtown Cleveland to facilitate overall transit network operations. The Transit Zone provides curb lanes for transit operations for a 2-mi area in downtown Cleveland where 90% of the system buses converge. The bus lanes in the Transit Zone include a full-time bus lane in one direction and a peak hour bus lane in the other direction.

Key elements of the analysis for the Euclid Corridor project included traffic analysis for Euclid and the two parallel facilities in the Euclid corridor; impacts on transit operations, including travel speed and changes in transit user travel times; and economic and land use analysis to assess potential impacts on corridor development and re-development.

Staff indicated that the BRT alternative was the only one that they could afford to fund. It was necessary to take travel lanes in the central portion of the corridor in order to provide the dedicated bus lanes required for New Starts funding. Staff concluded that the combination of the excess capacity on Euclid Street and the improvements in transit operations achieved with the BRT lanes made this project possible. Use of a dedicated transitway allowed them to meet the federal requirements for a dedicated transitway for the central 4.5 mi of the corridor.

EmX Franklin Corridor, Eugene, OR

Eugene implemented its first BRT line in February 2007. After 4 months, ridership on the line exceeded the 20-year forecasts and has continued to grow. Currently they are building the second line and are in the environmental process for the third line. In their evaluation for the BRT system, they considered numerous alternatives, including light rail, transportation system management, and the BRT system. They used a variety of solutions for different segments of the corridor, depending on the unique circumstances and options in each section. These include road widening in some places, removing parking, taking turn lanes, and taking travel lanes in order to get the space needed for the BRT operation.

In general, they tried to find solutions that did not require lane conversion, but it was necessary in portions of the corridor. In order to justify taking a travel lane, they needed to show that there would be sufficient capacity for traffic on the facility over a 20-year planning horizon. They used traffic modeling and simulation to evaluate traffic conditions with and without the BRT line. Financial analysis was done as part of the environmental analysis, but they did not do a traditional type of BCA. Instead, they used a cost-effectiveness approach as required for funding under FTA's Small Starts program.

The Eugene project was the first BRT project funded under FTA's Small Starts program. The Small Starts process was revised somewhat during the Oregon evaluation process. The most critical evaluation factor was the cost/new rider, i.e., how much would it cost to get each new rider on the system. They used FTA's SUMMIT software program to calculate the Transit System User Benefit (TSUB).

LEVEL OF SERVICE

An important consideration for BRT implementation is the impact of the BRT lane on traffic congestion in the adjacent mixed-flow travel lanes. The level of traffic congestion is expressed as a LOS category ranging from LOS A (best) to LOS F (failing). The most commonly accepted definition of LOS is given in the *Highway Capacity Manual* (*8*). This definition is a broad, qualitative measure of transportation conditions experienced by vehicle drivers. Although the HCM provides operational definitions for LOS for transit, pedestrian and bicycle facilities, references to "level of service" generally mean LOS for vehicles (and drivers) on roadways.

LOS is most commonly determined by a quantitative measure; it is measured differently for freeways and other "uninterrupted flow" facilities and for streets and highways with at-grade intersections and traffic signals. For freeways, service levels are associated with average travel speeds; for at-grade streets and highways, LOS is measured by average delay per vehicle at intersections. In both cases, LOS is usually quoted for the weekday AM and PM peak travel periods. Table 5 lists freeway LOS in terms of average speeds. They assume a 65-mph speed limit and a roadway designed to meet national standards.

LOS for at-grade, or interrupted flow, facilities is defined in terms of the delay experienced by drivers due to other vehicles using the roadway. They are termed interrupted flow facilities because traffic signals are used to interrupt intersecting traffic streams to apportion right-of-way so that drivers can make their movements in a safe and efficient manner at intersections. Even during low-volume conditions,

Table 5 Levels of service for freeway sections

LOS	Speed (mph)	
A	≥60	*"Level of service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of service measures such as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience."*
B	≥55	
C	≥49	
D	≥41	
E	≥30	
F	<30	

SOURCE: *Highway Capacity Manual,* 2000 (*8*).

drivers expect to have to stop at traffic signals occasionally. Excess delay is defined as the difference between the actual travel time a vehicle experiences and the time it would experience if there were few other vehicles on the roadway. As traffic volumes grow, drivers become increasingly unable to get through an intersection on one signal cycle (red-green-yellow-red) due to the combination of traffic on their roadway and volumes of crossing or turning traffic. This situation is termed a "cycle failure" by traffic engineers. As defined by the HCM, intersection LOS is divided into the six categories shown in Table 6.

Multimodal LOS

The HCM also includes LOS measures for modes other than vehicles on roadways. Different chapters of the HCM provide LOS categories and measures for transit, pedestrian, and bicycle modes. However, these LOS measures are based on the amount of facilities and services provided, rather than speed and delay criteria. Pedestrian and bicycle LOS measures typically described the presence and size of facilities provided (e.g., square feet of sidewalk, presence of bicycle lanes or other facilities) rather than an operational measure such as intersection crossing time. Transit LOS is expressed as a measure of capacity or accessibility (e.g., number of people residing within walking distance to bus routes, service frequency on a particular street), rather than the operating conditions for transit vehicles such as bus travel speeds or waiting times for passengers.

