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Evaluation Guidelines for Bus Rapid Transit Demonstration Projects

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The Federal Transit Administration's (FTA) Bus Rapid Transit Demonstration Program is supporting demonstrations of Bus Rapid Transit (BRT) in selected cities across the United States. The US BRT Demonstration Program aims to adapt the principles of highly successful BRT systems, such as those of Curitiba, Brazil; Lyons, France; and Nagoya, Japan, to U.S. conditions, laws, and institutions. A primary goal of the BRT Demonstration Program is to assess the demonstration projects through scientific evaluation. This document presents guidelines for planning, implementing, and reporting the findings of an evaluation of a BRT implementation site selected for the FTA BRT Demonstration Program. This document will provide a common framework and methodology for developing and then executing the evaluation of individual BRT demonstrations.

BRT is consistent with FTA Strategic Plan goals of improving mobility and accessibility and providing efficient transportation. FTA intends for the BRT Demonstration Program to address a number of transit issues and to improve bus service, operations, and ridership. Low-cost investments in infrastructure, equipment, operational improvements, advanced bus technologies and intelligent transportation systems can provide the foundation for BRT systems that substantially upgrade bus system performance.

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EVALUATION GUIDELINES FOR BRT DEMONSTRATION PROJECTS

Chapter 1. Overview of Evaluation Guidelines

A. Background

The Federal Transit Administration's (FTA) Bus Rapid Transit Demonstration Program is supporting demonstrations of Bus Rapid Transit (BRT) in selected cities across the United States (U.S.). The US BRT Demonstration Program aims to adapt the principles of highly successful BRT systems, such as those of Curitiba, Brazil; Lyons, France; and Nagoya, Japan, to U.S. conditions, laws, and institutions. It will develop a U.S. approach to dealing with existing auto traffic both in the BRT corridor and cross streets, on-street parking, turn conflicts, traffic signal preference for buses, speedier fare collection and boarding, vehicle control, information, marketing, and land use and development, to serve as a model for American transit operators, traffic engineers, and city officials considering BRT for their cities.

A primary goal of the BRT Demonstration Program is to assess the demonstration projects through scientific evaluation. Only by carefully documenting and analyzing their effects and features will it be possible to determine which aspects of BRT are most effective in which contexts, that is, the type of service and facility offered, the level of transit demand, the size of the region, and other factors. To maximize the effectiveness of these demonstrations, a consistent, carefully structured approach to project evaluation, as set forth in these Evaluation Guidelines, is desirable.

Participants in the BRT Demonstration Program are required to assist the FTA in monitoring in detail the experiences of their BRT implementations, collecting data, and preparing evaluation reports to document developments. Such information together with the opportunity for transit planners to visit operating U.S. BRT sites will facilitate the development of BRT at other locations in the U.S.

B. Purpose

This document presents guidelines for planning, implementing, and reporting the findings of an evaluation of a BRT implementation site selected for the FTA BRT Demonstration Program. Although these evaluation guidelines are intended for use by organizations engaged by the FTA or by the Research and Special Programs Administration/Volpe National Transportation Systems Center (Volpe Center) to evaluate the BRT demonstrations, they will also be useful to state and local organizations independently designing and evaluating BRT systems.

An objective of these guidelines is to foster consistency of evaluation philosophy and techniques, and comparability and transferability of results, to make cross-cutting studies of BRT features across varying settings possible, and to improve the quality and utility of information obtained from the BRT Demonstration Program. The guidelines are designed to emphasize the assessment of the Program's national objectives as well as those of the state and local implementing agencies.

This document will provide a common framework and methodology for developing and then executing the evaluation of individual BRT demonstrations. These evaluation guidelines are by no means comprehensive — that is, they do not offer a suggested or preferred course of action for every conceivable situation that might arise. Nor are they to be rigidly or blindly followed, since each demonstration and each site will be unique and will require somewhat tailor-made evaluation procedures.

C. Organization

This overview of the Evaluation Guidelines is followed by Chapter 2 which gives an overview of the FTA's BRT Demonstration Program highlighting FTA objectives of the Program and significant features of BRT; Chapter 3 which describes the evaluation process including the evaluation objectives, evaluation criteria, roles of participants, and evaluation phases; Chapters 4 through 8 which detail respectively, the five aspects of evaluation planning: the evaluation frame of reference, establishing the baseline or control, performance measures, data collection, processing and analysis methods, and the report outline; and Chapter 9 which discusses activities associated with implementing the evaluation.

Chapter 2. BRT Demonstration Program Overview

A. Objectives of BRT

BRT is consistent with FTA Strategic Plan goals of improving mobility and accessibility and providing efficient transportation. FTA intends for the BRT Demonstration Program to address a number of transit issues and to improve bus service, operations, and ridership. Specific objectives of the Program include:

- *Improve bus speeds and schedule adherence.* Perhaps the most fundamental expected result of a BRT demonstration would be an improvement in travel times and schedule adherence due to the lack of impediments to bus movement along exclusive bus lanes or busways. Bus speeds would be expected to improve not only in absolute terms, but also relative to the automobile traffic that parallels the exclusive lanes and to regular bus service on that same street or in parallel corridors.

- *Increase ridership due to improved bus speeds, schedule adherence and convenience.* Customers who use buses infrequently might ride more often, and some automobile users might convert to transit. An improvement in bus speeds might be noticeable to drivers of other vehicles, presenting a positive image of transit as an alternative to driving. BRT may also help retain riders who otherwise might have changed modes due to slow bus speeds.

- *Mimimize the effect of BRT on other traffic and local businesses.* If the creation of exclusive bus lanes reduces the number of lanes available for other traffic, then the possibility of increased congestion on the roadways is raised. Traffic flow on cross streets and oncoming left-turning traffic across the bus lanes may be disrupted as buses use their signal priority to travel unimpeded through intersections. Increased conflicts between buses and automobiles crossing exclusive bus lanes may also have safety implications. One of the challenges of implementing an exclusive bus lane would be to minimize this disruption while maintaining safety. Further, mobility on alternate routes may deteriorate, as drivers seek ways to avoid roads with exclusive bus lanes. On the other hand, successful BRT systems may convert enough new riders from automobile use to reduce traffic congestion.

  BRT systems that impose parking restrictions along exclusive bus lanes may initially be perceived as creating hardships for adjacent businesses; in time, however, BRT service may attract enough new pedestrian activity to boost the patronage of nearby businesses. Parking restrictions necessary for exclusive bus lanes may also help streamline the movement of all traffic in general.

- *Isolate the effect of each BRT feature on bus speed and other traffic.* FTA would like to assess the relative contribution of each component of a BRT system to determine its impact. Components of particular interest are exclusive bus lanes, signal preemption, fare collection methods, same-level boarding, and off-street bus terminals and transfer facilities in center city.

- *Assess the benefits of Intelligent Transportation Systems/Automated Public Transportation Systems (ITS/APTS) applications to the demonstration.* Because of its involvement in the Federal ITS/APTS program, FTA is especially interested in the effectiveness of these technologies in this demonstration. Applications of particular interest are signal priority systems for buses, smart card fare media, precision docking systems for buses, tight terminal guidance systems, automatic vehicle location (AVL), advanced communications systems, and exclusive bus lane enforcement systems.

- *Assess the effect of BRT on land use and development.* It is expected that a full-featured BRT system that includes exclusive lanes and/or roadways, elaborate bus stops, terminals or transfer facilities will be regarded by the general public, developers and investors as permanent and as significant as other fixed guideway facilities. Such a BRT system could be expected to have land use effects similar to those of rail systems. It may take some time, however, for these effects to be realized. BRT systems of lesser significance and appearance of permanency would likely have lesser or no land use impacts.

The participating transit agencies, local and state governments, and other organizations that have a stake in the demonstration may also have goals and objectives for the program that need to be assessed in the course of the evaluation. Data collection needs for these assessments must be factored into the overall evaluation plan.

In assessing the degree to which a BRT demonstration meets the above objectives, it is also important to weigh the realized benefits and impacts of the various features of the BRT implementation against their associated costs. Of great concern to the FTA and to any organization involved in providing bus service is getting the most benefit for the traveling public within the confines of their limited resources (tax dollars, operating subsidies and revenues). Those features that provide the greatest benefit for the least cost should emerge from the evaluation.

B. BRT Features

The list of potential features of BRT implementations is long, and not all make equal contributions in achieving BRT goals. A BRT evaluation needs to make a distinction between the defining and auxiliary features of a BRT demonstration in allocating evaluation resources. The depth of the evaluation effort on a specific BRT feature should be commensurate with its importance to the BRT concept at a site.

Low-cost investments in infrastructure, equipment, operational improvements, advanced bus technologies and intelligent transportation systems can provide the foundation for BRT systems that substantially upgrade bus system performance. Improved bus service in the context of a BRT demonstration would give priority treatment to buses on urban roadways and would be expected to include some or all of the following features:

- *Bus lanes*: Lanes on urban arterials or city streets are reserved for the exclusive or near-exclusive use of buses. The lanes may be located on the curbside or in the roadway median, or they may be set up as contra-flow lanes. Curbside lanes may be implemented on one- or two-way streets and may sometimes accommodate right-turning general-purpose traffic. Median lanes and contra-flow lanes are located in the middle of two-way streets and may need to accommodate left-turning vehicles. Bus lanes can also be created in abandoned rail rights of way. Studies show that dedicated lanes can improve bus operating speeds by 40 percent through the elimination of delays associated with traffic congestion and right-turning traffic, with signals remaining the only source of traffic delay.
- *Bus streets and busways*: A bus street or transit mall can be created in an urban center by dedicating all lanes of a city street to the exclusive use of buses. Streets are suited for conversion to exclusive transit use only if they are not necessary to provide routine access to buildings by general-purpose traffic. Busways connecting urban centers with the suburbs can be created on or adjacent to highways, on arterial streets, or in abandoned rail rights of way. Bus streets and busways provide for the greatest improvement in bus service by eliminating conflicts with general-purpose traffic.
- *Passenger amenities and information*: The operational and travel time benefits resulting from the separation of buses from general-purpose traffic can be augmented with improved bus shelters and stations. These facilities provide

protection from the elements. They can be equipped to provide safety equipment and systems that furnish information such as printed routes and schedules or electronically transmitted real time schedule data. Space can also be leased to commercial convenience services.

- *Bus signal preference and preemption*: Preferential treatment of buses at intersections can involve the extension of green time or actuation of the green light at signalized intersections upon detection of an approaching bus. Intersection priority can be particularly helpful when implemented in conjunction with bus lanes or streets, because general-purpose traffic does not intervene between buses and traffic signals.

- *Limited stop operations*: Limiting the number of stops on a route may have the greatest positive effect of any single BRT feature on system performance and efficiency. Certainly that has always been the justification for offering traditional express service as an alternative to local service. In the context of BRT, different strategies for the location of bus stops apply depending on the type of system. On busways where buses may attain relatively high speeds because they operate unimpeded by other traffic, each bus stop accounts for a significant portion of the total trip time. To maintain the primary benefit of a busway, that is, bus speed improvement, bus stops are located sparingly only at stations and major transfer points. In contrast, on a bus lane on an urban arterial or city street, more stops can be accommodated, such as every other or every third local bus stop, while still offering significant improvements over local service.

- *Traffic management improvements*: Low-cost infrastructure elements that can increase the speed and reliability of bus service, as well as improve traffic flow for other vehicles, include bus turnouts, bus boarding islands, curb realignments, and bus lanes and signaling technology for intersection queue jumping.

- *Faster boarding*: Conventional on-board collection of fares slows the boarding process, particularly when a variety of fares is collected for different destinations and/or classes of passengers. An alternative would be the collection of fares upon entering an enclosed bus station or shelter area prior to bus arrivals. This system would allow passengers to board through all doors of a stopped bus. A self-service or "proof-of-payment" system also would allow for boarding through all doors, but poses significant enforcement challenges. Pre-paid "smart" cards providing for automated fare collection speed fare transactions, but require that boarding remain restricted to the front door of the bus.

  Another impediment to reducing boarding time is the height difference between ground level and conventional buses, as most passengers are required to climb several steps, and passengers using wheelchairs can enter the bus only with the assistance of lift equipment, the operation of which is time-consuming. Changes in bus or platform design that could provide for level boarding, such as low-floor buses, raised platforms, or some combination thereof, could make boarding both faster and easier for all passengers.

- *Advanced bus technologies and other intelligent technologies*: ITS/APTS technologies can reduce operating and maintenance costs, improve safety, enhance intermodal transfers, and provide passenger information, all of which contribute to faster and safer transit trips. Precision docking systems, tight terminal guidance systems, and on board bus stop announcements reduce time spent at bus stops. Real-time passenger information kiosks and bus arrival announcements at stops, along with increased reliability of service, enable passengers to time their trips more efficiently. On board computerized maintenance monitors help reduce unexpected downtime. Smart cards and other automatic fare collection media, along with well-designed stations, can speed up transfers. AVL and advanced communications systems insure service reliability and efficiency, and reduce delays due to emergencies and breakdowns.
- *Integration of transit development with land use policy*: BRT supports transit-oriented developments (TODs). TODs are high density areas or corridors developed with building site and street designs that favor transit and pedestrian usage. A well-designed BRT system can provide high-quality service that can compete with automobiles in terms of travel time and convenience, particularly in TODs. The clustering of development has the additional benefit of conserving land and promoting the vitality of neighborhoods and urban commercial centers. BRT can be most effective when integrated within a broader planning framework encompassing land use policies, zoning regulations, and economic and community development.
- *Incremental development*: BRT features can be phased in stages to relieve budgetary pressures on transit agencies. As each of the various components of BRT is implemented, such as exclusive bus lanes, signal preference, and improved boarding and fare collection, the operator can realize incremental benefits.
- *Image and marketing*: The image and marketing of a new BRT system play an important role in attracting riders and converting automobile users to transit. The total look and presentation of a new BRT system should easily differentiate it from regular bus service. A well-conceived BRT image will denote speed, comfort, convenience, and ease of use, and will integrate the appearance of all aspects of the system, including its name, color scheme of buses and bus stops, logo, signage and printed information. Local marketing is especially important to get the word out to both current and potential riders.

Chapter 3. Evaluation Process

A. Evaluation Objectives

As stated in the *Federal Register* notice announcing the BRT Demonstration Program, the FTA evaluation objectives are:

- to document what happened and why,
- to measure project impacts and costs,
- to identify successful and unsuccessful aspects of the demonstration, and how they were influenced by site-specific characteristics,
- to determine if the demonstration met FTA and local goals and objectives, and
- to determine lessons learned that can be applied to other BRT projects and transit systems. An evaluation not only helps others learn from the demonstration, but also helps the involved parties to improve their own systems.

The transit agency sponsoring the demonstration and other local sponsoring organizations may have additional objectives for the evaluation.

B. Evaluation Criteria

The evaluation criteria are the aspects of a BRT demonstration project that will be examined to determine how successful the project is in accomplishing its objectives:

- *Travel times and schedule adherence*: There are many issues associated with these two parameters. It is important to consider total travel time, which consists of access, wait, transfer, in-vehicle, and egress time. In-vehicle time can be further broken down into travel time (when the vehicle is moving), time stopped at traffic signals, and dwell time at bus stops (deboarding and boarding time plus time waiting to merge with traffic in cases where there are no exclusive lanes). Most people attach different values to the different components of time, with in-vehicle time felt to be the least onerous, and waiting time the most onerous.

  The schedule adherence or reliability of service can be seen either as an independent parameter or as a component of the measurement of travel time, but in any case is measured by "delay," that is the difference between the actual and scheduled arrival of a bus at a stop. Sources of delay may range from heavier than normal general traffic to bus breakdowns. Irregular service leads to increases in mean waiting times. By definition, irregular service also increases the variance of travel times, which may in itself be an important factor. For example, some riders may seek other means of transportation rather than use a bus whose arrival time varies significantly from day to day.

  Irregular service also affects vehicle loading. Heavy crush loads due to gaps in service can lead to further delays, as boarding and alighting are slowed. At the extreme, passengers are passed by and must wait until the next vehicle arrives. Transit headways are inherently unstable; a control strategy is generally required to insure regular service and reduce waiting times. Punctual service is also important when transfers are common.

  Reducing the number of stops, a typical BRT strategy, decreases in-vehicle time but increases access time. This trade-off must be evaluated carefully. On the other hand, reducing vehicle dwell time (the time spent at a stop while passengers are boarding or alighting or while waiting to get back into traffic) has no downside. Reductions in dwell time can come from changes in vehicle design, station design to accommodate the new vehicles, fare collection policy, stop location, and stop design. A priority merge rule can speed the movement of buses back into the traffic lane. Improvements in the regularity of service can also reduce dwell time by reducing the incidence of crush loading.

Because travel times and schedule adherence are inherently stochastic, their *distributions* are important, characterized (at a minimum) by both means and standard deviations. Further, because travel times and schedule adherence vary by origin and destination and time of day, any measuring procedure should consider these and other forms of systematic variation in travel times and schedule adherence. Reducing travel time and increasing schedule adherence provide a direct benefit to passengers and are also a principal means of attracting more passengers.