Florida Interstate Highway System: Multimodal Corridor LOS Analysis (MMCLOS)

During the past several years, the Florida Department of Transportation (FDOT) has taken a leadership role nationally in the development of analytical tools and processes to assist local governments and Metropolitan Planning Organizations (MPOs) in understanding facility, corridor, and system LOS for these alternatives (*9*). The MMCLOS model was developed to provide FDOT with a transportation corridor LOS analysis technique from a multimodal perspective. It was designed to enable FDOT planners to evaluate the impacts of projects and project alternatives on the quality of service perceived by users of all modes of travel in a corridor. It reflects automobile, bicycle, pedestrian, truck, and transit modes in sufficient detail to allow for the development of multimodal LOS software for Florida Interstate High-

Table 6 Intersection Levels of Service

Level of Service (LOS)	Average Control Delay (seconds/vehicle)	Definition
LOS A	≤ 10.0	Operations with very slight delay, with no approach phase fully utilized.
LOS B	10.1–20.0	Operations with slight delay, with occasional full utilization of approach phase.
LOS C	20.1–35.0	Operations with moderate delay. Individual cycle failures begin to appear.
LOS D	35.1–55.0	Operations with heavier, but frequently tolerable delay. Many vehicles stop and individual cycle failures are noticeable.
LOS E	55.1–80.0	Operations with high delay and frequent cycle failures. Long queues form upstream of intersection.
LOS F	> 80.0	Operation with very high delays and congestion. Volumes vary widely depending on downstream queue conditions.

SOURCE: *Highway Capacity Manual*, 2000 (*8*).

way System (FIHS) corridor planning. The MMCLOS methodology addresses the shortcomings of the existing LOS measurements, which focus on vehicle delay at intersections. It builds upon the HCM, the *Transit Capacity and Quality of Service Manual* (TCQSM) (*10*), Florida's Mobility Performance Measures Handbook (*11*), and studies by FDOT into pedestrian and bicycle LOS measures.

MMCLOS is intended for application at the corridor (multi-facility) level of aggregation and the generalized/conceptual planning level. It concentrates on the supply side (quality of service), so demand analysis is not included except where absolutely necessary. MMCLOS is applied in three steps: (1) corridor definition, (2) computation of modal LOS, and (3) reporting of the results.

Most importantly, MMCLOS expands the problem definition beyond the number of lanes for cars and trucks to encompass the range of facilities and modes for moving people and goods through a corridor. In turn, this refocuses solution development from emphasis on more roadway lane capacity to multimodal facilities based on how many people, rather than vehicles, are served per unit of time such as the peak hour.

Person Throughput vs. Vehicle Throughput

In urban areas, transportation agencies have recognized the inability to provide good LOS for single occupant vehicles on major routes and have turned to a multimodal approach to LOS. This approach emphasizes person throughput over vehicle throughput.

The traditional definition and method of calculation for the LOS for a facility is based on the speed or delay for individual vehicles, regardless of the capacity or occupancy of each vehicle. Consequently, a vehicle with one occupant receives just as much priority as a vehicle with 50 occupants, such as a bus. Therefore, an improvement that benefits 50 single occupant vehicles would appear to be 50 times more effective in improving LOS than one that benefits a single bus with 50 occupants by the same amount.

In addition, current practice based on the HCM does not provide a consistent methodology to measure the intersection LOS for all users. In fact, the HCM procedures for measuring transit, bicycle, and pedestrian LOS rely on performance measures that are unique to each mode. As mentioned above, pedestrian LOS is based on pedestrian space and has no relation to the delay caused to pedestrians crossing intersections (*12*).

A more important measure for LOS would be the "person throughput" versus the "vehicle throughput" for an arterial or intersection. A 2004 survey of 106 metropolitan areas by the Research and Innovative Technology Administration (RITA) found areas as diverse as Little Rock, AK; Harrisburg, PA; and Dallas-Fort Worth, TX, use person throughput as a performance measure at both the spot and corridor levels for their transportation systems (*13*).

In planning for HOV lanes, the North Carolina DOT considers both person throughput and vehicle throughput; the latter is included to avoid the public perception of "empty lane syndrome." The minimum criteria for HOV lane implementation are that the HOV lane should carry at least 20% of the average number of persons the adjacent mixed-flow lanes carry and initial usage should be 400 to 800 HOVs per hour, 30 to 45 buses per hour, or some combination thereof (*14*).

Planners must balance the competing needs of transit and traffic objectives. In terms of increasing person-throughput capacity in a given corridor, transit priority measures, combined with high-frequency service, should be factored into the analysis. Finding safe and efficient ways to give buses priority requires significant cooperation between the infrastructure owner (Caltrans or a city/county) and the transit operator (*15*).

While these examples illustrate the use of person throughput as a critical measure, it has not been universally adopted. In many locations, traffic engineers still rely on the traditional HCM definition of LOS. Using this approach typically will underestimate the relative value of converting a mixed-flow traffic lane to exclusive BRT use, and traffic engineers may be reluctant to endorse lane conversion.

Person Capacity for BRT Systems

A more specific measure of person throughput or capacity has been developed specifically for transit. Different BRT elements determine the capacity of the system. Table 7 summarizes three key aspects of capacity: maximum capacity, design capacity, and operated capacity.

More specifically, three primary factors determine the maximum person capacity of a system—passenger capacity of BRT vehicles (how many passengers a vehicle can carry), the vehicle capacity of BRT

Table 7 Different aspects of capacity

Dimension of Capacity	Definition	Determined by
Maximum Capacity	The unconstrained theoretical capacity as determined by the physical characteristics of the system	• Vehicle Size (Maximum) • BRT Facility
Design Capacity	Maximum capacity scaled down due to standards and policies (constraints) related to passenger comfort, safety, and manageability	• Operating Policies
Operated Capacity	The capacity based on the vehicle size and frequency actually operated. The operated capacity is usually less than the maximum capacity since the operation is scaled to actual demand.	• Service Plan (Frequency) • Vehicle Size (Actual; size may be smaller than the system can handle)

SOURCE: Diaz et al., 2004 (*16*).

Facilities (how many vehicles per hour can use a specific BRT facility), and passenger demand characteristics (the maximum load points or potential bottlenecks in the system.) The ultimate determinant of actual capacity is the frequency of service and the size of the actual vehicles operated. Congested conditions along the facility where BRT operates can affect system capacity (as well as reliability by decreasing the travel speeds for BRT vehicles). Conversely, provision of separate running ways for BRT vehicles can increase the capacity substantially, along with system travel speeds, service reliability, and passenger satisfaction.

INTERVIEW RESULTS

The research team conducted telephone interviews with representatives from organizations and/or departments associated with each of the six selected locations, including representatives from the area's transit agency who were closely associated with each project. Interviewees and their associations are listed in Table 8.

Initially, researchers contacted the organizations via e-mail to explain the purpose of the interview and to identify the most appropriate person(s) to interview. Following identification of the correct person to interview, a list of questions was sent in preparation for the interview and a date and time for the interview was established.

Survey questions covered general background information, barriers or obstacles to project implementation, specific characteristics of each project, a project's cost and benefits, and lessons learned by implementing their particular project. Interviewees also were asked to provide any additional relevant documentation related to the decision-making process for the project. A summary of the results of the interviews is included in Table 9; detailed information is included in Appendix B, which is available online. Follow-up interviews were conducted with AC Transit, Lane Transit District, and the Greater Cleveland Regional Transit Authority to obtain additional information about their evaluation processes and criteria for lane conversions for BRT.

The interviews revealed a number of important lessons learned from implementation of the respective systems. A number of interviewees mentioned encountering economic issues during their BRT implementation. They specifically mentioned problems

Table 8 Project interviews

Interviewee Association	BRT Project
AC Transit	East Bay BRT, Oakland, CA
Planning and Development Department of Boston	Silver Line, Boston, MA
Los Angeles County Metropolitan Transportation Authority	Wilshire Boulevard (Line 720), Los Angeles, CA
Greater Cleveland Regional Transit Authority	Euclid Corridor, Cleveland, OH
Lane Transit District	EmX, Franklin Corridor, Eugene, OR
TransLink	B Lines (#98), Vancouver, B.C.

with the general financing of a project as well as business owners who did not want to locate their business along a BRT route due to the apparent financial risk. Many business owners were concerned that a BRT line would not generate returns on investments similar to that along rail lines. In Boston, Phase III of the Silver Line stimulated significant economic growth and development, a trend that appears to differ from other places.

Many places had to contend with public opposition to the system, especially in those areas where they planned to convert travel lanes to exclusive BRT use. After announcement of the proposed BRT project, the public was concerned about congestion levels worsening and were largely opposed to installing BRT. In these locations, the agencies increased their public education and public involvement campaigns. These places concluded that an informed public was generally more supportive of the proposed projects. When agencies took time to explain the minimal negative effects of a BRT system as well as the numerous rider benefits, public opinion generally changed. An integral part of gaining public support was sponsoring numerous workshops and other activities to involve the public as much as possible in project planning and to help project staff obtain a better sense of how community members envisioned a BRT system operating within their community.

In terms of logistics and operations, several interviewees mentioned the importance of incorporating working, up-to-date technology. Several interviewees cited LED real-time displays as vital to rider satisfaction. Interviewees also indicated that the public was more likely to use BRT if it offered similar benefits to rail, specifically consistency, reliability, and convenience. MBTA mentioned that it is important to select vehicles that can navigate BRT routes year-round, regardless of weather conditions, since this contributes to consistent service.

Interviewees commented that agencies should keep in mind that BRT systems have been most successful when planned in the context of their surrounding environment, rather than independently of it. This lesson applies to the corridor selection, the level of on-street parking that is retained versus eliminated, and where the route operates (e.g., whether it is in the median of the facility, uses parking lanes, requires conversion of a general-purpose traffic lane to dedicated BRT use, or will be implemented on new lanes).

ILLUSTRATIVE BENEFIT/COST ANALYSIS

Numerous models and strategies for project evaluation have been developed. Some of these include financial evaluation and elements of benefit/cost evaluation. Others use the FTA Small Starts process to assess cost-effectiveness rather than a benefit/cost ratio or other specific benefit/cost measures. Some of these models are summarized in this chapter, along with information about the FTA Small Starts evaluation process.

Analytical Models for Transportation Investments

Several models have been developed for the analysis of highway and transit investments, including the California Life-Cycle Benefit/Cost Analysis Model, FTA's Transit Investment Analysis Methodology model, and FHWA's Highway Economic Requirements System State Version model. These models are summarized below. These models were developed for different uses, but may provide some utility in analyzing BRT investments. However, they were not designed to evaluate the specific strategy of lane conversion for exclusive BRT use.

California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C)

The model consists of a Microsoft Excel 2002 spreadsheet that provides economic benefits and cost analysis for a range of capacity-expansion transportation projects. The model measures, in real-dollar terms, four primary categories of benefits that result from highway and transit projects: (1) travel time savings, (2) vehicle operating cost savings, (3) safety benefits (accident cost savings), and (4) emission reductions. The model estimates each of these benefits for a peak (or congested) period as well as a non-peak (or un-congested) period. By measuring benefits during these clearly different times, one can measure the difference in benefits. The model calculates anticipated average annual benefits (in millions of dollars) and benefits for a 20-year life cycle. The four primary categories of benefits are evaluated in terms of time and/or cost savings (*17*).