- *Ridership*: Maintaining and/or increasing ridership levels and increasing rider satisfaction are key elements of BRT. Although all BRT elements directly or indirectly contribute to a speedier, more convenient, and more attractive transit service, travel time is perhaps the single most important determinant of transit ridership levels (along with out-of-pocket costs such as fares or parking costs avoided). Reductions in travel time will generally increase transit passenger trips.

- *Impacts on other traffic*: Some BRT policies may have either positive or negative impacts on non-users of transit. Giving transit priority in terms of street design, traffic signals, or merging may increase travel times for other road users. On the other hand, such measures may actually reduce travel times for non-transit users. For example, eliminating on-street parking (even just in the peak hour in the peak direction) may disproportionately benefit transit users but improve travel for all road users. This change of course must be balanced against the cost of losing on-street parking.

- *Land use, urban design, and environmental impacts*: The structure of the urban environment can have a dramatic effect on people's willingness to use public transit. One component of the BRT evaluation will examine the extent to which transit-supportive land use policies can be instituted along with changes in transit service. These policies include those which make the pedestrian environment friendlier, and which encourage a range of mixed uses adjacent to transit. They may also permit more intense development near high-capacity transit stops. Land use policies may have ancillary benefits (permitting more high-density housing or improving the quality of the walking experience). However, their primary transit benefit is their effect on current and future levels of transit ridership.

- *Transit system image and public perception of transit service*: One objective of BRT is to improve the overall image of transit in general, and the BRT service in particular. Buses are often viewed as a sluggish mode of transportation compared to the automobile. BRT aims to change this perception to one of an efficient system that can compete with or better automobile speeds in an urban setting. All of the BRT components contribute to improving the image of transit; however, the marketing and promotion of the service are designed specifically for this purpose. The name of the BRT service, the logo, the color scheme and design of buses, bus stops, and signage, the design of information kiosks, Web sites and printed materials, and the advertisements all play an important role in the portrayal of BRT as an attractive alternative to the automobile. Improved image is ultimately measured by increased ridership, but surveys of the public can also indicate the success of marketing and promotional efforts.

- *Costs, productivity and cost-effectiveness*: Reductions in travel time allow transit agencies to provide the same amount of service with fewer operator and vehicle hours. This improves transit efficiency and productivity. However, these savings may be realized only when the changes in travel time are large, since other constraints on the deployment of resources may prevent a reduction in the labor force or in the fleet size. It may be possible to redeploy resources, i.e., to use the faster speeds to provide additional service.

The evaluation will examine each of these criteria with respect to the demonstration project as a whole. However, understanding the relative contribution of different components of the project is also important, so these criteria should be applied to individual components to the extent possible.

C. Evaluation Roles

The major players in a BRT demonstration evaluation are the local transit agency and its co-sponsors implementing the BRT system, the FTA, and a third-party evaluator designated by the FTA. The diversity of activities and generally long time frame (three to four years) for a demonstration necessitate close and continual coordination among the participants. Their roles break out as follows:

- The *evaluator* is responsible for developing a comprehensive evaluation plan, including the data collection plan, in conjunction with the local transit agency. The evaluator may be a contractor working directly for FTA or the Volpe Center acting as agent for FTA. As a partner in the demonstration effort, the evaluator will work with the transit agency in monitoring the collection of data and troubleshooting when necessary. The evaluator will prepare interim reports as needed and the final evaluation report.
- The *transit agency and its co-sponsors* in the demonstration will implement the BRT system as planned, participate in BRT consortium meetings, and cooperate with the evaluator in the development of an appropriate evaluation plan. They will provide data collectors and supervise their efforts. They will also make available any operating data and information needed by the evaluator for assessing the effectiveness of the demonstration.
- The *FTA* will provide overall guidance for the demonstration project, and will conduct workshops and seminars on relevant subjects for the BRT consortium.

D. Evaluation Activities

The evaluation process serves as a bridge between the *implementation* of a BRT system at a particular site and the *understanding* of its actual performance at that site and its potential effectiveness in other locales. The quality of the evaluation process directly influences the accuracy and perceptiveness of the demonstration assessment and ultimately affects the applicability and transferability of the findings.

Figure 1 is a flow diagram representing the evaluation activities for a BRT demonstration. Evaluation activities can be divided into two broad categories: planning the evaluation and implementing the evaluation. Each activity is described briefly below, and in much greater detail in the succeeding chapters.

1. Evaluation Planning

Evaluation planning develops a detailed, structured blueprint for conducting the evaluation. It is during the planning phase that the specific data requirements are set, and the performance measures and data analysis methods are developed. Data collection techniques and procedures are determined. A well thought out evaluation plan will insure that the appropriate data are collected in proper ways to provide objective information for the evaluation criteria and determining how well the demonstration has met its objectives. Planning should be completed long before the actual demonstration begins to allow for adequate time to collect "before" or baseline data for measuring demonstration performance.

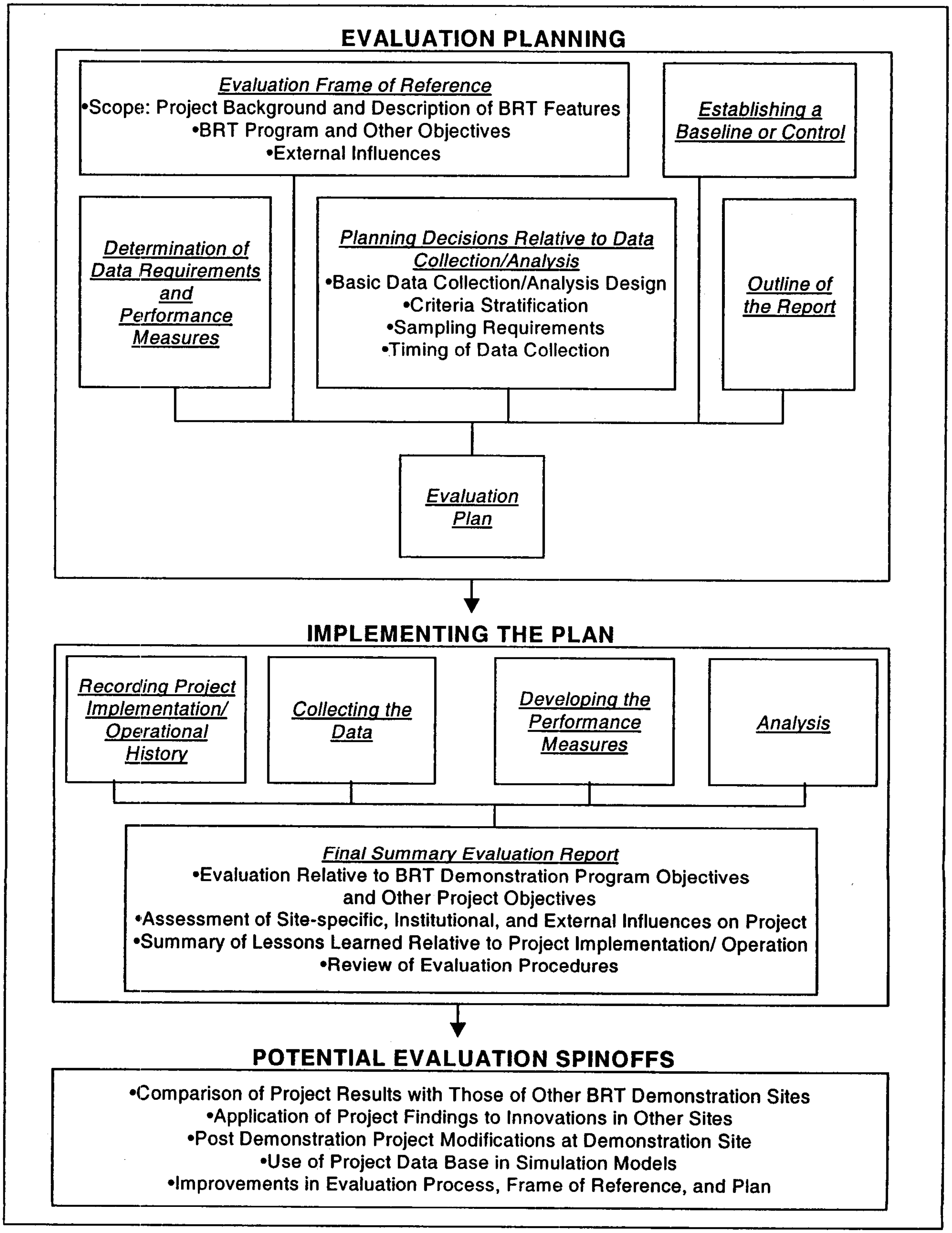
Specifically, evaluation planning consists of:

- *Developing the evaluation frame of reference*: Planning must consider the three elements of the evaluation frame of reference, that is, the backdrop against which the evaluation takes place: the scope of the BRT demonstration; the FTA BRT Demonstration Program objectives and those of other participants; and external influences. The frame of reference sets the stage for the evaluation.

  The scope of the BRT demonstration refers to the comprehensiveness of the project: which BRT features are included in the demonstration; how extensive is the demonstration site; what agencies are participating and other institutional factors; how long the demonstration period will last.

  External influences refer to circumstances outside the scope of the demonstration that may affect the demonstration's performance. The effects of such things as major increases or decreases in population, economic recessions or booms, major highway construction projects, and natural and other disasters can be easily confounded with the effects of the demonstration. For example, a major urban redevelopment project may attract new residents and new bus riders regardless of the improvements in service due to the BRT demonstration. To the extent possible, the evaluation analysis must endeavor to control for these influences or separate out these effects.

Figure 1. Evaluation Activities for a BRT Demonstration



In this task, a schedule for the evaluation is established. Depending on whether the demonstration project has a beginning and end or it represents the implementation of a new system that will continue to operate indefinitely, the evaluation period will occur after or during the demonstration project. Dates must also be set for the baseline data collection period, prior to the evaluation period (see below). Dates for progress reports, interim reports, and the final report deliverables should also be included.

- *Establishing a baseline or control*: Before the demonstration project actually begins, the performance of the bus system must be measured so that any effects due to the BRT demonstration can be discerned. If the BRT demonstration is being applied to an existing bus route, then a "before/after" sampling scheme will allow a comparison between performance measures taken before the demonstration and during and/or after the implementation of the demonstration. The impacts of the demonstration are then clearly seen (after allowing for external influences as described above). If the BRT demonstration creates a new service or new bus route, then other methods of establishing a baseline are needed. For example, to determine how many riders of the new service are switching from other bus routes or from their automobiles, pre-demonstration and post-demonstration counts of ridership on other routes and of traffic on parallel roads may be in order.

- *Determining the performance measures*: Planning should determine the appropriate performance measures consistent with the evaluation frame of reference. The measures will provide the information necessary for assessing the evaluation criteria with respect to the BRT system as a whole as well as its individual components.

  BRT projects in the demonstration program vary widely in the number of possible BRT components they include. As the number of components grows, the complexity of their evaluation and the number of performance measures increases at an even faster rate. It becomes more difficult to isolate the effectiveness of an individual component because typically several components are implemented simultaneously and their effects are co-mingled. Even when components are implemented in succession, their incremental effects can depend on the implementation order. To understand fully and to provide confirmation of a particular component's effectiveness may require its evaluation at several sites.

- *Determining the data collection and data processing techniques*: A wide range of data collection measures is at the disposal of evaluation planners. Their use depends on many variables, including the budget, the availability of personnel resources to collect data, the availability of electronic or automated technology, the schedule, the desired accuracy and sensitivity of the results, and other administrative considerations, such as workers' union and political issues. They can be categorized into four basic categories:

  1. <u>*Manual data collection*</u>: data collectors record observations by hand. For example, they may ride the buses or station themselves at bus stops to count

passengers, measure dwell time at bus stops, note delay, or time the trip duration. They may write the observations on paper forms or enter them directly into forms programmed into software on their laptop computers.

2. <u>Automated data collection</u>: electronic equipment records data digitally. For example, automatic vehicle location (AVL) systems can record the precise times vehicles start and stop on a trip. These times when compared to the schedule can be used to calculate the delay, trip duration, and trip phases such as dwell time at bus stops. Automatic passenger counters can count the number of passengers on each trip. Video cameras can record the ease with which passengers board the buses. Agency electronic databases may provide financial data.

3. <u>*Surveys*</u>: written or telephone surveys or interviews may be used to acquire data that are not readily observable, such as reasons for using the BRT service or previous modal choice. Passenger survey forms may be passed out in stations or on the buses and collected by data collectors or mailed in later. Telephone surveys may help to gauge the general public's awareness of the new BRT service. Focus groups may also provide insights into the public's attitudes and perceptions.

4. <u>*Published data*</u>: public databases and other sources may provide non-operational data, such as population, economic and demographic data for the ridership base, road usage data, land use and zoning patterns.

Much of the survey and manually observed data will need to be input into the computer and processed along with the automated data to produce the performance measures. Determining how the data will be processed and developing the software in the planning stages can save valuable time once the data are collected and produce timely results.

- *Outlining the report*: creating the outline for the final report in the planning stages can help focus the information gathering process on only the data relevant for the final evaluation report, and make it possible to write some sections of the final report before all the data processing is complete.

Generally speaking, the evaluator will write the evaluation plan with inputs from organizations participating in the BRT demonstration. The FTA will review the plan prior to its implementation.

2. Implementing the Plan

The evaluation implementation phase is the period during which the evaluation plan is implemented. Activities during this phase include the collection and analysis of data relative to project objectives and issues, the collection and analysis of data on site characteristics, the compilation of a chronology describing the story of the implementation and operation of the demonstration, the recording of institutional and external factors, problems and changes that might influence BRT demonstration findings and results, and the writing of the Final Evaluation Report.

This phase not only generates information on which the final assessment of the demonstration is based, but also provides feedback information relative to ongoing transit operations. The ongoing evaluation activities, while adding to the cumulative body of quantitative and qualitative information regarding the project impacts, provide interim indications of costs and functions of BRT components and the preliminary effects of these components on transit system performance. These interim findings may serve as useful input to the local agency responsible for implementing and operating the demonstration by suggesting the need for operational modifications.

The culmination of the evaluation is the Final Evaluation Report, to be written by the evaluator, which presents the following types of findings:

- Evaluation of the project in terms of its attainment of relevant BRT Demonstration Program objectives.
- Insight into project issues associated with operational feasibility and characteristics of the BRT components.
- Assessment of the influence of site-specific characteristics and external factors on demonstration results.
- Lessons learned, based on practical experience, relative to the implementation of the BRT system (possibly to include recommendations for project modifications in the demonstration site or for future implementations in other locales).
- Appraisal of the evaluation procedures employed in terms of effectiveness, cost, accuracy, etc.

The body of the final evaluation report should include narrative, tables and graphic exposition, while detailed quantitative data and documentation of procedures should be provided in technical appendices. Since the report is intended for a variety of audiences — including transportation planners; transit operators; federal, state, and local officials; and private industry -- it should contain an executive summary highlighting the salient project findings.

It is anticipated that each BRT demonstration will give rise to potential implementation and analytical spin-offs. The Final Evaluation Report, while essentially documenting the history and effects of a single project, also serves the broader function of increasing the understanding of and stimulating the application of the demonstrated BRT components and technologies in other localities. Information presented in the report provides a versatile basis for comparing the effects of a particular BRT component with those of other similar projects, suggesting modifications to the applications for future use, and predicting the effectiveness and utility of the BRT components in other cities. Moreover, the report's assessment of project evaluation procedures can serve as a stimulus for improving the state-of-the-art of evaluation techniques. These broader functions of the Final Evaluation Report generally materialize after the demonstration period.

Chapter 4. Evaluation Frame of Reference

The evaluation frame of reference provides an in-depth understanding of the site characteristics that might influence the outcome of the project or the interpretation of results. Obviously, the BRT demonstration project will not be implemented in a static environment, and it will affect the surrounding area. An examination of certain site characteristics is necessary to assess fully and accurately the impacts of the BRT demonstration. An additional function of site data is to enhance the comparability and transferability of BRT demonstration project findings.

Table 1 shows examples of site data requirements that would be helpful in BRT demonstration projects. Individual demonstration sites may require additional data. Most of these data should be readily available from published sources, public databases such as the U.S. Census, or the transit agency and local organizations such as the Chamber of Commerce. The attitudinal data of the public toward transit may be problematic, requiring a survey, but these data would be of value as the baseline for measuring the effectiveness of the marketing of the new BRT service in the area.

Chapter 5. Establishing the Baseline or Control

In general, a single set of measurements taken while the BRT demonstration is in operation will be insufficient for assessing the demonstration's impact, since it will not provide any yardstick by which to interpret the measurements. It is recommended, therefore, that every evaluation be structured around some form of comparison. The two main forms of comparison are "before/after" and "test/control." In a before/after comparison, a given measure is collected on a system element before the demonstration begins and then again while the demonstration is operational. In a test/control comparison, a given measure is collected on a system element that has been affected by the introduction of a BRT system component and also on an equivalent system element that has not been similarly treated (control unit). Each type of comparison is somewhat limited: the before/after comparison fails to show what portion of the change in the measure is due to external factors; the test/control comparison shows the difference between "after" measures and hence accounts for external factors, but fails to indicate the degree of change from the "before" state to the "after" state.

Ideally, it would be desirable to conduct a before/after comparison in conjunction with a test/control comparison. In other words, the evaluation plan should, if possible, involve the observation of both a control and test unit before and after (or during) the BRT demonstration.