Highway Economic Requirements System for State Use (HERS-ST)

The FHWA developed the HERS-ST model as a direct extension of the national-level HERS model.

Table 9 Lessons learned from implementing BRT projects

Lessons Learned	Project Interviews					
	East Bay BRT Oakland, CA	Silver Line Boston, MA	MetroRapid Los Angeles, CA	Euclid Corridor Cleveland, OH	EmX (Franklin Corridor) Eugene, OR	B Lines Vancouver, B.C.
1. Construct a route along the areas with proven ridership. Evaluate routes serving low-income neighborhoods when planning a bus route—these areas tend to have the strongest transit ridership.	X					
2. Identify the most controversial aspects of a project and focus on them.	X			X		
3. Take a proactive approach to parking for commercial areas.	X					
4. Operate in the median to minimize impacts on adjacent properties, parking and non-motorized travel modes.		X				
5. Do not design shelters through a community process—it is unlikely the final decision will be functional.		X				
6. Find an appropriate vehicle to use for the BRT route given the particular climate, clientele, and physical characteristics of the route.		X				
7. BRT routes can stimulate commercial growth and redevelopment.		X		X		
8. Financing can become a significant issue to a project's progress.		X		X		
9. Bus-only lanes are not essential for generating a significant improvement in speed. ITS strategies along with changes in bus operations (e.g., skip stop operation) can result in improvements in travel speed and trip length.			X			
10. Real-time displays should be installed from the very beginning in all stations. They cut the perceived wait time in half.			X			X
11. Once the system is in operation, if congestion or inconsistency (travel times and route reliability) begin to occur, bus-only lanes will become a necessity.			X			
12. BRT implementation is an important part of selling the system.			X			
13. Government support is essential for planning, implementation and long-term operation.			X	X		

14. Work closely with transit operations and utility company staff.			X	X		
15. Careful corridor selection is important. Evaluate the network in which the BRT would operate to plan the most effective BRT system within the surrounding environment.				X		
16. Address perceived as well as real issues.				X		
17. Overlay zoning can help reduce long-term operating costs.				X		
18. Third-party agreements can generate scheduling issues for BRT operation.				X		
19. It is difficult to design a BRT system that successfully accommodates cars, bikes, pedestrians, and sidewalk cafes due to conflicts in use of the curb lane and adjacent sidewalk space.				X		
20. BRT projects may generate public opposition (especially if they involve taking a mixed-flow traffic lane or parking), which will inevitably slow down the project.				X		
21. Hire a dedicated staff for key planning and implementation functions to maintain continuity and streamline the process as much as possible.				X		
22. The mode of travel one provides is less important than the quality of service. Strive to create a straightforward, effective route structure with reliable service.					X	
23. Work to convince the public and the local government that the agency can run the route through the short term and over the long term.					X	
24. Spend time explaining the degree to which the BRT route may or may not impact the traffic conditions for all travel lanes.					X	
25. Persistence pays. It takes a lot of effort to implement these kinds of projects.					X	
26. Build for the future.					X	
27. Compromises made early on in the project to get it off the ground can create issues later on.					X	
28. Involve the community as much as possible in all stages of planning and implementation of the system.						X
29. Choose a BRT project title carefully—terminology can generate confusion among the traveling public.						X
30. Spend time branding. Create feature comforts associated with the BRT line to distinguish it from other, local bus lines.						X
31. Invest in good, accurate technology for system operation.						X

FHWA created it in order to examine the relationship between national highway investment levels and the condition and performance of the nation's highway system. The HERS-ST model uses engineering standards to identify highway deficiencies and applies economic criteria to select the most cost-effective mix of highway system improvements. It consists of a software package that predicts the investment required to achieve certain highway system performance levels. The model considers capital improvement projects directed at correcting pavement and/or capacity deficiencies. The HERS concept has been extensively and favorably reviewed over the past decade. While this model is oriented toward highway investments rather than transit investments it may provide some insights for the evaluation of BRT-related lane conversion projects (*18*).

Transit Economic Requirements Model

The FTA developed the Transit Economic Requirements Model (TERM) to estimate investment for rural transit and special service transit for the "Maintain" and "Improve" scenarios and the processes used to determine asset decay curves and the findings of the surveys undertaken since the 2004 C&P report. The model operates by estimating the physical conditions of the U.S. transit assets and the total annual capital expenditures to be undertaken in all urbanized areas from federal, state, and local governments to maintain or improve the physical condition and level of service of the U.S. transit system infrastructure. TERM also determines the allocation of projected investment among transit asset categories, including vehicles, maintenance facilities, guideways, stations, train control, electrification, communication systems, and the sensitivity of the investment projections to variations in the rate of future growth in the demand for transit services (*19*).

FTA Funding for BRT

To qualify for funding under the FTA's New Starts and Small Starts programs, proposed projects must meet the criteria shown in Table 10. Small Starts projects are defined as projects requesting under $75 million in Section 5309 Capital Investment Grant funding with a total cost of less than $250 million—both expressed in year of expenditure dollars. Applicants for funding are evaluated and assigned a value of Low, Medium-Low, Medium, Medium-High, and High. Specific dollar breakpoints are defined for each of these five groups; and criterion-specific ratings are subsequently combined to derive the summary justification ratings for each project.