For example, consider a BRT demonstration that modifies an existing bus route by applying a number of BRT components such as reducing the number of stops, creating an exclusive bus lane on the city streets, and adding signal priority for the buses. If pre-demonstration and post-demonstration measures of bus travel time are made only on

Table 1. Basic Site Data

Economic and population data:

- Population
- Population density
- Number of persons in the labor force
- Number of households
- Age, sex, education, occupation, income distributions
- Household auto ownership
- Number of persons with no driver's licenses
- Modal split, by trip purpose or time of day
- Attitudes towards and knowledge of transit system

Existing (pre-demonstration) transit service and facility characteristics:

- BRT corridor/route length
- Time of service operation throughout day
- Days of service operation throughout week
- Service frequency
- In-service vehicles on BRT corridor
- Fare schedule
- Fare collection procedures
- Cross-section plans of streets and facilities
- Typical bus stop/shelter/station designs
- Bus designs, seating arrangements

Site map highlighting:

- BRT corridors and routes
- Bus stop and station locations
- Existing transportation network
- Central business district
- Other important activity centers
- Air quality attainment and non-attainment areas

Other site features:

- Weather conditions
- Seasonal population variations
- Institutional/political climate
- Economic conditions and trends
- Cost of living
- Population/employment growth rate
- Land use development patterns
- Residential mobility
- Air quality conditions and other environmental concerns

the BRT route and a reduction in travel time is indicated, it may not be possible to determine if the improvements are attributable to BRT or to external factors. For instance, a decrease in automobile traffic due to the closing of a major employment center in the area may have contributed along with the BRT components to the decrease in bus travel time. To account for BRT's contribution to the reduction, it would be necessary to make before and after measurements of bus travel time on routes which are comparable to the BRT route and therefore susceptible to the same set of external factors.[1] The difference between the travel time reduction on the test (demonstration) versus control routes can then be taken as the true change due to the BRT components. To make these statements, it is necessary to be fairly confident that conditions affecting both control and test units are reasonably similar -- a requirement which is sometimes difficult, if not impossible, to assure.

Thus the proper use of the combined before/after and test/control approach guarantees to the greatest extent that any observed improvement is due to the BRT demonstration. The evaluator should employ both types of comparisons wherever appropriate and feasible. The determination of appropriateness of the combined approach involves a consideration of the time span of the demonstration.

In the event that only one type of comparison is feasible, there are alternative techniques and precautionary measures available to compensate for the absence of the other type of comparison. If no control group exists, then the evaluator should be especially observant throughout the evaluation period of possible external factors that might influence the interpretation of project results. Any statistics regarding the before/after change due to the applied BRT components should be examined very carefully in the context of the external factors, and any conclusions based on such statistics should be qualified accordingly.

If, due to project timing, there is no opportunity to perform before measurements, the evaluator should attempt to obtain surrogate data for the before period. Possible sources would include: (1) surveys conducted after the demonstration is operational which question people about conditions or their behavior prior to the demonstration; and (2) demographic and travel data collected by the local highway department, planning agency, or transit operator some time prior to the demonstration. The surrogate data can provide some indication of the magnitude of the before/after change experienced by the test and control groups.

Test/control comparability raises some interesting problems. The test and control units should be as nearly alike as possible to rule out any chance of the observed change being a result of something other than the demonstration. If the BRT route parallels another route in the same corridor or follows the same route as regular service, then the logical control would be one of these. When the BRT route is new, then the matching of test and

[1] A complete study of the effects of BRT on travel characteristics would involve not only the measurement of bus travel time, but also that of autos using a variety of measurement techniques including time study runs in autos to measure speed and delays, observation of auto left turns that might become more difficult with the installation of exclusive bus lanes, comparison of traffic volumes and times waiting at signals on the main and cross streets.

control routes could be done on the basis of such descriptors as route length, total trips along the route, peak headway, and average speed.

Chapter 6. Performance Measures

Performance measures are statistics that describe a characteristic of the BRT system that relates to its performance. They are keyed to the BRT evaluation criteria enumerated in Chapter 3. There are two basic types of measures:

- *Quantitative* — a measure expressed in terms of counts, dollars, measurements, or other physical units
- *Qualitative* — a measure expressed in terms of people's attitudes, perceptions, or observations

Certain issues such as land use and urban design may not lend themselves to quantitative or qualitative performance measures but may best be addressed in descriptive terms.

It is possible to measure many of the BRT evaluation criteria from two vantage points: the actual and perceived attributes of the service. For example, it might be appropriate to measure the *actual* travel time minutes saved by the BRT service as well as people's *perceptions* of time saved. No accepted rule exists for determining when to examine both measures. Clearly, it may be prohibitively expensive to employ both for each area of interest. On the other hand, mere reliance on quantitative measures may result in overlooking what is in fact the major behavioral determinant of the BRT system's ultimate acceptance by the public — people's perceptions of the system, that is, passengers, the public in general, merchants who may have opposed BRT due to decreased parking, and the citizens who would have preferred rail. These issues should be addressed in the Evaluation Plan.

A. Stratification

Stratifying quantitative measures can provide insights on how BRT components function and interrelate. It improves the quality of the evaluation by allowing an assessment of how changes in measures relate to the stratification categories, hence facilitating the formulation of more specific findings and conclusions. Examples of stratification are:

- *Peak versus off-peak time periods*
- *Day of the week*
- *Weekend versus weekday*
- *Access, waiting, in-vehicle, transfer and egress travel times*
- *Seasons of the year*

- *Weather conditions (e.g., fair, rain, snow)*
- *BRT project phase or BRT component if possible*

Whereas collection of an unstratified measure provides only a single, average reference point, the use of a stratified measure provides a series of reference points, each of which may be significant to the analysis and interpretation of results. Knowledge of inter-category differences in results enhances transferability. For example, if signal priority for buses produces the greatest travel time savings during peak hours, but no savings in off-peak hours, then other sites considering implementing signal priority may benefit from this knowledge.

There are three types of stratification:

1. Additive, where each stratum is a portion of the whole, as in phases of travel time (access, waiting, dwell, in-transit, signal stops, transfer, egress),
2. Categorical, as peak and off-peak, and
3. Class intervals, where raw data are grouped into intervals or ranges denoting, for example, "low," "medium," and "high" observations

In the examples of stratification above, peak/off-peak, day of the week, weekday/weekend, season, and weather would be categorical, while trip phases and BRT project phases would be additive. An example of a class interval stratification scheme would be the grouping of continuous air quality measurements into intervals denoting low, medium, and high concentrations of a toxin, or grouping transit riders by age groups.

B. Measures for Evaluation Criteria

One way to view performance measures is by the evaluation criteria they are used to assess. The following sections discuss relevant issues for each evaluation criterion and the performance measures, both quantitative and qualitative, that can help address them. The performance measures are generally not unique to one or another evaluation criteria: the same measure can often shed light on a number of issues. Table 2 summarizes this section.

1. Travel Time

As the "rapid" in BRT denotes, one of the main goals of implementing BRT systems is to reduce travel time for riders. BRT can affect travel time for all phases of a trip:

- *Access* — stop location can reduce (or increase) the distance patrons must walk from their residence or place of work to the bus stops.
- *Waiting* — kiosks at bus stops with accurate information from AVL systems on the times buses will arrive will permit patrons to reduce their wait time; precision docking will reduce the time it takes for the bus to line itself up for loading; increased bus speed due to BRT components improves schedule adherence allowing patrons to reduce their wait time at bus stops.

Table 2. Summary of Performance Measures by Evaluation Criteria

Evaluation Criteria	Measures	Stratification	Baseline/Control	BRT Components	Data Collection Methods	Hypotheses
Travel Time	# minutes per trip	peak, off-peak	parallel bus routes thru corridor	exclusive lanes	AVL	BRT will decrease travel time
	bus speed	weekday, weekend	other modes thru corridor	busways	data collectors on buses	
		season	before/after on BRT, parallel routes	signal priority		
		weather conditions		skip-stop operation		
		walking/dwell/travel/stopped at signals		bus bulbs, curb modifications		
		route, section of route		low-floor buses, bus design		
		BRT component if incrementally implemented		precision docking		
				fare media		
				AVL		
				traffic mods and enforcement		
Schedule Adherence	# minutes delay per trip	peak, off-peak	other bus routes thru corridor	exclusive lanes	AVL	BRT will improve schedule adherence
		weekday, weekend	other modes thru corridor	busways	data collectors on buses, at stops	
		season	before/after on BRT route	signal priority		
		weather conditions		skip-stop operation		
		dwell/travel/stopped at signals		bus bulbs, curb modifications		
		route, section of route		low-floor buses, bus design		
		bus stop		precision docking		
		BRT component if incrementally implemented		fare media		
				AVL		
				traffic mods and enforcement		
Ridership - Quantitative	# passengers per trip	peak, off-peak	other bus routes thru corridor	bus image, marketing	automatic pax counters	BRT will increase ridership
	total # passengers	weekday, weekend	before/after on BRT route	low-floor buses, bus design	data collectors on buses, at stops	
		season		fare media		
		weather conditions		all BRT components contributing to reduced travel time and increased schedule adherence		
		route, section of route		information systems		
		BRT component if incrementally implemented				
Ridership - Qualitative	modal switch	peak, off-peak	before/after for BRT route	all BRT components, directly or indirectly	passenger surveys	BRT will improve quality of ride
	satisfaction	weekday, weekend				
	demographics	season				
	transit usage characteristics	weather conditions				

Table 2. Summary of Performance Measures by Evaluation Criteria (continued)

Evaluation Criteria	Measures	Stratification	Baseline/Control	BRT Components	Data Collection Methods	Hypotheses
Traffic Congestion along Corridor	# autos	peak, off-peak	other bus routes thru corridor	exclusive lanes	automatic auto counters	BRT will have no effect on traffic congestion in corridor
	# minutes for autos to travel the corridor	weekday, weekend	other modes thru corridor	busways	timed auto trips along corridor	
		season	before/after on BRT route	signal priority		
		weather conditions		traffic mods and enforcement		
		section of route				
		BRT component if incrementally implemented				
Traffic Congestion along Cross Streets	# minutes autos stopped at cross street signals	peak, off-peak	before/after on BRT route	signal priority	data collectors at cross streets	Signal priority will increase wait time on cross streets
		weekday, weekend		traffic mods and enforcement		
		season				
		weather conditions				
		section of route				
		BRT component if incrementally implemented				
Environmental Impacts - Air Quality	parts per billion of toxins in air	peak, off-peak	other bus routes thru corridor	alternative fuel buses	air quality measurement equipment	BRT will improve air quality
		weekday, weekend	before/after on BRT route	BRT components contributing to reduced dwell time and time at signal stops		
		season				
		weather conditions				
		section of route				
		BRT component if incrementally implemented				
Land Use/Urban Design	number of new passenger convenience businesses in area of stations/stops changes in zoning to allow high density development in vicinity of BRT route	N/A	before/after BRT implementation	all components as a system	direct observation local databases	BRT will lead to more efficient land use and transit-oriented urban development
Transit System Image	perception of BRT by patrons and public	BRT component if incrementally implemented	before/after BRT implementation	all components, particularly marketing and system design	passenger surveys	BRT will improve the image of transit
					surveys of general public	
Cost	$ for BRT system	BRT component	before/after BRT implementation	all BRT components	transit agency databases	
	$ per component					
Cost-effectiveness	$ per min. saved	BRT component	before/after BRT implementation	all BRT components	all of the above	BRT benefits will outweigh costs
	$ per min. delay reduction	BRT system as a whole				
	$ per unit toxin eliminated					
	$ per new rider					
	$ per % improvement in transit image					

- *In-vehicle: dwell* — automated fare media or paying fares prior to loading will speed up the loading process; low-floor buses make it quicker for encumbered and disabled patrons to board and deboard; precision docking will enable boarding passengers to line themselves up where the bus doors will open; "next stop" announcements on board the buses speed up deboarding.
- *In-vehicle: in-transit* — signal priority, exclusive lanes, busways, bus lane markings, bus bulbs, traffic enforcement, and elimination of some stops on the route all speed up the bus when it is moving.
- *In-vehicle: signal stop* — signal priority would reduce the amount of time a bus spent stopped by traffic signals at intersections.
- *transfer and egress* — efficient design of transit stations and terminals makes it easier for passengers to make their way from one bus to the next or to the exit; automated information displays make it easier for passengers to find their connecting buses; improved schedule adherence eliminates waiting for delayed connections.

The most critical question here is "How much time does the BRT service save?" The relevant measure is travel time savings, measured for each phase of a bus trip and for the trip as a whole. Savings is derived as the difference between the trip times for BRT service (the "after" times) and the baseline (the control or "before" times), depending on the choice of the baseline. Total trip time is of interest as well, for example, to compare to the time it takes to drive the same route in an automobile. This would be equivalent to the sum of the separate times for the two phases. Another related measure is bus speed in miles per hour.

All these measures should be calculated as averages (means) of the observations taken for each stratum of the desired stratification schemes, and should be reported along with the corresponding confidence intervals based on the standard deviations of their means. In most BRT sites, it is expected that measurements would be broken down at a minimum by route or route segment, peak and off-peak time periods, day of the week, and season. BRT projects with staged implementation of BRT components would allow for measurement of the effects of each individual component before the next one was initiated. Depending on the BRT components being implemented at a site, breaking travel time down by the relevant trip phases might be called for. If, for example, the BRT project involves only signal priority and the elimination of some stops on the route, then the main focus of data collections efforts should be on the relevant phases (in-transit and signal stop times), although measurements for other individual phases would be of interest to serve as a baseline for future improvements to the service, and total trip time would still be an important measure to estimate.

Sample size determination is a function of the desired precision of the resulting estimates and the budget for data collection. Sample size issues are addressed in Appendix A.

2. Schedule Adherence

Related to travel time, schedule adherence is a comparison of the *actual* arrival times of a bus at scheduled stops to the *scheduled* times of arrival; a bus can be on time, late or early. The same BRT components that affect the dwell, in-transit and signal stop phases of travel time also affect schedule adherence in similar ways. The critical question here is "Can passengers count on the buses being on time?" The measure for schedule adherence is the average numbers of minutes of difference between the actual and scheduled bus arrival, and its standard deviation. It can be calculated for individual stops or the trip as a whole for stratification schemes similar to those for travel times, and can be compared to corresponding statistics for the baseline, either the period before the BRT project was implemented or the control routes.

3. Ridership

Ridership is an indirect function of all the BRT components. Faster, cleaner operating, more attractively designed buses running between clearly marked stops, stations, and terminals with accurate information on expected bus arrival times and schedules will likely attract new riders and improve the transit experience for existing patrons.

Critical questions to be answered here are "Has the BRT service affected the number of riders?" and "How do riders view the service?" The actual numbers of riders, a quantitative measure, are of interest in a BRT evaluation, as well as qualitative measures regarding their opinions of the service, their reasons for using it, their frequency of usage, their views on other related issues, and their socioeconomic and demographic characteristics. Variations in ridership are of interest by route, route segment, time of day, day of week and season. Means and standard deviations for each breakdown category should be calculated. Comparison of BRT ridership with the "before" time period can show the effect of the BRT demonstration. Changes in ridership can be correlated with individual BRT components if they are implemented in stages. Socioeconomic data can be correlated with other data, for example, frequency of usage by income level, age, reason for using, or distance of residence from nearest stop.

4. Impacts on Other Traffic

The BRT demonstration project may have significant effects on other traffic on the BRT route, both positive and negative. Decreased traffic levels along its routes may result if the BRT system is able to entice enough automobile drivers to shift modes. A secondary benefit, though difficult to measure, would be improved air quality from fewer cars on the roads. Parking restrictions and increased enforcement of traffic and parking regulations along an exclusive bus lane may improve the traffic flow for automobiles as well as BRT vehicles. On the negative side, signal priority may increase the time vehicles on side streets have to wait at traffic signals. Dedicated bus lanes on arterials may increase traffic congestion on the remaining all-purpose lanes or nearby streets.

Appropriate quantitative measures of traffic congestion would be automobile travel times, traffic levels, vehicle accidents, time waiting to turn across exclusive lanes, and time waiting at side street signals measured along the BRT and parallel routes both before and after the BRT demonstration. These measures could be broken down by time of day, day of week, season, BRT route, and route segment. Again, means and standard deviations are required.

5. Land Use and Urban Design

Complementary land use policies can help increase ridership over time. Such policies in urban settings can encourage the use of transit by helping maintain or increase the density and diversity of land uses around transit lines, pedestrian-friendly road design, and pedestrian-oriented land uses (e.g., with parking behind structures). Additionally, land use policies can facilitate the incorporation of transit in suburban areas. For example, subdivisions can be designed to provide more convenient transit access. Shopping malls can be designed around a transit station, rather than having transit stops at the periphery of vast parking areas.

Measuring the degree to which these changes occur as a result of the BRT system is more of a descriptive exercise than one requiring specific quantitative or qualitative measures. Moreover, impacts of the BRT system on land use and urban design, by their nature, may not occur until long after the evaluation period. For businesses to make the decision to locate near a transit stop or to build a shopping mall with transit access on the BRT line, the BRT transit system has to establish a sense of permanency and reliability (and the community has to cooperate with appropriate zoning and incentives). Short of the construction of a busway structure, this sense of permanency could take considerably longer than the evaluation period to evolve.