In addition to the cost and funding limits specified above, a Small Starts project must either (a) meet the definition of a fixed guideway for at least 50% of the project length in the peak period, (b) be a new fixed guideway project, or (c) be a new corridor-based bus project with all of the following minimum elements:

- Substantial transit stations;
- Traffic signal priority/pre-emption, to the extent, if any, that there are traffic signals on the corridor;

Table 10 New Starts and Small Starts project justification criteria and supporting measures and categories

Criteria	Measures/Categories
Cost-Effectiveness (New Starts and Small Starts)	• Incremental Cost per Hour of Transportation System User Benefit
Transit Supportive Land Use and Future Patterns (New Starts and Small Starts)	• Existing Land Use • Transit Supportive Plans and Policies • Performance and Impacts of Policies
Mobility Improvements (New Starts Only)	• User Benefits per Passenger Mile • Number of Transit Dependents Using the Project • Transit Dependent User Benefits per Passenger Mile • Share of User Benefits Received by Transit Dependents Compared to Share of Transit Dependents in the Region
Environmental Benefits (New Starts Only)	• EPA Air Quality Designation

SOURCE: FTA, 2009 (*20*).

- Low-floor vehicles or level boarding;
- Branding of the proposed service; and
- 10-min peak/15-min off-peak headways or better while operating at least 14 hr per weekday.

Only projects that feature all of these elements are eligible for Small Starts funding. Projects proposed in corridors with any pre-existing elements are not eligible for Small Starts funding, but would be eligible for funds under FTA's formula capital and discretionary bus programs.

Ranking for Financial Feasibility

All Small Starts projects need to achieve an overall rating of "medium" or better rating for project justification and local financial commitment. All Small Starts that receive a Project Construction Grant Agreement are required to complete a Before-and-After Study describing the impact of the project on transit services and ridership and evaluating the consistency of predicted versus actual project characteristics and performance.

If the project sponsor can demonstrate the following, the project will receive a medium financial rating:

- A reasonable plan to secure funding for the local share of capital costs or sufficient available funds for the local share (all non-New Starts funding must be committed before receiving a Project Construction Grant Agreement);
- The additional operating and maintenance cost to the agency of the proposed Small Starts project is less than 5% of the agency's operating budget; and
- The agency is in reasonably good financial condition.

How FTA Evaluates Small Starts Projects

The criteria by which FTA and its contractors evaluate and rate Small Starts projects are similar to the criteria for rating standard New Starts projects. The same qualitative criteria and quantitative benchmarks are used to evaluate factors including existing land use, transit-supportive corridor policies, supportive zoning near transit stations, tools to implement land use policies, performance of land use policies, and potential impact of transit investment on regional land use (*21*). However, there are two primary differences for Small Starts projects:

- The "Growth Management" factor (referred to as factor 2A in the *Reporting Instructions for the Section 5309 New Starts Criteria*) has been eliminated, acknowledging the relatively smaller scope and more limited regional influence of Small Starts projects.
- The "Other Land Use Considerations" factor has been eliminated since land use-related issues reported under this factor can generally be considered under one or more of the existing land use factors.

Economic development impacts (defined as increases in employment, population, and related factors such as personal income and business sales) are considered an integral part of the land use criterion. The second and third land use categories—plans and policies, and performance and impacts—directly assess the expected increase in station area development as a result of the proposed Small Starts project. Land use plans, policies, and implementation tools include "economic development" plans and tools directed at increasing development, jobs, and related economic benefits in the Small Starts corridor. The "performance and impacts" category directly assesses actual examples of development occurring, as well as the potential for additional development to take place, considering market demand as well as planning factors.

Overall Project Ratings. The overall project rating is determined by averaging the rating for project justification and local financial commitment. When the average of these ratings is unclear (e.g., project justification rating of *Medium-High* and local financial commitment rating of *Medium*), FTA will round up the overall rating to the higher rating (e.g., a project justification rating of *Medium-High* and a local financial commitment rating of *Medium* yields an overall rating of *Medium-High*) except in the following circumstances:

- A *Medium* overall rating requires a rating of at least *Medium* for both project justification and local financial commitment.
- A *Medium-Low* overall rating requires a rating of at least *Medium-Low* for both project justification and local financial commitment.

Cost-Effectiveness. In its evaluation of the cost-effectiveness of a proposed project, FTA considers the incremental cost per hour of transportation system user benefits in the forecast year. Transportation system user benefits reflect improvements in regional mobility—as measured by the weighted in- and out-of-vehicle changes in travel-time to users of the regional transit system that would result from implementation of the proposed project. The cost-effectiveness measure is calculated by (a) estimating the incremental "base-year" annualized capital and operating costs of the project (over a lower cost "baseline" of transit service), and then (b) dividing these costs by the projected user benefits. The result of this calculation is a measure of project cost per hour of projected user benefits (i.e., travel-time) expected to be achieved if the project is added to the regional transit system. Proposed projects with a lower cost per hour of projected travel-time benefits are more "cost effective" than those with a higher cost per hour of projected travel-time benefits.

The cost per hour of transportation system user benefits is a sound measure for cost-effectiveness because it captures the benefits that accrue to *all* transit users (including existing transit riders), including direct time savings and other attributes of premium transit services such as service reliability, safety and security, branding, span of service, and so on. In addition, it does a better job of reflecting how improvements in travel time and other attributes of major transit capital investments such as reliability, security, and permanence cause increases in ridership—rather than simply the patronage outcome. Table 11 presents the thresholds FTA will use in FY 2009 for assigning a *High, Medium-High, Medium, Medium-Low* or *Low* cost-effectiveness rating for each proposed project. FTA publishes updates to these breakpoints annually to reflect the impact of inflation.