Nevertheless, the evaluation should address land use and urban design impacts of the BRT demonstration to the extent possible. There may be signs of changing land uses in the vicinity of BRT bus stops during the life of the evaluation period. New commercial enterprises to serve the passengers, such as dry cleaners, film drop-off's, fast food vendors and other convenience markets, may crop up along the BRT line during the course of the evaluation period, and should be noted. The evaluation should address the new construction of high-density housing, retail businesses or office parks on the BRT route, as well as any changes in the local zoning that may have occurred in conjunction with, as a result of, or to encourage these developments.

6. Transit Image and Public Perception

The relevant questions here are "Has the BRT system changed the public's perception of transit in general?" and "Does the public have a positive image of the BRT service?" Some BRT components, such as the design of the buses, bus stops, stations and terminals, the signage, the logo for the BRT service, passenger information systems, and marketing strategies for the service, are meant to influence directly the public's image of transit, and the BRT service in particular. All of the BRT components, however, contribute to the overall public perception of the service.

Quantitative measures of the public perception would be indicated indirectly by changes in ridership. Direct measures would be qualitative, based on the attitudes of both riders and nonriders, i.e., the public in general, and would be obtained through surveys. Sample questionnaires are included in Appendix B, and survey methodology is discussed in Chapter 7.

7. Costs, Productivity and Cost-effectiveness

The relevant questions here are "How much does the BRT system and its components cost?"; "Does the component work as expected?"; "How efficiently are the system components employed to produce the service?"; and "How do the costs compare to the impacts?"

There are myriad measures that can be examined to answer these questions. Costs are fairly straightforward: dollar costs of BRT equipment purchased, labor, contracts, etc. Labor hours might also be of interest.

BRT system productivity may be measured in terms of BRT system operating costs per vehicle mile, vehicle hour, passenger mile, etc. For individual BRT components, evaluating productivity would more likely involve an assessment of how well the component functioned and whether it met expectations. Specific productivity measures would vary with the type of BRT component being evaluated. For example, appropriate productivity measures for a signal priority system might include the number of activations, the amount of extra time the signals remained green, the malfunction rate, the resulting change in overall trip time (see Section 1. Travel Time), and the resulting change in schedule adherence (see Section 2. Schedule Adnerence). Suggested productivity measures for other BRT components are discussed in Section C below and summarized in Table 3.

Cost-effectiveness is generally the ratio of the cost of a BRT component or system to a statistic describing its impact, productivity, or result. For example, the cost effectiveness of signal priority may variously be described as its cost per minute of trip time savings, cost per minute of improvement in schedule adherence, and cost per activation.

Often these questions are examined in the context of an overall economic cost-benefit analysis. Costs and benefits can vary depending on the perspective. The point of view of the transit agency is important; it typically wants to know if the system's benefits exceeded its costs. In some demonstrations, the FTA may also be interested in the perspective commonly adopted in policy analysis, that is, to consider all benefits and all costs accruing to society as a whole. In this framework, a cost must be a real use of goods or services, whether traded in the market or not. (A cost and a negative benefit are equivalent.) If the good or service is traded in a competitive market, its cost can usually be estimated by its market price; if not, other indirect techniques can be used to estimate its value. A cash transfer is not a benefit or cost, however, the benefit to one party is exactly negated by the cost to the other. It is often important to specify these distributional consequences, to the extent possible. These types of analyses would involve estimating, for example, the dollar value of a passenger's time or the value of cleaner air.

Examining the benefits and costs of a project can answer the question of whether the benefits exceeded the costs. It is also important to know if a project is the best use of resources, or the most effective way of achieving the goal of the program. In this case it is important to compare the project to other alternatives.

C. Measures for BRT Components

An alternative way of organizing performance measures is by BRT component. The following sections discuss the potential benefits of each major BRT component and the performance measures, both quantitative and qualitative, that can help gauge them. The list is by no means exhaustive, as there are too many other technologies and features that may be included as part of individual BRT demonstrations to include them all here. In general, the analysis of each BRT component should address how the component was implemented, how much it cost, and if it worked as expected, in addition to its impacts. As with the measures for the evaluation criteria (see Section B, Measures for Evaluation Criteria), the same performance measure can often be used in the evaluation of a number of BRT components. Table 3 summarizes measures for specific BRT components.

1. Express Rights of Way (Busways and Exclusive Bus Lanes), Transit Malls, and Bus Lanes on Arterials

The primary benefits of express rights of way and bus lanes on arterials are travel time savings for riders switching to the BRT service from local service and from other slower modes, less crowding on the local service due to fewer riders, increased productivity, and an improved image of transit. Another benefit is an increase in transit ridership from riders who switched from the automobile and other modes. Improved air quality may result from less auto usage, although the improvement may be too small to detect, especially within the time frame of the demonstration.

Measures appropriate for assessing the impacts of both express rights of way and bus lanes on arterials include all phases of travel time, transit ridership, bus speed, and passenger loads on BRT and parallel routes. Rider surveys will help gauge satisfaction with the BRT service compared to other modes including automobile and regular transit service, and improvements in the image and visibility of BRT and transit in general.

Express rights of way and transit malls have more capital costs than other BRT options including bus lanes on arterials. Busways and off-street transit malls typically require the acquisition of land and rights of way, an expensive proposition, as well as the construction of the bus lanes themselves. Exclusive bus lanes and bus lanes on arterials may require considerable road and curb modifications. All require construction of bus stops, information kiosks, and other passenger amenities, signage, marketing. In many cases, new vehicles will have to be purchased. Operating costs can be estimated based on vehicle hours. The net change in operating costs should be considered after accounting for any reductions in service on parallel routes. If there are reductions in parallel service, the change in travel time due to increased waits or greater schedule delay on those routes should be estimated and included as a cost in a cost-benefit analysis.

Table 3. Summary of Performance Measures by BRT Component

BRT Component	Performance Measures
Busway	average and maximum bus speed
	travel time by trip phase
	ridership
	passenger loads on BRT and parallel routes
	passenger satisfaction
	improvement in transit image
	capital and operating costs
Exclusive Bus Lane	average and maximum bus speed
Bus Lane on Arterial	travel time by trip phase
	ridership
	passenger loads on BRT and parallel routes
	passenger satisfaction
	improvement in transit image
	accidents
	traffic on BRT route and parallel streets
	waiting time for oncoming traffic to turn
	waiting time for traffic on cross streets
	capital and operating costs
Transit Mall	ridership
	transfer time
	dwell time
	passenger satisfaction
	improvement in transit image
	capital and operating costs
Limited Stop Operation	average and maximum bus speed
	travel time by trip phase, especially access and in-vehicle phases
	traffic on BRT route and parallel streets
	ridership
	passenger loads on BRT and parallel routes
	passenger satisfaction
	improvement in transit image
Low-floor Bus/Same Level Boarding	travel time by trip phase, especially waiting and dwell times
	ridership
	equipment functionality and reliability
	passenger satisfaction
	improvement in transit image
	passenger loading rate
	capital and operating costs

Table 3 (continued)

BRT Component	Performance Measures
Articulated Buses	passenger loads on BRT and parallel routes
	travel time by trip phase, especially waiting time
	bus functionality and reliability
	passenger satisfaction
	improvement in transit image
	capital and operating costs
Clean-Emission Buses	parts per billion of toxins in air
	bus functionality and reliability
	passenger satisfaction
	improvement in transit image
	capital and operating costs
Traffic Signal Priority	travel time by trip phase, especially time stopped at signals and waiting time
Queue Jumper	activations per trip
	extra time signals remained green
	malfunction rate
	accidents
	schedule adherence
	ridership
	passenger satisfaction
	improvement in transit image
	capital and operating costs
Proof-of-Payment Fare Collection System	travel time by trip phase, especially dwell and boarding times
Smart Card	schedule adherence
	passenger satisfaction
	improvement in transit image
	equipment functionality and reliability
	capital and operating costs
Next-Bus Display	travel time by trip phase, especially waiting time
	ridership
	passenger satisfaction
	improvement in transit image
	equipment functionality and reliability
	capital and operating costs
Improvement to Bus Stops/Shelters	ridership
Transit Information Kiosks	passenger satisfaction
	improvement in transit image
	equipment functionality and reliability
	capital and operating costs

Table 3 (continued)

BRT Component	Performance Measures
Bus Bulb	travel time by trip phase, especially dwell time
	passenger satisfaction
	improvement in transit image
	capital cost
Next-Stop Announcement System	travel time by trip phase, especially dwell time
	passenger satisfaction
	improvement in transit image
	equipment functionality and reliability
	capital and operating costs
Precision Docking/Tight Terminal Guidance System	dwell time
	schedule adherence
	equipment functionality and reliability
	capital and operating costs
AVL	travel time by trip phase
	schedule adherence
	passenger satisfaction
	improvement in transit image
	interventions per trip
	equipment functionality and reliability
	capital and operating costs
BRT Image/Logo	passenger satisfaction
Marketing/Promotional Campaign	improvement in transit image
	ridership
	costs

2. Limited Stop Operation

The major benefit from limited stop operations is travel time savings. There are potential travel time savings for riders switching from local routes to the BRT route, remaining on local routes (from less crowding due to fewer riders), and switching from other modes. One drawback to limited stop operations is that it may increase the distance patrons have to walk to the bus stop, but the extra time it took would likely be offset by in-vehicle travel time savings. Other benefits include the increase in transit ridership and the benefits associated with less automobile use.

Capital costs include the vehicles, signs on buses, signs at stops, marketing, and bus stop and station modifications. Operating costs can be estimated based on vehicle hours. The net change in operating costs should be considered after accounting for any reductions in service on parallel routes. If there are reductions in parallel service, the change in travel time due to increased waits or greater schedule delay on those routes should be estimated and included as a cost in a cost-benefit analysis.

Rider survey results will help gauge satisfaction with the BRT service compared to other modes used including automobile and regular transit service.

3. Bus Design

The benefits of larger buses, such as articulated buses, are the reduction in pass-ups, decreased crowding, and the ability to carry larger loads more efficiently. This will greatly reduce waiting time for passengers unfortunate enough to be passed up currently, but also reduce total travel time for all passengers, since less crowding will lead to faster loading and unloading and therefore reduced travel time. This better service and greater capacity may increase ridership. User opinions of the change in vehicles will be important to assess. Appropriate measures for gauging the impacts of larger buses include travel time, dwell time, pass-ups per trip, passenger loads, and total ridership, as well as qualitative measures of passenger satisfaction.

The benefits of low-floor buses include faster loading and unloading times, contributing to faster overall travel time. Low-floor buses may also attract new riders from groups that currently find boarding standard buses too difficult, such as the disabled, elderly, and parents with small children in strollers. Appropriate measures for gauging the impacts of low-floor buses include travel time and dwell time, as well as qualitative measures of passenger satisfaction.

The benefits of clean emission buses, such as LNG-fueled buses, include improved air quality. Appropriate measures of the impact of clean emission buses include air toxin measurements.

The cost of buses includes the capital costs of the vehicles and any modifications that need to be made to curbs, bus stops, maintenance facilities, or depots, and training operators and other personnel on how to use and maintain the new vehicles. On the operating side, there may be increased operating and maintenance costs compared to a new standard size bus.

4. Traffic Signal Priority and Queue Jumpers

The major benefit from traffic signal priority and queue jumpers comes from reduction in travel time for BRT riders and incidentally, people in private cars or other bus routes in the corridor, as well as a reduction in the variance of travel time. There also may be improvements in reliability due to signal priority, resulting in a reduction in waiting times at bus stops.

Capital costs of the project include vehicle and signal controller hardware and software, evaluation, restriping, signage, and road widening with queue jumpers. Operating costs include enforcement, maintenance, and a portion of dispatching or control center costs, if applicable. Another potential source of costs to society is any increase in travel time for cross traffic.

5. Proof-of-payment or Other Fare Collection System

The benefits of a streamlined fare collection system, such as a proof-of-payment or smart card system, are reduced dwell time due to less fare payment delay. In the absence of these fare payment methods, ticket or token vending machines at bus stops allowing waiting passengers to purchase tickets before the bus' arrival would reduce dwell time to a lesser degree. If a proof-of-payment system is chosen, dwell time may also be reduced due to the ability to load the bus through multiple doors. The reduction in dwell time at each stop adds up to a reduced total travel time, providing a benefit both to customers and to the operator. In addition, the reduced dwell time could reduce the variance of total travel time along the route and therefore reduce passenger waiting time and increase schedule adherence.

The costs of the fare policy change include possible smart card reader equipment, vehicle door modifications, signage, publicity, and training for operators. The cost of inspections in a proof-of-payment system can have a significant effect on operating costs. This increased cost is potentially partly offset by the reduction in operating labor costs due to higher average travel speed. There may also be a cost due to inspection-related delays. Inspections may have a side benefit of reducing crime or at least improving passengers' perceptions of safety.

Although fare evasion losses in a proof-of-payment system are not a net social loss (they represent a transfer from the transit agency to fare evaders), they affect the agency's bottom line and are therefore of concern.

6. Bus Stop Design

Well-designed bus stops can provide a variety of benefits to BRT riders. A standardized design that is easily distinguishable from other bus stops makes it easier for passengers to identify the BRT stops, and provides a positive visible image of the BRT service to all passers-by. Passenger amenities, easily readable and non-destructible schedule information, and next-bus displays offer conveniences that may attract riders. Curb design that accommodates bus entrance characteristics or makes it easier for buses to pull up to the bus stops, such as bus bulbs, can reduce dwell time and make it easier for encumbered passengers or the disabled to board.

Appropriate measures include passenger satisfaction, dwell time, and ridership level. Capital costs include the construction of bus stop shelters and other amenities, curb and road modifications, electronic information displays, and signage.

7. Station, Terminal and Bus Plaza Design

Similar to the design of bus stops, the design of stations, terminals and bus plazas or malls can produce a number of benefits for BRT riders. Perhaps the most significant benefit of these structures is the image they can project, if well-designed, of a permanent, modern, efficient bus system. Another benefit is the reduction of dwell, access, and transfer times.

Appropriate measures include passenger satisfaction and perception of transit, and dwell, access and transfer times.

Capital costs are significant and include design and construction, land and right-of-way acquisition, fare collection, passenger information and other equipment, installation of technologies and equipment, and personnel training. Operating costs include salaries of personnel located at these sites, as well as maintenance costs.

8. Passenger Information Systems

The primary benefit for passenger information systems is the reduction in passenger anxiety associated with not knowing the length of the wait until the next bus or the next bus stop. In the case of real time "next bus" systems at bus stops, the knowledge could lead to time savings by influencing the decision about whether to take the local or express bus. The passenger may also decide to do a brief errand instead of waiting at the stop. Kiosks in shopping centers or other locations and web sites permit passengers to budget their time better and reduce wait time at bus stops. The prerequisite for these systems is an AVL/communications system that can track the buses in real time and relay the information to passenger information displays. The greater information may have a positive impact on user satisfaction and could lead to greater ridership. "Next stop" announcements allow passengers to move to the doors prior to the bus stop for faster disembarking and reduced dwell time. These systems may work in conjunction with the AVL system, but simpler in-bus technology can also provide this service.

The primary way to determine these impacts is through passenger surveys. Customers can be asked about their opinion of the information they obtain at bus stops and their impression of the frequency of service. In other deployments, it has been found that users perceive the service to be more frequent, even without any service changes.

The costs of the system include wayside hardware and installation and costs associated with a communications system and an AVL or other system, including a server, radio communications equipment, bus hardware, software, installation, and training. Operating costs include maintenance of hardware.

9. Precision Docking and Tight Terminal Guidance Systems

The main benefit to these systems is reduced dwell times due to the ease with which a vehicle can precisely enter a terminal and/or line itself up with the boarding location and passengers form boarding lines where the doors will open. Appropriate measures would be changes in dwell times. Costs would be incurred for the purchase and installation of the systems, and training of drivers.

10. Automated Vehicle Location Systems

Automated vehicle location systems (AVL) are typically the prerequisite for several of the BRT components discussed above, namely signal priority and next-bus announcement information systems. Combined with a transit control center and a means to communicate with the buses, AVL can make an entire transit system run more efficiently, producing travel time savings in almost all phases. AVL can be used, for example, to space buses more evenly by speeding them up or slowing them down, to dispatch a replacement bus or assistance in the case of a breakdown or emergency, or to augment service when there is an unexpected increase in passengers along a route. Sometimes closed circuit television (CCTV) cameras are used in conjunction with the AVL system to monitor traffic congestion in critical places along the bus route. All of these service improvements would be expected to attract new riders.

Measures appropriate for assessing the benefits of AVL would center around those for travel time, especially the in-transit, signal stop, and waiting phases, and schedule adherence. Because AVL would be expected to reduce variability in waiting times by improving schedule adherence, the variances of the performance measures would be expected to decrease.

Capital costs of an AVL system may include not only the hardware and software for the buses and control center, but also possibly the establishment of the control center itself. Operating costs would include personnel (salaries, training of dispatchers and bus drivers) and maintenance.