Table 11 FTA cost-effectiveness breakpoints for Small Starts

Cost-Effectiveness Rating	Breakpoint
High	$11.99 and under
Medium-High	$12.00–$15.49
Medium	$15.50–$23.99
Medium-Low	$24.00–$29.99
Low	$30.00 and over

SOURCE: FTA, 2004 (*22*).

Mobility Improvements. In its evaluation of the mobility improvements that would be realized by implementation of a proposed project, FTA evaluates four measures:

1. User benefits per passenger mile on the project
2. Number of transit dependents using the project
3. Transit dependent user benefits per passenger mile on the project
4. Share of user benefits received by transit dependents compared to share of transit dependents in the region

The mobility rating is the average of the rating for the first measure above (which applies to all riders of the New Starts project) and the combined ratings for the subsequent three (that apply only to transit dependents). The process FTA uses to establish measure-specific ratings and the overall mobility improvements rating is as follows.

User Benefits per Passenger Mile on the Project. This measure reflects the travel time savings, as measured by minutes of transportation system user benefits in the forecast year anticipated from the proposed project compared to its baseline alternative. In order to rate projects in comparison to other proposed New Starts, this measure is normalized by the annual passenger miles traveled on the New Starts project in the forecast year. The result is a measure of the intensity of the user benefits.

As noted previously, projects are aligned in ascending order of user benefits per passenger mile and categorized into five groups, separated by the logical breakpoints indicated by the submitted data for the measure. Projects in the highest grouping (that is with the most user benefits per passenger mile) receive a "5," while projects in the lowest grouping receive a "1."

Number of Transit Dependent Individuals Using the Project, and Transit Dependent User Benefits per Passenger Mile on the Project. These two measures represent the number of transit dependents affected by the project and the intensity of the benefit per passenger. The dependent user benefits are defined identically to the user benefits per passenger mile measure above but for transit dependent passengers. To obtain a rating for each measure, values for each of the measures are aligned in ascending order and categorized into five groups, separated by breakpoints that identify logical groupings of values. Projects in the highest grouping receive a "5," while projects in the grouping with the lowest values receive a "1." These ratings are then used to obtain a single rating for both measures. The single rating is not a result of averaging but the result of a lookup table that determines the single rating based on the ratings of the two measures.

Share of User Benefits Received by Transit Dependents Compared to Share of Transit Dependents in the Region. This measure represents the extent to which the project benefits transit dependents compared to their regional representation. For example, if 10% of the user benefits for the project accrued to transit dependents, but they represented 20% of the region's population, the measure would be 0.5, indicating that the project did not benefit transit dependents compared to their share of the region's population. To obtain a rating, project values for the measure are aligned in ascending order and categorized into five groups, separated by breakpoints that identify logical groupings of values. Projects in the highest grouping receive a "5," while projects in the grouping with the lowest values receive a "1."

The final rating for mobility for transit dependents is determined by adjusting the rating for transit dependent persons using the project and their user benefits per passenger mile by the share rating. A share rating below "3" could result in lowering the transit dependents rating while a share rating that is higher than "3" could increase the rating. The effect of the share rating is determined by whether its significance (ratings of "1" or "5" are more significant) and whether the rating it affects is near a breakpoint.

Local Financial Commitment Rating

FTA assigns a summary local financial commitment rating of *High, Medium-High, Medium, Medium-Low* or *Low* to each project following consideration of individual ratings applied to the following measures for local financial commitment:

1. Share of non-Section 5309 New Starts funding;
2. Stability and reliability of the proposed project's capital finance plan, including:
   - Current capital condition,
   - Commitment of capital funds, and
   - Reasonable capital planning assumptions and cost estimates and sufficient capital funding capacity;
3. Stability and reliability of the proposed project's operating finance plan, including:
   - Current operating financial condition,
   - Commitment of operations and maintenance (O&M) funds, and
   - Reasonable operations planning assumptions and cost estimates and sufficient O&M funding capacity.

These ratings are based on an analysis of the financial plans and documentation submitted to FTA by local agencies. FTA's evaluation takes into account the stage of project development, particularly when considering the stability and reliability of the capital and operating finance plans. Expectations for firm commitments of non-federal funding sources become increasingly higher as projects progress further through development (preliminary engineering, followed by final design) and are rated accordingly (*22*).

The summary local financial commitment rating considers the non-Section 5309 New Starts funding share of project capital costs. The following ratings are assigned to this criterion:

- >60% = *Low* rating
- 50–60% = *Medium* rating
- 35–49% = *Medium-High* rating
- < 35% = *High* rating

CHAPTER 4 CONCLUSIONS AND SUGGESTED RESEARCH

CONCLUSIONS

Circumstances When It Is Desirable to Convert a Lane to BRT

Net Benefit for All Corridor Users

One of the most critical evaluation factors in considering conversion of a mixed-flow traffic lane for exclusive BRT use is the potential benefits and dis-benefits that will accrue to all corridor users. Perceived dis-benefits for drivers may be more than offset by improvements for transit users, especially if there is a substantial mode shift from private automobiles to transit. Increasing transit capacity and transit utilization in the corridor will result in an increased person throughput for the corridor.

In addition, IT improvements on the facility, and on parallel and intersecting facilities, may offset the traffic impacts of converting a travel lane for exclusive BRT use and actually improve travel conditions for all vehicles. It is critical that all of these factors are taken into account in the evaluation of a proposed lane conversion to determine the net benefit of the proposed action and the cost-effectiveness of the potential investment.