11. Marketing and Promotional Efforts

Marketing and promotional efforts can have a tremendous effect on the success of a BRT demonstration. The greater the degree to which people are informed of the BRT service, its features, and its improved performance over regular bus service, the greater the increase in BRT ridership. These efforts may include a wide range of activities, such as public service announcements describing the new BRT service and its advantages on radio and television; ads and articles in newspapers, pamphlets and flyers; events staged in malls, bus stations and stops, and local attractions with high public visitation rates; distribution of pamphlets on the new service through the mail; posting of signs and posters throughout the city; coordinated visual design of all aspects of the service including the logo, signage, color scheme and appearance of buses, bus stops, and all published materials. These efforts can create an identity and a positive image for the BRT service in the minds of the BRT service area residents. Ultimately they will attract new riders.

Measures for assessing the effectiveness of a marketing campaign would be obtained mainly through surveys of the general public and the riders of the BRT system. Surveys of the general public, including both users and non-users, would focus on their recognition of BRT service and the extent of their familiarity with its features, as well as how they heard of it and their opinions of the various promotional efforts.

Costs would include both labor associated with the design and implementation of the marketing and promotional programs, and costs associated with the materials, air time on television and radio, advertising in publications, etc. The majority of these costs would occur prior to the opening of the BRT service, but some would be expected to be ongoing.

Chapter 7. Data Collection Methods

Once the relevant measures for project evaluation have been determined, it is necessary to identify appropriate data collection and derivation techniques. The main methods of data collection are through manual observation, automated data recording, surveys and published data. Derived measures are calculated either through the use of simple arithmetic or special analytic models. They build on basic data collected through some of the above means. As illustrations, a simple derived measure would be dividing the passenger load for a trip by the bus capacity to get the load factor for that trip. Examples of more complicated derived measure would be: (1) subtracting the mean number of passengers per day before the BRT demonstration from the mean number of passengers per day after the BRT demonstration to get the increase in ridership; (2) obtaining a benefit/cost ratio by dividing the increase in ridership due to BRT by the cost of the BRT components in the demonstration; and (3) cost per new rider.

In view of the large number and variety of possible relevant measures, these guidelines suggest only general methods of data collection for each measure, and encourage the evaluator to develop other equally effective methods, since the continual development and implementation of novel techniques have the potential for increasing the efficiency or accuracy of evaluations. Although there is no requirement for uniformity among data collection techniques, there is a need for consistency and comparability of the data obtained by these collection techniques. The techniques can differ from project to project, as long as they are comparable in terms of accuracy and yield data in a form suitable for analyses both within the project and among projects.

The potential applicability of some specific techniques is discussed below, drawing where possible from previous experience.

- Travel time, speed, and vehicle volume data collection techniques can range from manual to automatic. In general, automatic techniques are effective only where the magnitude of data requirements or some other special circumstances warrant their use. Some of the more sophisticated automatic procedures are subject to reliability problems. Failure of these devices can cause loss of vital data, which will in turn delay the evaluation, and considerably increase costs. In addition, the measurement accuracy of automatic or semi-automatic devices may be questionable, particularly if they have not been used extensively before. In cases where definitive information on device accuracy is not available, it is essential to confirm the accuracy of automatically collected data by periodic use of manual devices.

Simple manual devices can be deployed to maximize utilization of data collection personnel. For example, special counters may enable an observer to keep track of the number of boarding and deboarding passengers at a bus stop while simultaneously timing the duration of the stop.

- Past experience has shown that there is a lack of consistency between passenger counts recorded by transit personnel and counts by onboard or roadside observers. For instance, in one project, it was found that bus drivers tend to overestimate the passenger load and that on-board and on-street counters tend, on the average, to be consistent with each other. If transit personnel are to record such data, it is essential that verifications be made during the project to detect any potential bias or unusual variability in these data.
- Demographic, behavioral, and attitudinal data on users and non-users of the services, as well as attitudinal information from transit operators, can be collected through a wide variety of survey and interview techniques, with varying degrees of respondent cooperation, accuracy, and cost. In view of the large amount of documented survey experience relating to both transportation and general market research contexts, and in view of the large anticipated role of surveys in BRT evaluations, Appendix B has been devoted to a discussion of survey design and execution.

In evaluating the array of existing and potentially innovative collection techniques relative to a particular measure, the evaluator should consider factors such as the cost and accuracy of each method, the availability of local resources to implement each method, the ease of implementation, and the ultimate data analysis requirements.

With respect to cost, the evaluator should determine whether the anticipated cost of using a particular technique is justifiable in terms of the contribution to the overall project evaluation of the specific measure being collected. Clearly, the total project expenditure for data collection should be allocated among individual measures, taking into account each measure's contribution to the project evaluation. The evaluator should make special note of any data item which is relevant to the evaluation but whose collection cost appears to be disproportionately high in relation to other items.

The evaluator should determine whether the accuracy of a particular technique is consistent with the accuracy requirement for the measure, which in turn is dependent on the relative importance of the measure. A very accurate technique is probably not warranted for a relatively insignificant measure, especially if that technique would be expensive to implement. In addition, a high degree of accuracy for some measures may be inconsistent with a lesser degree of accuracy for others. The evaluator should also evaluate alternative techniques in light of the available local resources -- labor resources as well as equipment. An attempt should be made to utilize existing equipment or rental equipment arrangements wherever feasible, rather than opting for techniques which require the purchase of new equipment (which might not be needed by the locality after the BRT evaluation).

The Evaluation Plan should justify the selection of a particular technique applicable to each measure in terms of these considerations. In the case of a novel technique, the evaluator should demonstrate acceptable accuracy before it can be used as the sole source for data collection.

Table 2 indicates the general data collection methods to be used for the BRT evaluation criteria. Rather than attempt to include in these guidelines detailed instructions for ride and point checks, boarding counts, farebox readings, speed and delay measurements, running time measurements, and other transit operational data, these guidelines refer the evaluator to two documents in particular from the many in the body that address transit data collection techniques: "Review of Transit Data Collection Techniques," FTA, March 1985; and "Transit Data Collection Design Manual," FTA, June 1985. These documents accompany the guidelines under separate cover as Appendix C. Guidelines for the design of passenger and other surveys are found in Appendix B. Appendix A addresses statistical issues in determining sample size for both surveys and other performance measures such as traffic congestion along BRT routes and cross streets, air quality readings, etc.

Chapter 8. Report Outline

The Final Evaluation Report will be the predominant means for disseminating the results of the demonstration project. As such, the main body of the report should be comprehensive, well organized, and to the point. It should "tell the story" of the demonstration, highlighting the significant findings in an easy-to-read and interesting manner. Issues needing detailed elaboration may be treated extensively in appendices to the report. Given the unique characteristics of each demonstration project, it is not necessary to follow the suggested outline below exactly as written. However, the final report should address all the topics contained therein.

I. Executive Summary: this should be capable of standing on its own and being published separately.

II. Project Background

  A. Description of FTA, sponsor and other project goals and objectives, and other relevant issues,

  B. Description of the project, including the BRT components being demonstrated, and

  C. The overall project cost.

III. Project Development

A. Site Characteristics.

1. Demographics and socioeconomic characteristics,

2. Transportation characteristics: modal shares, traffic conditions, transit system characteristics (route miles, schedules, fare structure, ridership, transit market characteristics), and

3. Land use: densities, development patterns, levels and character of pedestrian activity, degree of auto/transit orientation.

B. Planning, Design and Implementation.

1. Chronology of the project (the "project story") and milestones,

   a) Problems encountered and resolution, and

   b) Changes necessary to plan, including errors, abandoned technologies.

2. Institutional setting: the role of the transit agency, city, MPO, state and other organizations in the project; private and community participation; laws and regulations,

3. Design elements and the physical image of the system, including the vehicles, facilities and amenities,

4. Marketing and promotional efforts, and

5. Integration of the BRT system with land use planning and community development.

IV. Evaluation Overview: description of the basic evaluation procedure and the timing of the evaluation phases.

V. Results: this section will be the core technical discussion of the report illustrated as necessary by charts, graphs, and data tables.

A. Impacts: discussion, based on performance measures, of how the overall project and individual components impacted the evaluation criteria.

1. Service quality: travel time and schedule adherence,

2. Ridership,

3. Impacts on other traffic,

4. Land use and urban design,

5. Transit system image, public perceptions and support for transit service, and

6. Costs, productivity and cost-effectiveness.

B. Attainment of objectives: assessment of the individual BRT components and the overall project in terms of their attainment of the objectives of all involved parties (FTA, transit agency, other), and

C. Feasibility: insight into the operational feasibility of BRT components as related to the site characteristics.

VI. Lessons Learned

A. Summary of benefits,

B. Summary of costs, capital and operating,

C. Assessment of site-specific characteristics and external factors on the outcome of the demonstration, including the effects of institutional factors (organizations, individuals, process); are modifications necessary?,

D. Effects of marketing,

E. Transferability of results: identify BRT components most likely to succeed elsewhere; suggest variations that might be necessary in other locales or might work better in other conditions, and

F. Appraisal of evaluation procedures and recommendations for improvements/changes.

Appendices

1. Evaluation Plan
2. Data Collection Instruments
3. BRT Project Costs, Including Evaluation Costs
4. Detailed Performance Measures and Supporting Data
5. Marketing/Promotional Materials
6. Detailed Transit Agency and Transit Service Information
7. Detailed Assessment of Evaluation Process
8. Other Relevant Information and Documents

Chapter 9. Evaluation Implementation

This chapter presents guidelines for implementing the evaluation of a BRT demonstration. Activities that occur during the evaluation implementation phase include data collection and analysis relating to site characteristics and performance measures, and the writing of the Evaluation Report, according to the plans and procedures laid out in the Evaluation Plan.

The evaluator is responsible for monitoring and/or performing data collection activities, data reduction and analysis, subjective analysis of information relative to project issues, and synthesis of project findings into a Final Evaluation Report. In accordance with these functions, this chapter of the guidelines is organized into two sections: monitoring/performance of data collection; and data reduction, analysis, and presentation.

A. Data Collection

Each BRT demonstration will undoubtedly involve significant data collection efforts. Given the considerable amount of time and money that will be spent on data collection, careful management and oversight of the data collection process are essential. Where possible and appropriate, data collection may involve the use of students from local colleges and universities.

The evaluator is responsible for ensuring that data collection is performed according to the Evaluation Plan. There are two potential alternatives associated with data collection. One of these occurs when the local sponsor or operator collects all data (under FTA and/or local funding), and the evaluator acts in a monitoring role to assure the quality and timeliness of data collected, as well as adherence to procedures laid out in the Evaluation Plan. The second is one in which both evaluator and local sponsor collect various elements of the data, although this may not be possible within the evaluator's project evaluation budget.

Both alternatives require the evaluator to maintain open channels of communication with the site, in the form of visits, telephone and written correspondence with the appropriate local agencies as well as subscriptions to local newspapers. In the rare instance where day-to-day contact with the site is necessary, the evaluator may need to arrange to base a member of the evaluation team at the site.

Whether data collection is being performed by the evaluator or by the local sponsor, they must stay closely involved in all phases to make sure the procedures specified in the Evaluation Plan are followed, to discuss progress and problems, to work out solutions to the problems, to observe key phases of field data collection, and to perform independent spot checks. The evaluator is expected to inform the FTA of the status of data collection in periodic written progress reports.

Over and above monitoring data collection activities, the evaluator should keep abreast of the status of the BRT demonstration. This awareness of project operational status is important so that: (1) data collection activities can be smoothly coordinated with ongoing project activities (causing minimum disruption of day-to-day operations), and (2) evaluation results can be interpreted in the context of project history. The evaluator should maintain close contact with the transit agency.

In addition to keeping abreast of project operations, the evaluator should be continually watching at the site for unexpected (external) events that might affect the validity of project results. In any demonstration, no matter how well controlled or planned, the possibility remains for unexpected events to occur that may have an impact on measures of the project's performance. These unexpected occurrences may threaten the validity of the analysis.

Unanticipated developments at the site can take the form of temporary events such as a driver strike or longer-term phenomena such as the closing of a major thoroughfare. The following are examples of unexpected factors that have been experienced in earlier FTA projects:

- Changes in employment: thousands of aerospace employees were laid off in Seattle, Washington.
- Changes in freeway traffic volumes: The Shirley Highway experienced a shift from arterials to the freeway upon completion of new lanes and sections. Minneapolis, Minnesota noted a shift to the freeway due to arterial street construction and land developments within the project. Seattle noted volume shifts on the freeway entrance and exit ramps where new lanes had been added or preferential treatment was given to buses. Seattle also experienced a queuing problem onto the freeway from autos that were diverted from converted ramps.
- The national energy crisis: Minneapolis experienced a drastic change in traffic volumes from auto to transit during the energy crisis. Although it cannot be determined whether the shift in volumes was directly attributable to this factor, the timing of the initiation of the project during this period may have had some impact on data interpretation.

As previously noted, the use of a test/control evaluation design will, in certain cases, mitigate the impact of these unplanned events on the validity of the project results. The evaluator is responsible for informing the FTA of any unplanned phenomena which arise during the course of the evaluation. Progress reports should describe the potential effects on validity of any phenomena noted, as well as propose changes in the project and/or evaluation to compensate for the unplanned occurrences.

Although data collection should generally proceed according to the Evaluation Plan, there may be instances where modification to the originally planned procedures is warranted. The previous paragraph indicated that external events at the site might be cause for modifying the evaluation. Two additional reasons for deviating from the planned approach are discussed below, namely, operational changes in the project, and availability of improved evaluation techniques.

Operational changes in the project can come about as a result of evaluator recommendations or decisions by FTA and the local sponsor. The evaluator needs to assess the impact on the evaluation of any forthcoming or proposed operational changes, and recommend appropriate modifications of the Evaluation Plan to the FTA.

In order to further the state of the art of transit evaluation, the evaluator is responsible for performing an ongoing assessment of data collection procedures used. The evaluator should maintain close control over data collection procedures used and summarize findings with respect to certain techniques for further examination. These findings will include, as a minimum:

- A narrative description of how the collection procedure was planned and implemented,
- An indication of areas in which the technique outperformed expectation,
- An indication of areas in which the technique was deficient,
- Some summary of the inherent variability in collecting project measures due to the technique itself, as opposed to variability due to other demonstration factors,
- An estimate of the cost of implementing the technique, and
- Where two techniques have been employed to collect the same basic measures, cross-comparisons and a recommendation as to which technique should be used in similar future demonstrations.

This information will ultimately be incorporated into an appendix of the Final Evaluation Report.

B. Data Analysis

The evaluator is responsible for performing all data reduction and analysis, regardless of which agency has collected the data. Data reduction involves the computer processing of raw data to yield statistics such as means, standard deviations, ratios, ranges, frequency distributions, coefficients of determination, correlation coefficients, F ratios, and "t" statistics. The specific statistic to be calculated and the need to control for other variables will depend in part on the type of measure and type of comparison involved. Quantitative measures such as travel time and vehicle passenger counts might be processed into average values for each level of stratification used. If a comparison of two time periods is involved, the percentage change from the earlier to the later period might be calculated, or two multiple regression equations might be calibrated and their coefficients compared. Quantitative measures relating to schedule dependability might be summarized into average values as well as standard deviations, with comparisons calculated as ratios of standard deviations. Some qualitative measures, for example, might be obtained through surveys and might be presented to yield frequency distributions for the response categories. It should be stressed that the level of analytical sophistication and choice of quantitative and qualitative measures will vary from site to site depending largely on the objectives being evaluated.

Data reduction may involve the use of statistical inference techniques. If the data are based on a 100 percent data collection effort (i.e., no sampling), then exact values of the statistics listed above can be calculated. However, if the data have been obtained by sampling (more likely), results cannot be presented as precise values, since there is a certain probability that the calculated values are different from the true population values.

It is recommended that data based on samples be processed into two-sided confidence intervals using a confidence level of $\alpha = .05$. Appendix A presents further guidelines relative to calculating confidence intervals.

The evaluator should arrange for smooth transfer of collected data from the collection site (e.g., buses, transit company, roadside stations) to the processing site. Special attention should be paid to details such as labeling and dating of forms, tapes, etc. to make sure that valuable data are not lost or altered.

The basic data collected during a demonstration should be maintained on appropriate storage devices (e.g., hard discs, floppy discs), and transferred to the FTA at the conclusion of the evaluation.

Data analysis involves the interpretation and synthesis of the processed data and other information to draw conclusions relative to the attainment of project objectives and issues, and relative to project transferability. Statistics such as those cited above, which range from the simple to the complex, are carefully examined and pulled together to obtain a comprehensive, in-depth understanding of the impacts of the BRT project, and the underlying reasons for observed changes. The evaluator must apply sound judgment as well as knowledge and experience relative to transit system operations, traffic operations and travel behavior in order to interpret the collected data and place it in proper perspective. To the extent possible, the results of the demonstration at the site should be supplemented by an assessment of the influence of site-specific and external factors on project outcome, so that conclusions can be made regarding the potential applicability and effects of implementing the BRT system in other sites across the country. To further enhance project transferability, the analysis/synthesis phase should provide a compilation of lessons learned regarding the operation of the BRT system.

The evaluator should understand and be aware of the importance that the use of appropriate statistical techniques can attach to the analysis and interpretation of project results. In view of the fact that most aspects of an urban transportation system tend to be dynamic and variable from hour-to-hour, day-to-day, and month-to-month, observed differences could be attributable only to this inherent variability and not to the BRT components. Furthermore, factors other than the planned and controlled innovations could also be directly related to the observed changes in those measures being collected. It is important to note that, while no single technique exists for removing the potential influence of these external factors, it is possible by careful analysis, to at least point out the occurrence of such events and create an awareness for those who review the project's conclusions and/or recommendations. Hence, it is important to be able to specify whether the observed differences in, for example, travel time are within reasonable bounds of expected variability inherent in the given transportation system, or whether the observed differences cannot be accounted for just by system random variability. If the latter case were true, taking into consideration the potential external influencing factors, one could conclude that the BRT component or system has in fact provided a real change in the measures being considered. It is to this capability for making valid inferences that the specific statistical techniques apply.

Presentation of project results in the Final Evaluation Report should be in the form of quantitative and qualitative exposition, with exhibits such as tables, graphs, and bar charts serving as the focus for narrative discussion. With respect to the format for exhibits, creative techniques for displaying information are encouraged, so long as the information is presented in a clear and accurate manner. Excessive discussion of all elements of a table or exhibit tends to be redundant and masks the really important findings. Back-up exhibits that contain significantly more detail of simple statistical results, multiple regression analyses, and benefit-cost analyses should be contained within technical appendices.

The evaluator should perform data reduction and analysis as data are collected, so that interim results are available throughout the project evaluation. These interim findings will not only satisfy general curiosity regarding the project's effects, but will also provide feedback information relative to ongoing project operations and evaluation. Examination of preliminary evaluation results may suggest opportunities for modifying the project and/or evaluation procedures so as to increase the utility of the demonstration.

APPENDIX A

STATISTICAL METHODOLOGY

This Appendix presents guidelines for determining appropriate sample sizes for estimating BRT performance measures. The determination of appropriate sample sizes and data analysis requirements is a crucial aspect of evaluation planning, since the number of sample units required determines the level of activity and resources needed for data collection and processing. Just as failure to plan the basic evaluation approach will mean not having the proper framework in which to observe and evaluate the BRT demonstration, failure to plan or improper planning of sample size requirements and data analysis procedures will threaten the ultimate statistical validity and usefulness of project results. An insufficient quantity of data, whether due to no planning or to an underestimate of needs, will be manifested in the loss of potentially valuable analyses and/or a loss in accuracy and validity of the analyses based on the data. On the other hand, excessive quantities of data will mean the unnecessary expenditure of funds and possibly the sacrifice of other data items which could be useful but which are beyond a constrained budget. The intent is to obtain an appropriate balance between analysis requirements and resource availability. It should be remembered that small samples, if they are well planned, can yield useful and interpretable data.

DEFINITIONS

To assure a complete understanding of the concepts presented in this Appendix, the following terms are identified:

Sample Unit - An individual item in a sample of items or responses, each of which is identifiable by one or more measures. Examples of sample units are bus trips, passengers, time periods.

Population or Universe - A population is usually a group of items about which inferences are desired. Examples of populations would be all inbound bus trips during a.m. peak periods, all those persons within 15 minutes access time of the transit system, or all users of a BRT service.

Sample - A finite subset of sample units drawn from a population. Samples can be drawn by appropriate procedures which will permit inferences to the population from which the sample was drawn or they may be obtained by non-controlled devices. Examples of samples would be some of the a.m. peak period BRT bus trips, or a subset of passengers within a service area.

Observation - One or more measures which describe the sample units included in the sample either directly or derived from measurements, such as travel times or passenger counts.

Population Parameter - A specific descriptive characteristic of a population assumed to be constant at any moment or period in time.

Sample Statistic - A summary value obtained from a sample observation, usually descriptive of the sample but desired for purposes of making inferences about the population or changes in the population parameter.

DATA ANALYSIS DETERMINATION

A major intent of using samples is to make inferences about changes in transit system characteristics or in the attitudinal/behavioral characteristics of the community being served. Before estimating sample size requirements, it is necessary to determine the appropriate types of analyses to be performed (i.e., what will be done with the data once they have been collected?). Types of statistical analyses which can be performed are numerous. As a general guideline, the evaluations for BRT projects should be limited to fairly fundamental types of analyses (i.e., involving the calculation of means, standard deviations or variances, proportions, ratios, and ranges). Suggested statistical techniques for performing these analyses are discussed later in this Appendix.

More sophisticated statistical methods, such as multiple regression, factor analysis, and discriminant analysis may also be applicable in the current generation of BRT projects. As more experience is gained with the data collected during these projects, it may be possible to institute some of these more sophisticated techniques.

The use of a simple analytical framework has three main advantages: (1) the results are expressed in numerical terms that have a direct relation to specific project objectives; (2) the evaluation results are meaningful to a wide audience; and (3) the results of a particular project are more easily compared with those of other projects.

The types of statistical analyses which can be performed and the appropriate equations and tables to be used in performing these analyses and determining sample sizes are presented in an organized, thorough manner in M.G. Natrella, *Experimental Statistics Handbook 1991.*[2] Included in this handbook are procedures for estimating average performance from a sample, estimating variability of performance for a sample, comparing two or more samples with respect to average performance or variability of performance, characterizing the functional relationship between two variances, and comparing samples with respect to discrete classifications such as income, mode of travel to work, etc. Other excellent references are given at the end of this Appendix. Since most of the specific equations to be employed in dealing with these situations are clearly presented in Natrella and other commonly used statistics reference books, the remainder of this section will be devoted primarily to a discussion of some of the statistical considerations for the evaluator.

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[2] The evaluator is encouraged to obtain a copy of this book, since it is referenced throughout this section of the guidelines as a source for tables, equations and other materials. It is available through the National Technical Information Service, publication number PB93-196038INZ, NTIS sales desk by phone: 1-800-553-6847 (703-605-6000) or by Internet: http://www.ntis.gov/support/orderingpage.htm.

Of the numerous cases presented in Natrella, the following basic set of underlying questions is considered applicable for BRT projects:

If estimates of population parameters only are required:

- What is an estimate for the average value (mean) of the measure?
- What is an estimate for the variability (variance or standard deviation) of the measure?
- What is an estimate of the proportion of units that have a given characteristic?

If comparisons between two groups (e.g., before versus after, test versus control) are involved:

- What is the difference between the average value of the measure, X, for group A and the average value of the measure, X, for group B?
- What is the difference between the variability of the measure, X, for group A and the variability of the measure, X, for group B?
- What is the difference between the proportional measure, X, for group A and the proportional measure, X, for group B?

The same types of questions can be asked when there are more than two groups (for example, time periods) involved in the comparisons. Here, however, the methods for analysis become more complex, and greater care must be exercised in selecting and applying statistical techniques.

In connection with addressing the question "What is the value...?" or "What is the difference...?", it is recommended that results be given in terms of two-sided confidence intervals. By determining a confidence interval (an interval which contains the true parameter, or difference between two parameters, with a known probability), the decision-maker can interpret with more confidence the significance of an estimate of a population parameter or a difference between two parameters.

SAMPLE SIZE DETERMINATION

As long as appropriate sampling methods are applied, the accuracy of a statistic computed from a sample will be greater with a larger sample size. However, this relationship can be one of diminishing returns for very large sample sizes. Moreover, there is a cost, in time and money, which serves as a constraint on sample sizes in each BRT project. The key aspect of sample size determination is finding the proper balance between desired accuracy and cost: on the one hand, the sample should not be so small that the results lack the required accuracy; conversely, the sample should not be wastefully large.

In Chapter 6, variable stratification (the categorization of collected data by such factors as time of day) was discussed. It was mentioned that the data collection activities should be planned with the finest level of stratification consistent with constraints of time, cost, and acceptable accuracy and confidence. For example, if means are needed for trip phase by time of day by season, then sample sizes should be determined for each combination of trip phase, time of day and season. It is important that this determination of desired level of stratification be made as early as possible, since, from the statistical point of view, the sampling plans must include sufficient data in each category of interest for which cross-tabulations are to be performed. The formulas for determining sample size must be applied with respect to each category, so that the appropriate quantity of data is collected for each one. Clearly, an attempt at further stratification after the data have been collected would reduce the accuracy and/or confidence associated with these new sub-stratifications.

The appropriate sample size formula depends on the type of statistical analysis to be performed. Sample size formulas applicable for calculating means, variances, proportions, etc., are given in Natrella and the references at the end of this Appendix, so the following discussion will be somewhat general. The sample size calculation process should be viewed as providing input for the broad scoping and planning of the data collection effort. The specific sample size values obtained from the formulas should be taken as rough indications of lower limits for data collection, rather than as precise targets or cut-off points. Prudent expansion factors based on expected response rates should be applied to the calculated sample size values so that the ultimate amount of usable data (i.e., the net sample size after the collection activities and editing) is sufficient to yield results with the desired level of precision and statistical accuracy, and allows for unforeseen stratification. As data are collected, it should be possible to modify sample requirements for subsequent phases of a project.

As has been mentioned earlier, it is desired to have results presented in the form of confidence intervals. Determining the sample size for calculating a confidence interval requires three input factors:

1. The desired confidence level,
2. An estimate of the variability in the population, and
3. The desired precision of the results.

The confidence level of a statistical calculation $(1 - \alpha)$ can be defined as the proportion of samples of size n for which the calculated confidence interval may be expected to contain the true value of the population parameter being estimated. For purposes of obtaining a sample size estimate, it is recommended that the value $\alpha = .05$ be used. A more conservative sample size (i.e., bigger) would be obtained using the value $\alpha = .01$.

An estimate for variability is usually taken as the standard deviation. It is desirable initially for this value to be an overestimate to allow for a conservative determination of sample size. While it is preferable to have some prior knowledge about the variability of those measures to be collected, Natrella gives an excellent approach for cases where the true standard deviation is unknown.

Determination of an acceptable level of precision is perhaps the most difficult input factor. In the case of estimating means, variability measures, and proportions, the task is to determine the acceptable accuracy[3], say d, for each confidence interval. The sample

[3] "Accuracy " refers to the half-width of the confidence interval. If a confidence interval is expressed as the estimate plus or minus d, then "d" represents the accuracy of the estimate in this discussion.

size calculated on the basis of a prescribed d and $\alpha = .05$, reflects an acknowledged (permissible) risk that 5 times in 100 the real precision will be worse than d. In the case of estimating the difference between means or between other statistics, the analogous task is to specify the absolute value of a minimum desired detectable average difference b. Here, too, if $\alpha = .05$, then the sample size will reflect an acknowledged risk that 5 out of 100 times the true difference between the two groups being compared will exceed b.

In establishing values for d and α, consideration must be given to the problem of trading off the cost versus benefits of increased precision. The cost of increased accuracy can be seen as the marginal amount of time and money needed to collect an additional sample unit. The benefits of increased accuracy can be viewed in terms of additional confidence in the results of a particular project and the consequent willingness of FTA to make policy and funding recommendations on the basis of these results. Clearly, FTA does not want to encourage cities to implement BRT innovations which have only a negligible impact on the quality or usage of transit service; this would argue in favor of setting relatively large values of d and α. On the other hand, there is a desire to learn whatever possible about the effects of implementing new techniques; if the minimum detectable difference is set too large, the resultant sample size may be too small to detect the existence of minor, possibly unanticipated changes which might be of interest.

Working with FTA, the evaluator should indicate the value of d or α selected for each measure to be collected, and should explain the rationale for choosing the particular value in terms of the cost-benefit considerations discussed above. Issues concerning sample size determination and precision are discussed in *Sampling Techniques*, by W. G. Cochran, and other references at the end of this Appendix.

DATA COLLECTION

Once the minimum sample size for each stratification category of each sampled measure has been determined using the appropriate formula and the above three prescribed input factors, the data collection phase can be implemented. As was mentioned above, the evaluator should apply a prudent expansion factor based on the expected number of non-respondents to the minimum sample size to obtain a target sample size.

Field observations should be scheduled for a sufficient number of days to collect the target quantity of sample units. In most cases, the scheduling of data collection will present no particular problems: the required number of "representative" days can be designated, as well as alternate dates to be used in the event of unusual weather conditions or other atypical occurrences on the planned dates. However, there may arise a situation where the day-to-day variability is known or suspected to be significant in relation to the variability within a day. In this case, arbitrary spreading of the data collection phase over several consecutive days may adversely affect the inferences to be made. Depending upon the project objectives, it may be more appropriate to schedule data collection for consecutive weeks on a particular day of the week (the most representative day).[4]

ANALYSIS METHODS

Since numerous statistical methods are available, the balance of this Appendix discusses a family of statistical techniques appropriate for project analyses. The measures can be classified as discrete or continuous. A discrete measure is one that assumes only a fixed and known set of values. Examples of such measures would be passenger counts, responses to qualitative questions, and classifications of survey responses into categories such as "yes/no." Continuous measures may assume (in theory) an infinite set of values. The accuracy of these measures is constrained only by instruments used in collecting the data and the errors inherent in the data collection methodology. Examples of continuous measures are travel time and vehicle speeds.

Depending on the type of measure being collected, one or more of the following statistics may be obtained:

1. Averages (mean values),
2. Standard deviations (variances),
3. Ratios, proportions,
4. Ranges for the raw data, and
5. Frequency distributions of the raw data.

In addition to these five basic statistics, past experience on several FTA projects indicates the importance of the more complex measures such as the coefficient of variation, namely, the ratio of the standard deviation to the arithmetic mean, and statistics associated with multivariate analysis, such as the coefficients of determination, standard errors, and "t" statistics. The evaluator should be alert to the potential use of other statistical measures in the analysis of project data.

Confidence intervals will be computed for differences between means and proportions and for ratios of variability measures. The procedures for calculating confidence intervals on ratios of means and other ratios will not be given here, due to the complexity of the mathematical formulas.

Actual calculations of confidence intervals depend usually on four elements: (1) the sample statistic being used to estimate the population parameter (defined above); (2) some measure of variability associated with this statistic (e.g., the sample standard deviation); (3) the confidence level; and, (4) the sample size.

Commonly used confidence levels have 99 percent and 95 percent probabilities associated with them. These correspond to $\alpha = .01$ and $\alpha = .05$. It is recommended that

[4] The preceding discussion deals with day-to-day variability with a known pattern. In the unusual situation of day-to-day variability which exceeds within-day variability and does not follow a particular pattern, the target sample size must be calculated according to different procedures, which give a number of sample days as well as a number of samples per day.

the evaluator compute and report confidence interval estimates based on both values of α. This allows the decision-maker to assess both intervals and to determine which risk level is acceptable. (Note: For $\alpha = .05$, while there is a 95 percent chance that the method employed will contain the true value of the parameter being estimated, there is also a 5 percent chance that the intervals will not contain this true value).[5]

It should be noted that the sample size, "n," which should be used in computing confidence intervals is the actual number of sample observations made, which, in most cases, will be different from the number originally planned.

Appropriate methods of analysis are now described in terms of discrete and continuous measures. It is implicit in any analyses performed using inferential statistical methods that the reasonableness of assumptions will be tested, for example, normality. If the data being collected can be classified as discrete, the following techniques may be used:

1. Confidence intervals on a sample proportion to estimate the true population proportion. The appropriate techniques here will be to use either the binomial distribution or the normal distribution, depending primarily upon the sample size.
2. Confidence intervals on differences between two proportions. In this situation, the appropriate methodology is again to use the binomial distribution or normal distribution, depending on sample size.[6]

If the data element being collected during the project can be classified as continuous, then appropriate methodologies which can be used are:

1. Establishing confidence intervals on sample mean values to estimate population mean values. The appropriate methodology will involve the student's "t" distribution.
2. Establishing confidence intervals on sample mean differences. The appropriate methodology will be to use the student's "t" distribution.
3. Determining whether differences observed from more than two sample mean values can be classified as significant. The appropriate methodology here would involve use of the F distribution and the analysis of variance, coupled with the application of appropriate linear contrasts techniques.
4. Establishing confidence intervals on a single variance. The appropriate methodology will be chi-square.
5. Establishing confidence intervals on ratios of variances. The appropriate methodology will be the F distribution.[7]

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[5] It should be noted that while the use of confidence intervals is required, the evaluator may apply statistical tests of significance, where appropriate.

[6] When appropriate, other methods, such as chi-square, may be used to assess significance of differences in discrete classifications where there are more than two alternatives.

[7] For more than two variances, tests of significance rather than estimating confidence intervals may be appropriate.

METHODOLOGY DOCUMENTATION

The evaluator shall document and explain all considerations in data analysis and sample size selection for each measure including:

- how variability was estimated,
- rationale for the desired level of precision chosen, and
- how the final sampling plan was established to ensure that an adequate sample size would be available for analysis

In addition, the method planned for performing all statistical calculations and tests should be documented by reference to the appropriate equations and tables in Natrella or other reliable sources.

REFERENCES

The following are considered to be excellent references for statistical methods:

- Cochran, W.G., *Sampling Techniques*, John Wiley & Sons, Inc., New York, 1977.
- Moore, David S. and George P. McCabe, *Introduction to the Practice of Statistics*, W.H. Freeman & Co., New York, 1998.
- Natrella, M.G., *Experimental Statistics*, National Bureau of Standards Handbook 91, U.5. Government Printing Office, Washington, D.C., 1966.
- Snedecor, G.W. & W.G. Cochran, *Statistical Methods*, The Iowa State University Press, Ames, Iowa, 1989.