Support of Land Use and Development Policies and Plans

Like other forms of high-capacity, high-quality transit, BRT has a potential to promote transit-supportive land development and re-development. Concentrating development in conjunction with high-quality transit service provides greater accessibility to housing and employment opportunities, potential increases in property values in the corridor (especially at station locations), and creates more livable places. See Table 12 for more information.

Smart Growth land use policies and plans and high-quality transit are mutually supportive.

Table 12 BRT elements and transit-supportive land development

Element	Impacts
BRT Running Way	Research shows that the effect of investments in running ways is three-fold: • They improve the convenience of accessing other parts of a region from station locations. • Increased accessibility increases the likelihood that property can be developed or redeveloped to a more valuable and more intense use. • Physical running way investments signal to developers that a local government is willing to invest in a significant transit investment and suggest a permanence that attracts private investment in development.
Stations	Station design has the greatest impact on the economic vitality of an area. A new BRT station provides opportunity to enhance travel and create a livable community at the same time. Station designs that effectively link transit service to the adjacent land uses maximize the development potential. It is important to note that the inclusion of routes in BRT systems that combine feeder service and line-haul (trunk) service reduces the need for large parking lots and parking structures, thereby freeing land at the most accessible locations for development.
Vehicles	Vehicles can reinforce attractiveness (and, indirectly, the development potential) of BRT-adjacent properties to the extent that they: • Demonstrate attractive aesthetic design and support brand identity of the BRT system • Suggest permanence or a willingness on the part of the public sector to invest in the community • Reduce negative environmental impacts such as pollutant emissions and noise. Experience in Boston and Las Vegas suggests that developers do respond to services that incorporate vehicles that are attractive and that limit air pollutant and noise emissions. Successful developments in Pittsburgh, PA, and Ottawa, Canada, where more conventionally designed vehicles are deployed suggests that development can still occur with all vehicle types as long as service improvements highlight the attractiveness of station locations.
Service and Operations Plan	The flexible nature and high frequencies of BRT service plans allow it to expand or contract with changes in land use quickly and easily.

SOURCE: FHWA, 2004 (*24*).

Concentrated, multi-use development provides a better environment in which transit can operate in a more cost-effective manner. On the other hand, high-quality transit service can help to facilitate concentrated development resulting in more efficient land use.

The economic benefits of transit supportive land development generally can be classified into three categories:

Generative impacts produce net economic growth and benefits in a region such as travel time savings, increased employment and income, improved environmental quality, and increased job accessibility. This is the only type of impact that results in a net economic gain to society at large.

Redistributive impacts account for locational shifts in economic activity within a region such that land development, employment, and, therefore, income occur at transit stations along a route, rather than being dispersed throughout a region.

Transfer impacts involve the conveyance or transfer of moneys from one entity to another such as the employment stimulated by the construction and operation of a transit system financed through public funds, joint development income, and property tax income from development redistributed to a transit corridor through station development (*23*).

Climate Change Implications and Air Quality

BRT can help to achieve broader objectives related to how areas should develop or redevelop to improve efficient use of land, mixed land use/development, reduce total VMT, and reduce emissions. This can be accomplished in several ways, including

- The technology of BRT vehicles themselves, which may include using larger and fewer vehicles, and/or using propulsion systems that are cleaner and result in less emissions per passenger.
- Mode shifts from private automobiles to transit, resulting in lower vehicle miles traveled overall. On a passenger/mile basis, public transportation produces substantially less volatile organic compounds, carbon monoxide, and carbon dioxide than identical trips using private automobiles.
- Improved transportation system efficiency, reduction in emissions per travelers due to increased transit use, and reduction in use of private automobiles—to the extent that people switch modes for travel in the BRT corridor and the extent to which congestion and associated increases in emissions are reduced.

Legislative and Policy Support (Local and Statewide)

Another criterion for the implementation of BRT is in response to adopted policies or regulations that encourage/require more efficient travel modes and systems. A good example of this is the Caltrans policy supporting BRT. In February 2007, Director's Policy DP-27 was issued. The policy is intended to ensure consistency and commitment in the department's approach to BRT and to state clearly the department's intent to be an active and constructive partner in the development of BRT where the state's facilities are involved.

The Director's Policy instructs Caltrans staff to work closely with local jurisdictions, regional transportation planning agencies, transit operators and other stakeholders to plan, develop, implement, and advocate BRT systems. It includes language focusing on maximizing people throughput (versus vehicle throughput) and empowering the Caltrans BRT coordinator to work with District Traffic Operations (Freeway Operations/HOV) and transit operators to leverage transit utilization of existing facilities. The policy outlines specific responsibilities for staff at different levels in the department in order to carry out the intent of the policy: "improved mobility options through the full integration of BRT as an investment alternative into system and comprehensive corridor planning documents and project development processes . . . to clearly establish a corporate expectation for conducting business between the Department and local BRT agencies" (*25*).

SUGGESTED RESEARCH

The objective of the Phase II research is to develop a tool to help practitioners analyze the cost-effectiveness and public feasibility of converting an existing mixed-flow travel lane to a BRT lane or other means of providing increased people throughput for specific transportation facilities. The research will be divided into four tasks as follows.

Task 1 involves the identification and evaluation of information sources related to existing benefit/cost models, evaluation criteria for projects requesting funds under the FTA's Small Starts program, the

SUMMIT model used for evaluation by FTA, and alternative methods to address LOS issues associated with lane conversion.