All but Natrella may be purchased at most university book stores or through Amazon.com. See the footnote for purchase information on Natrella.

APPENDIX B

SURVEY EXECUTION AND DESIGN

It is anticipated that the evaluation of every BRT demonstration will require data that can be obtained only from surveys, and will therefore require some form of survey data collection. Among the possible survey respondents are BRT service users, auto users, and service area residents who do not use transit. Typical survey objectives might include: determining user and non-user characteristics, attitudes toward transit service, and past and present travel behavior; and measuring modal shift. Although the specific contexts in which the surveys are conducted may differ, there is still a need for consistency of procedure in survey design and data collection to insure comparability of results.

In surveys, the researcher is collecting data from real life situations, which means that many unanticipated, spontaneous, and unusual situations will arise. To compensate for the survey researcher's lack of control of the experimental situation, the need for consistency and the establishment of general policies or guidelines to handle a great variety of possible developments is most important.

This Appendix contains guidelines for use in formulating and carrying out surveys. It discusses how to define the populations to be sampled (i.e., the survey universes), describes how to select samples that will be representative of that universe, examines techniques for surveying the samples selected, presents suggestions as to survey content and format (including a list of standardized questions and, in some instances, standardized responses to serve as a basic set for most surveys), and discusses the problem of non-response bias.

It should be stressed that this Appendix presents no hard and fast rules, but merely guides the evaluator in designing and executing surveys. In determining survey methodology, the evaluator should consider potential alternatives and give the rationale for decisions made in terms of the survey objectives, site characteristics, and any other relevant factors that have influenced the decision.

It should also be noted that the typical limited budget for a demonstration evaluation would likely preclude the evaluator from conducting these types of surveys, although the transit operator may be able to provide resources for a user survey, and often does conduct one as a matter of course. Nevertheless, the survey guidelines are presented for those fortuitous circumstances that would support survey research, for the information they provide is invaluable to understanding the effects of a BRT system.

DEFINING THE SURVEY UNIVERSE

The first step in executing surveys is to define the survey universe (i.e., the groups about which the surveys are seeking knowledge). It is apparent that knowledge about BRT service users' travel behavior, characteristics, and attitudes toward transit is needed in an evaluation of BRT service. Further, an evaluation of BRT service will usually not be complete without some data on non-users, particularly to identify who they are and why they do not use the service. Accordingly, there are two survey universes that are relevant for BRT demonstrations: users of the BRT service, and non-users of the service. Users are defined as those who ride this service at least occasionally but still on a regular basis, e.g., regularly twice a month. Non-users, or potential users, are defined as those using alternate modes (i.e., other than the BRT service) who make trips that could be made on the BRT service.

Occasionally, there will be a third survey universe of interest, the general population of the region in which a BRT demonstration is being implemented. Attitudinal surveys of this universe will be used to obtain a profile of the community in which the BRT service is being provided. It should be apparent that many of the questions asked users, non-users, and the general population will be different.

Definition of the BRT service area allows a more precise definition of non-users and the general population. The BRT service area is defined as the area that comprises on the order of 90 to 95 percent of the origins and destinations of the users of the service. Since non-users are potential users, the origins and destinations of non-users should be comparable to those of users. Non-users can now be defined as persons not using BRT who make trips that begin in the origin portion of the service area and end in the destination portion of the service area at the same times as BRT users make these trips. The general population in the region of the BRT demonstration can now be defined as the population residing within the service area.

The BRT demonstration service area may not be well defined at the outset of the project and must initially be estimated. At the other extreme, in projects in which park-and-ride is a significant access mode, it may be impossible initially to estimate the service area accurately. A conservatively estimated area that includes all possible park-and-riders would have to be initially defined as the origin portion of the project service area. Once survey data on the origins of park-and-riders is obtained, a more accurate estimate of the service area can be made, and non-users can then be identified.

SAMPLING THE SURVEY UNIVERSE

The next step in executing surveys is selecting an appropriate sample for surveying users, and, where applicable, selecting appropriate samples for surveying non-users (potential users) and the general population.

The purpose of sampling is to reduce the amount of data collection required. Rather than obtaining information from every member of the universe, the principles of sampling provide ways to obtain information from a very small portion of the universe. Sampling procedures also indicate the accuracy with which the characteristics of the universe have been represented.

A key assumption in sampling is that, prior to drawing a sample, the complete universe has been identified. Therefore, every member of that universe has a known probability of being selected for inclusion in the sample. The quality, or representativeness, of any sample is directly derived from the completeness of the identification of all members of the designated universe.

For these reasons, careful definition of the universe and selection of a source from which to draw a sample is very important. If the listing of the universe, or the sampling source, is biased through failure to include all members, whether deliberate or random, the sample may magnify the bias and may not represent the universe.

A sample of users can be selected from among those onboard the transit vehicles or among those at transit collection points (i.e., stations), park-and-ride lots, or transfer points. Selecting a sample of non-users (or potential users) is considerably more involved than it is for users. While the user group is identifiable (and can be directly sampled), the non-user group cannot explicitly be identified before it is sampled. A larger group must first be sampled, and then the trip origins and destinations of the survey respondents[8] examined in order to identify non-users (i.e., those whose trip origins and destinations are within the project service area). A definition of the BRT service area (as previously discussed) is a prerequisite for identifying non-users.

In a project in which travel by users and non-users is in a specific direction through a corridor; non-users, specifically auto users, can be sampled from license plate matches. A screenline is selected which intercepts the main arterials carrying autos between the origin and destination portions of the BRT service area. A sample of the license plate numbers of the autos crossing the screenline is recorded and a list of names and addresses of the owners of these autos is obtained from Department of Motor Vehicle records. This list (or a subset of this list) constitutes a sample in which a large percentage are BRT non-users. Some of those crossing the screenline do not make trips that begin and end in the BRT service area, and are, therefore, not non-users. However, the entire sample must be surveyed because it is not known who the non-users are until the trip origins and destinations of all those in the sample who completed their surveys are examined. In certain very specific cases, samples can be selected directly from the traffic stream (e.g., at toll booths, at off-ramps, or from among carpoolers assembling at parking lots).

In demonstrations where travel by users and non-users is not in a specific direction nor through a corridor, the non-user universe cannot be sampled using the above methods. In such cases, a sample may be drawn from households in the origin portion of the particular BRT route's service area. Lists of households from which to select a sample could be obtained from utility records, insurance company records, census block statistics, telephone books,[9] property tax records, etc. Many of the people in these households do not make trips ending in the destination portion of the BRT route service area, and are, therefore, not considered potential users. As previously discussed, the entire sample must

[8] This information is requested in the survey.

[9] Where the telephone book is used as the sampling source, there is considerable danger of obtaining a biased sample. Many households choose to have unlisted telephones. Also, lower income people are less likely to have telephones, as are residents of boarding houses.

Random digit dialing not only poses potential bias problems but also will be costly because business and non-residential phones will be selected.

still be surveyed because the non-users (potential users) cannot be identified until after the entire sample is surveyed.

If the preceding method is used for obtaining a sample of non-users, it should be noted that the households selected constitute a sample in which a moderate percentage of the people are users. It may be desirable to identify users before they are surveyed (by asking all those sampled if they are users) in order to ask them questions pertaining to their use of the BRT service.

In all samples of households, an attempt is made in each household to survey only that individual in each household who makes a trip ending in or near the destination portion of the BRT service area.[10] More than one household member is surveyed only when more than one makes this type of trip.

Where a sample of the general population of a region is needed, the sample will always be selected from among the households in the BRT service area. Again, lists of households can be obtained from utility records, insurance company records, telephone books, census block statistics, etc.

Regardless of the methods chosen for selecting samples of both users and non-users (and possibly of the general population), every effort should be made to assure that samples selected are unbiased and large enough for the desired statistical confidence. Such an approach involves estimating the percent of persons surveyed who are in the universe (i.e., who make applicable trips in the BRT service area), estimating the response rate, and developing a random selection process that aims at the desired number of samples.[11]

In developing a random selection process to sample users' onboard vehicles, examination of vehicle operating schedules and recent passenger counts, if available, will be necessary to design where and when to select the vehicles on which to sample users. However, the following sources of bias in vehicle operating schedules must be considered when deciding on a particular schedule for developing a sampling source: (1) unscheduled vehicle runs, most likely to occur during peak hours, and therefore with high passenger loads; (2) schedule delays, breakdowns, and accidents, also most likely to occur during peak hours when there are high load factors; and (3) the occurrence of external influences on ridership in the interim, such as a strike among people who might have formerly used this mode of transportation, the opening of a new shopping center or school along the route, or unique events such as a concert. These sampling hazards should be kept in mind and some attempt should be made to build corrections into the research design to compensate, such as oversampling on certain routes.

In many situations, developing a random selection process that obtains the desired sample size simply involves selecting every I^{th} person going past a given point, or every J^{th} person on a list of users of a given system, or every K^{th} person on a list of employees at a given location, or recording the license plate number of every L^{th} auto going past a given

[10] This comment is also applicable to surveys that are sent to registered automobile owners whose names were obtained from license plate matches.

[11] See Appendix A for a discussion of sample size determination.

point. To obtain a random sample of the households in the origin portion of a project service area, every M^{th} household on a list of all of the households in the area could be selected; or the random clustered household sampling method could be used. This method divides the origin portion of the BRT service area into smaller areas (usually blocks) of approximately equal population and randomly chooses a sample of the resulting clusters in which every household in each cluster is a part of the sample.

The possibility of sampling bias occurring through use of a particular sampling method should not rule out its use. That sampling method may be very appropriate in certain demonstration evaluations. However, where little can be done to minimize the effect of bias, other sampling methods should be considered.

For each survey required for a particular evaluation, the evaluator must carefully describe the universe to which survey research findings will be generalized and identify the most complete enumeration or sampling source available for that universe. Actual selection of a sampling source must be justified in terms of its complete coverage of the affected universe and also in light of the survey objectives.

TECHNIQUES FOR SURVEYING THE SAMPLES SELECTED

The final step in executing a survey is determining what techniques are applicable for surveying the samples that have been selected. There are five basic techniques for surveying these samples:

1. Self-administered questionnaires handed out by individuals (e.g., survey takers, bus operators, personnel at employment or activity centers), and collected by individuals (not necessarily the same individuals who handed out the questionnaires).
2. Self-administered questionnaires handed out by individuals and returned by mail.
3. Self-administered questionnaires given out by mail and returned by mail.
4. Face-to-face interviews.
5. Telephone interviews.

A summary of the applicable techniques to be used with each possible sampling method is shown in Table B-1.

With all of these techniques, the greater the amount of personal contact between user and survey takers, the higher the response rate and the quality and detail of the responses. However, the greater the amount of personal contact, the higher the cost.[12] In fact, the face-to-face interview initiated at homes, while eliciting the highest response rate, is generally too costly to be considered in the evaluation process. It should only be used in conjunction with the random clustered household sampling method, where the number of personal home interviews to be conducted is small and covers a small area.

[12] In choosing a survey technique, careful attention should be paid to costs associated with the data processing and analysis of survey findings.

Table B-1. Summary of Survey Sampling Methods and Applicable Survey Techniques

Sample Population	Sampling Method	Survey Technique	Where Surveys Are Distributed	Where Surveys Are Completed
Users	Passengers on transit vehicles	A	Onboard transit vehicles	Onboard transit vehicles
		B	Onboard transit vehicles	In homes or onboard transit vehicles
		D	Onboard transit vehicles	Onboard transit vehicles
Users	Passengers at transit collection points	A	At transit collection points	Onboard transit vehicles
		B	At transit collection points	In homes or onboard transit vehicles
		D	At transit collection points	At transit collection points
Users	Passengers from service registration lists	C	In homes	In homes
		D	In homes	In homes
		E	In homes	In homes
Users, Non-users	People at specific employment or activity centers	A	At activity centers	At activity centers
		B	At activity centers	In homes
		D	At activity centers	At activity centers
Users, Non-users	Autos crossing a screen line -- selected by license plate matches	C	In homes	In homes
		E	In homes	In homes
Users, Non-users	Autos crossing a screen line -- selected directly from traffic stream	B	At toll booths or sides of roads	In homes
Users, Non-users	Households in the origin portion of the project service area selected directly from traffic stream	C	In homes	In homes
		D	In homes	In homes
		E	In homes	In homes
General Population	Households in the BRT service area selected directly from telephone listings, census data, etc.	C	In homes	In homes
		D	In homes	In homes
		E	In homes	In homes

Codes for Survey Technique:

A: Self-administered questionnaires handed out by individuals and collected by individuals (not necessarily the same ones as handed out the questionnaires)
B: Self-administered questionnaires handed out by individuals and returned by mail
C: Self-administered questionnaires mailed out and returned by mail
D: Face-to-face interviews
E: Telephone interviews

By significantly decreasing the area in which a given size sample lies, the cost of using personal home interviews is reduced.

Where a self-administered questionnaire is used to survey a sample, the response rate will inevitably be lower than where a face-to-face or telephone interview is used. To improve the response rate it may be desirable to allow for a wave of follow-up procedures, such as phone calls and postcard follow-up.

Generally, the self-administered questionnaire is the most easily conducted and most cost effective survey technique. Self-administered questionnaires initiated onboard or at collection points are most widely applicable. If the questionnaires are short enough to be completed by all users while they are onboard and there are few standees, the users should be instructed to complete the questionnaires while onboard and return them as they leave the vehicle. If the questionnaires are initiated onboard and the number of vehicles on which users are surveyed is not large, consideration should be given to stationing survey takers onboard each vehicle to hand out and collect the questionnaires, give instructions, and answer any questions. If the questionnaires are initiated at collection points and the number of points at which users exit their vehicles is small, consideration should be given to stationing survey takers at the exit points to collect the questionnaires. The additional expense incurred with this degree of personal contact generally pays off (i.e., the response rate is high and the cost per completed survey is low).

Where self-administered questionnaires are too long to be completed by all users while they are onboard or where there are many standees, questionnaires that are to be mailed back should be used. The response rate for a mail back questionnaire will be considerably lower than for a questionnaire completed onboard. This should be kept in mind when developing the sampling techniques.

When questionnaires are sent by mail, a cover letter giving instructions and explaining the purpose of the survey should accompany each questionnaire as should a self-addressed, stamped envelope for mailing back the completed questionnaire. It would also be advisable to send out "follow-up" letters a few days after the questionnaires are sent out as a reminder to complete the questionnaires.

There are situations where it is advantageous to conduct personal interviews of users on board vehicles or at employment or activity centers rather than to have these users complete self-administered questionnaires.[13] Where the total user population to be surveyed is small, a high response rate may be needed to obtain the desired statistical confidence. In such a situation, a self-administered questionnaire may not obtain a high enough response rate, while personal interviews of users onboard vehicles would. Where there may be considerable misgivings about answering a self-administered questionnaire, as on a crowded bus or train in some parts of some large cities, personal interviews conducted onboard vehicles may be the only means of obtaining an acceptable response rate. Where the users are asked about concepts or behavior that are somewhat complex, a

[13] When surveying users at collection points, there generally is not enough time to question them by personal interview.

personal interview will be much more effective than a self-administered questionnaire in eliciting usable responses. Handicapped and elderly users may have difficulty writing and it may be difficult for them to respond to a lengthy self-administered questionnaire. It should be noted, however, that personal interviews are relatively expensive and labor intensive.

Where samples are selected from service registration lists, users can be sent self-administered questionnaires by mail. Where it seems that a very low response rate would be obtained with the mail back questionnaire, or where a high response rate is necessary, the telephone interview would be superior. Moreover, sampling bias would be minimized because all of the users' telephone numbers would be known from the registration lists.[14]

For surveying non-users, no single technique is widely applicable. Where a sample of auto users crossing a screenline is surveyed, questionnaires could be sent to the auto drivers by mail (from license plate matches) or these same auto drivers could be interviewed by telephone; or auto users selected directly from the traffic stream could be given questionnaires to be returned by mail. For example, where autos are selected by license plate matches, auto occupancy would be recorded along with license plate number, and mail-back surveys mailed out according to auto occupancy. Those who drove alone would be mailed one form; carpool drivers would be mailed a set of different forms — a carpool driver form for themselves, and carpool passenger forms to be given to those who rode with them.

In some projects, where autos are also selected by license plate matches, the owners of the observed autos are surveyed by telephone interview. No carpool passengers are surveyed in this fashion. Carpool passengers can be surveyed directly from the traffic stream. In one situation, many carpoolers assembled at a parking lot designated partly for that function. Before each carpool left the lot, each member of the carpool was given a self-administered questionnaire to be mailed back.[15]

Where a sample of households in the origin portion of the BRT service area, which includes non-users (and users), is surveyed, no single survey technique is widely applicable. Questionnaires could be sent to those households by mail to be returned by mail, telephone home interviews could be conducted, or personal home interviews could be conducted where the sample is selected using the random clustered sampling method.