Task 2 involves developing a framework for the benefit/cost tool and identification of data elements needed for the model. A proposal for the model's software platform and framework will be developed after the research on data elements has been completed and cost and benefit calculation methods have been developed.

Task 3 involves developing the benefit/cost model itself, beta testing of the preliminary model, and development of a web interface for the model. In addition, a user-friendly spreadsheet tool will be developed that is scalable and transferable among different agencies.

Task 4 involves development of a concise and comprehensive User's Guide for the model that can be used by a variety of practitioners.

ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 20-65/Task 21 by ICF International. ICF International was the contractor for this study.

Karen Jones Savage, AICP, Senior Manager at ICF International, was the Project Director and Principal Investigator. The other authors of this report are Terence Plaskon, J.D., Senior Associate at ICF International, and Liza Wallis, Research Assistant at ICF International. The work was done under the general supervision of Ms. Savage.

REFERENCES

1. Schrank, D., and T. Lomax, *Urban Mobility Report,* Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2007.
2. Metro's BRT 25, "Analysis of Top Bus Rapid Transit Projects in North America," *METRO Magazine,* April 2006, pp. 22–26; April 2007, pp. 29–32; and April 2008, pp. 21–24.
3. "Highway and Transit Investments: Options for Improving Information on Projects' Benefits and Costs and Increasing Accountability of Results," *GAO Report 05-172.* United States Government Accountability Office, Report to Congressional Committee, 2005, p. 12.
4. Federal Transit Administration, "Bus Rapid Transit Demonstration Program," December 2002, as cited in *Bus Rapid Transit, A Handbook for Partners,* Caltrans, February 2007, p. 5.
5. Levinson, H., et al., *TCRP Report 90: Bus Rapid Transit, Vol. 1,* Transportation Research Board of the National Academies, Washington, D.C., 2003, Summary.
6. Transit Cooperative Research Program, Project A-23, 2001, as cited in *Bus Rapid Transit, A Handbook for Partners,* Caltrans, February 2007, p. 6.
7. Cleveland, Ohio/Euclid Corridor Improvement Project, http://www.fta.dot.gov/publications/reports/planning_environment_2924.html. (As of November 24, 2008).
8. *Highway Capacity Manual,* Transportation Research Board, National Research Council, Washington, D.C., 2000.
9. Winters, P., et al., "Assessing Level of Service Equally Across Modes," Center for Urban Transportation Research College of Engineering, University of South Florida, for FDOT, 2001, p. 2.
10. Kittelson & Associates, Inc., et al., *TCRP Report 100: Transit Capacity and Quality of Service Manual,* 2nd Edition, Transportation Research Board of the National Academies, Washington, D.C., 2003.
11. *Florida's Mobility Performance Measure Handbook.* Florida Department of Transportation, Tallahassee, FL, 1998.
12. Milam, R., and C. Mitchell, "Conventional Level of Service Analysis, Thresholds and Policies Get a Failing Grade," Presented at TRB Annual Meeting, Washington, D.C., 2008, DVD, Introduction.
13. http://www.itsdeployment.its.dot.gov/Results.asp?ID=1018&rpt=M&filter=1&Year=2004. (As of November 24, 2008).
14. http://www.ncdot.org/projects/hov/hPlaGuidelines.html. (As of November 24, 2008).
15. *Bus Rapid Transit: A Handbook for Partners,* Caltrans, February 2007, p. 10.
16. Diaz, R., et al., "Characteristics of Bus Rapid Transit for Decision-Making," Federal Transit Administration, August 2004, Project No: FTA-VA-26-7222-2004.1, pp. 3–70.
17. Booz-Allen & Hamilton, California Life-Cycle Benefit/Cost Analysis Model, [Cal-B/C], Technical Supplement to User's Guide, Caltrans, Sacramento, CA 1999, p. 1-1.
18. http://www.fhwa.dot.gov/infrastructure/asstmgmt/hersindex.cfm. (As of March 12, 2009).
19. http://www.fhwa.dot.gov/policy/2006cpr/appc.htm. (As of March 12, 2009).
20. http://www.fta.dot.gov/planning/newstarts/planning_environment_222.html. (As of March 12, 2009).
21. FTA's *Guidelines and Standards for Assessing Transit-Supportive Land Use,* http://www.fta.dot.gov/documents/Evaluation(1).pdf. (As of March 12, 2009).
22. http://www.fta.dot.gov/planning/newstarts/planning_environment_9063.html#ID_Overall_Project_Ratings. (As of March 12, 2004).

23. *TCRP Report 35: Economic Impact Analysis of Transit Investments: Guidebook for Practitioners,* as cited in *Characteristics of Bus Rapid Transit for Decision-Making,* Federal Highway Administration, Washington, D.C., 2004.
24. *Characteristics of Bus Rapid Transit for Decision-Making,* Federal Highway Administration, Washington, D.C., 2004, pp. 4–18.
25. Caltrans Director's Policy, DP-27, Bus Rapid Transit Implementation Support, February 2007.

APPENDIXES A, B, AND C

Appendixes A, B, and C as submitted by the researchers are not published herein. They can be found on the TRB website along with the online version of this report. Their titles are as follows:

Appendix A: BRT Examples
Appendix B: Interview Results
Appendix C: Bibliography

TRB

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

These digests are issued in order to increase awareness of research results emanating from projects in the Cooperative Research Programs (CRP). Persons wanting to pursue the project subject matter in greater depth should contact the CRP Staff, Transportation Research Board of the National Academies, 500 Fifth Street, NW, Washington, DC 20001.