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[14] It should be noted, however, that it will not be possible to contact all the persons in the telephone survey sample within the survey time frame. Those not contacted may be a non-random group, with the result that those who are actually interviewed by telephone may no longer be representative of the universe. Therefore, great care must be exercised when sampling by telephone interview.

[15] Some carpool drivers might have been surveyed twice if their license plates had been recorded.

SURVEY DESIGN PRINCIPLES

It is apparent that, because different surveys are directed at different survey universes using different sampling sources and different techniques, surveys will vary in content and length. Nonetheless, all surveys should have the same basic organization, sequence, and wording of standardized questions. This section presents basic principles on survey organization, length, question sequence and wording, and standardized questions that should be followed in designing the survey instrument.

Organization

There should be four elements in all surveys, whether user or non-user. They are in order of their appearance in a survey:

1. *Introduction* - a brief statement of the survey's purpose and potential utility, with a guarantee of the respondent's anonymity. It will be verbally delivered if an interview technique is selected, or will be printed at the beginning of a self-administered questionnaire.
2. *Behavioral and attitudinal measures* - the set of questions specifically measuring the survey's objectives, such as modal shift, satisfaction with level of service, etc.
3. *Social and demographic measures* - measures of the respondent's characteristics which are important in interpreting responses to behavioral and attitudinal measures. Transition to this section of a survey needs to be prefaced by either a verbal or written explanation, as appropriate, such as "Now we need to know a little about you...."
4. *Closing statement* - a brief expression of thanks to the respondent for participating, with some indication of the importance of the eventual utilization of his or her responses, and a request for any additional comments or observations from the respondent.

Length

The overall length of the survey depends on the particular objectives of the survey and the survey techniques used. In general, surveys completed on transit vehicles should be shorter than surveys completed at home, since they are being administered to respondents in a less comfortable environment.

Self-administered questionnaires that are handed out should be limited in length to one side of a sheet of paper or a large postcard. Surveys to be completed on board transit vehicles whether in interview or self-administered format should be shorter than surveys which can be filled out at the respondent's convenience and returned by mail. Moreover, they should be short enough so as not to delay the respondent in his or her trip or current activity.

The length of surveys completed in the home varies depending on the method of administration. Telephone surveys should be fairly short, since it is difficult to retain a respondent's attention for a long period given the impersonal nature of the contact. Self-administered mail-back questionnaires sent by mail can be longer than self-administered mail-back questionnaires handed out because there is more opportunity to enlist the respondent's cooperation. However, mail-back questionnaires given out by mail should not be as extensive as personal interviews conducted in the home, since the personal contact that might encourage longer attention/cooperation span on the part of the respondent is lacking.

Question Sequence and Wording

There are several general principles describing question sequence and wording that apply to all questions. First, questions should be arranged logically to lead the respondent into the frame of reference of the issue under study. It is recommended, following the introductory material, to begin the questionnaire or interview schedule with behavioral or attitudinal measures of responses to transportation alternatives because these relate most closely to the announced purpose of the data collection effort. Social and demographic data should be collected near the end of the survey instrument, reserving any questions about income as near to the end of the survey as possible.[16]

Questions should be as short as possible and in clear, concrete language. Visual format is also important. In self-administered questionnaires, it enhances the respondent's likelihood of completing the form, and in interview format surveys, it makes the interviewer's task faster and easier. Questions should be laid out in a fashion that ensures ease of coding and processing responses and appears attractive at the same time. Fill-in questions should be avoided where possible, because they often are difficult to code. Where they are used, responses should be anticipated and precoded to reduce costs and enhance consistency. Coding blocks can be left at one side of the survey form and the field editor can check to insure that the information is transferred. This procedure makes the survey also function as a code sheet.

The survey should be checked to ensure that it is as parsimonious and logical as possible. There are several ways to do this. First, every question ought to be evaluated to ensure that it contains a measure related to one of the specific project objectives.[17] Second, advance planning of the data analysis, through the construction of dummy tables, will ensure that every variable measured contributes to the eventual data analysis. Finally, pretesting of the survey instrument will identify any questions that, because they are confusing to the respondent or of limited use in the evaluation, should be changed or omitted. Pretesting has even more far-reaching benefits. It will uncover any procedural problems that may arise during the survey process and reveal any problems that are

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[16] Measures of income are the most difficult to obtain accurately and arouse the greatest resistance in the respondent. Sometimes a respondent is asked to point to an amount on a card or circle an approximate amount to lessen the resistance. However, these items arouse such resistance that they must be at the end of the data collection instrument so the hostility produced will not destroy the rest of the data collection.

[17] There are several exceptions to this guideline. One is the deliberate use of one or two meaningless questions in order to lead the respondent into a particular frame of reference. This is frequently necessary when seeking information on embarrassing, unusual, highly specific or complicated issues. This technique will increase the validity of the data subsequently collected. A second exception is measuring respondent's opinions of service features that have not changed as part of a set of questions about respondents' reactions to improved service features. This combination of questions will measure if a "halo effect" exists in terms of respondents' overall positive evaluation of the mode when only several aspects have been changed.

particularly characteristic of urban areas, such as a sizable number of functional illiterates or foreign-speaking respondents who cannot complete a self-administered questionnaire or a systematic refusal to participate by some sectors of the population. The pretest of the survey form must be conducted with respondents as identical to the proposed survey respondents as possible without contaminating the sampling source.

Finally, all survey questions should be checked against the provisions of the *Privacy Act of 1974, as amended* to verify that none of the questions violates any person's right to privacy as spelled out in the Act. It is recommended that the evaluators familiarize themselves with the provisions of the Act.

Standardized Questions

It will be useful to ensure that the data collected in different evaluation projects is consistent in format. Fostering consistency means that an economical amount of data will yield a maximum amount of information. Secondly, consistency facilitates comparisons among demonstration projects, generating a more universally applicable understanding of the responses to transit innovations. Finally, and most importantly, developing consistent data collection categories based on the U.S. Census will mean that results of any survey can be corrected for sampling error and potentially extrapolated to any other area. This section discusses standardized formats for measuring behavioral, attitudinal, and social/demographic characteristics.

Behavioral Measures

Selecting questions to measure travel behavior is very much influenced by the objectives of a particular survey. Some general suggestions regarding ways to collect and code such information to increase consistency among surveys will be described.

The following measures of travel behavior are most likely to be asked in almost every survey: transit vehicle boarding and alighting points (user surveys only), trip origin and destination (all described in terms of addresses), trip purpose, and trip start and end times. Additional frequently collected data for surveys includes access mode to transit vehicle, when the present mode was first used for this particular trip, the former mode used for this particular trip (with some attempt to control for external influences, such as a residential move), reason for switching mode, fare (user surveys only), tolls and parking cost (potential user surveys only), frequency of use, access time at origin and destination (user surveys only), availability of mass transit alternatives, back-up mode, and number of transfers required (user surveys only).

Figure B-1 contains examples of bus, automobile driver, and automobile passenger surveys. These exhibits, together with the preceding discussion, indicate the possible range of information that can be collected on travel behavior. Clearly, the determination of particular items to include in a survey depends on the survey objective, desired survey length, and circumstances under which the survey is conducted. Furthermore, the specific wording of the questions relating to travel behavior depends on the method of administering the survey and the overall tone of the survey and sequence of questions.

Figure B-1. Sample Survey Forms

On-Board Bus Survey

KATY TRANSITWAY TRANSIT USER SURVEY

This survey is being undertaken by the Texas Transportation Institute, the Texas State Department of Highways and Public Transportation and METRO in order to obtain information about your use of the Katy Transitway. Please take a few minutes to answer the questions below and return this form to the survey taker before leaving the bus.

1. **What is the purpose of your bus trip this morning?** ___Work ___School ___Other
2. **What is the Zip Code of the area where this trip began?** (For example, if this trip began from your home this morning, you would list your home Zip Code.) ____________
3. **What is your final destination on this trip?** ___Downtown ___Galleria/City Post Oak/Uptown ___Texas Medical Center ___Greenway Plaza ___Other (specify Zip Code____________)
4. **Have you ever carpooled or vanpooled on the transitway?** ___Yes, carpooled ___Yes, vanpooled ___No
5. **How important was the opening of the Katy Transitway in your decision to ride the bus?**
   ___Very important ___Somewhat important ___Not important
6. **If the Katy Transitway had not opened, would you be riding a bus now?**
   ___Yes ___No ___Not sure
7. **How many minutes, if any, do you believe this bus presently saves by using the Katy Transitway instead of the regular traffic lanes?** ________Minutes in the morning ________Minutes in the evening
8. **How long have you been a regular bus rider on the Katy Transitway?** ____________________
9. **Does your employer pay for any part of your bus pass?**
   ___Yes, my employer pays $________ toward the cost of my bus pass and I pay $________.
   ___No, I pay the entire amount
10. **Was a car (or other vehicle) available to you for this trip? (check one)**
    ___No, bus was only practical means
    ___Yes, but with considerable inconvenience to others
    ___Yes, but I prefer to take the bus
11. **Before you began riding a bus on the Katy Transitway, how did you normally make this trip? (check one)**
    ___Drove alone
    ___Carpooled
    ___Vanpooled
    ___Rode a park-and-ride bus on the regular freeway lanes
    ___Rode a regular route or express bus
    ___Did not make this trip prior to using the Katy Transitway
    ___Other (specify____________________)
12. **Do you feel that the Katy Transitway is, at present, being sufficiently utilized to justify the project?**
    ___Yes ___No ___Not sure
13. **What is your . . .** **Age?**______ **Sex?**________ **Occupation?**____________________
14. **What is the last level of school you have completed?** ____________________

Comments:____

____

____

____

THANK YOU FOR YOUR COOPERATION.

Figure B-1 (continued)

Carpool/Vanpool Survey

METRO

Metropolitan Transit Authority
500 Jefferson Street
PO Box 61429
Houston, Texas 77208-1429

713 739-4000

Dear Carpooler/Vanpooler:

Your vehicle was observed traveling eastbound on the Katy Transitway the week of September 11. Since you have first-hand knowledge of the transitway, we need your help in a special study being conducted by the Texas Transportation Institute, a transportation research agency of the Texas A&M University System. Because the Katy Transitway is one of the first transitways to operate in Texas, it is extremely important that we determine what effect it has had on your travel.

Please take a few minutes to answer the enclosed questionnaire. Your answers will provide valuable information concerning carpooling/vanpooling on the Katy Transitway. Because of the small number of poolers contacted, your specific reply is essential to ensure the success of the project. All information you provide will remain strictly confidential.

Your cooperation and timely return of the completed questionnaire in the enclosed postage-paid envelope will be greatly appreciated. Thank you for your time and assistance in this important undertaking.

METRO

Enclosures

Figure B-1 (continued)

KATY TRANSITWAY CARPOOL/VANPOOL SURVEY

Undertaken by the Texas Transportation Institute, The Texas A&M University System in cooperation with the Texas State Department of Highways and Public Transportation, the Metropolitan Transit Authority of Harris County and the U.S. Department of Transportation

1. **Is your vehicle a carpool or a vanpool?** ____Carpool ____Vanpool

2. **What is the primary purpose of your a.m. carpool/vanpool trip?** ____Work ____School ____Other

3. **How many members are regularly in your carpool/vanpool (including yourself)?** ____________________

4. **Who makes up your carpool/vanpool group?** ____Family Members ____Neighborhood friends ____Co-Workers

5. **Does your carpool/vanpool use a park-and-ride or park-and-pool lot as a staging area?**
   ____Yes (please specify which lot you typically use ____________________) ____No

6. **How long have you been a regular user of the Katy Transitway?** ____________________

7. **Which <u>transitway</u> entrance do you normally use to access the Katy <u>Transitway</u> in the morning?**
   ____I-10 West of SH 6 ____Addicks Park-and-Ride Flyover Ramp ____Gessner

8. **What time do you normally enter the transitway in the morning?** __________a.m.

9. **What is your a.m. carpool/vanpool destination?** ____Downtown ____Galleria/City Post Oak/Uptown
   ____Greenway Plaza ____Texas Medical Center ____Other (specify Zip Code__________)

10. **When did you join your present carpool/vanpool?** Month:__________ Year:________

11. **How important was the Katy Transitway in your decision to carpool/vanpool?**
    ____Very important ____Somewhat important ____Not important

12. **If the Katy Transitway had <u>not</u> opened to carpools/vanpools, would you be carpooling/vanpooling now?**
    ____Yes ____No ____Not sure

13. **Prior to carpooling/vanpooling on the Katy Transitway, how did you <u>normally</u> make this trip?**
    ____On the transitway
    ____Bus ____Vanpool ____Carpool

    ____On the Katy Freeway general purpose lanes
    ____Bus ____Vanpool ____Carpool ____Drove Alone

    ____On a parallel street or highway (Street Name____________________)
    ____Bus ____Vanpool ____Carpool ____Drove Alone

    ____Did not make this trip

14. **How many minutes, if any, do you believe your carpool/vanpool saves by using the Katy Transitway instead of the regular traffic lanes?** ________Minutes in the morning ________Minutes in the evening

15. **Do you feel that the Katy Transitway is, at present, sufficiently utilized to justify the project?**
    ____Yes ____No ____Not sure

16. **What is your . . .** Age?______ Sex?________ Occupation?____________________

17. **What is the last level of school you have completed?** ____________________

18. **What is your home Zip Code?** __________

We would appreciate your additional comments: ____________________
____
____

THANK YOU FOR YOUR COOPERATION.
Please return this form at your earliest convenience in the postage-paid envelope provided.

Figure B-1 (continued)

Freeway Motorist Survey

METRO

Metropolitan Transit Authority
500 Jefferson Street
P O Box 61429
Houston, Texas 77208-1429

713 739-4000

Dear Motorist:

Your vehicle was observed traveling eastbound on the Katy Freeway between 6:00 and 9:00 a.m. the week of October 9. Since you have first-hand knowledge of traffic conditions on the Katy Freeway, we need your help in a special study being conducted by the Texas Transportation Institute, a research agency of the Texas A&M University System.

To help serve the travel demand, the State Department of Highways and Public Transportation and the Metropolitan Transit Authority have constructed the Katy Transitway for use by buses, carpools and vanpools. Vehicles using the transitway travel inbound toward downtown in the morning and outbound in the afternoon. The Katy Transitway has been constructed within the median of the freeway and is protected from other traffic by concrete barriers. The location of the transitway in the median has not reduced the number of general traffic lanes available to motorists.

Because the Katy Transitway is one of the first transitways to operate in Texas, we need your help to determine how it is working. Please take a few minutes to answer the enclosed questionnaire. The questions on this survey concern your routine trips made on the Katy Freeway in the morning, from 6:00 a.m. to 9:00 a.m. Because of the small number of motorists contacted, your specific reply is essential to ensure the success of the project. Your answers will remain strictly confidential.

Your cooperation and timely return of the completed questionnaire in the enclosed postage-paid envelope will be greatly appreciated. Thank you for your time and assistance in this important undertaking.

METRO

Enclosures

Figure B-1 (continued)

KATY FREEWAY MOTORIST SURVEY

Undertaken by the Texas Transportation Institute, The Texas A&M University System
in cooperation with the Texas State Department of Highways and Public Transportation,
the Metropolitan Transit Authority of Harris County and the U.S. Department of Transportation

1. **What was the purpose of your trip?** ___Work ___School ___Other

2. **What are your reasons for driving your car on the freeway mainlanes rather than traveling in a high-occupancy vehicle on the transitway?**
   ___Need car for job
   ___Car is more convenient and flexible
   ___No convenient bus, vanpool or carpool available
   ___Work irregular hours
   ___Other (specify________________________________)

3. **How many days per week do you normally make this trip?** ___________

4. **How do you usually make this trip?**
   ___Drive alone ___Vanpool ___METRO regular route or express bus
   ___Carpool ___METRO park-and-ride bus ___Other (specify______________)

5. **How many people (including yourself) were in your vehicle for this trip?** ___________

6. **Which on-ramp did you use to enter the Katy Freeway for this trip?** ______________________

7. **What was the destination of your trip?**
   ___Downtown ___Texas Medical Center ___Other (specify Zip Code below)
   ___Greenway Plaza ___Galleria/City Post Oak/Uptown ______________

8. **Based on your observation of the number of vehicles currently using the Katy Transitway, do you feel that it is being sufficiently utilized?** ___Yes ___No ___Not sure

9. **Based on your perception of the number of persons currently being moved on the Katy Transitway, do you feel that it is being sufficiently utilized?** ___Yes ___No ___Not sure

10. **Do you feel that the Katy Transitway is a good transportation improvement?**
    ___Yes ___No ___Not sure

11. **What is your . . .** **Age?**________ **Sex?**__________ **Occupation?**________________

12. **What is the last level of school you have completed?**______________________________

13. **What is your home Zip Code?**______________

We would appreciate your additional comments:______________________________
____
____
____

THANK YOU FOR YOUR COOPERATION.
Please return this form at your earliest convenience in the postage-paid envelope provided.

Figure B-1 (continued)

13818

BUS RIDERS SURVEY

IF YOU HAVE ALREADY COMPLETED THIS SURVEY, PLEASE RETURN THIS QUESTIONNAIRE TO THE SURVEYOR WITHOUT FILLING IT OUT.

The purpose of the following questions is to evaluate Tri-Met's new fare collection system. Your answers will help Tri-Met understand how well the new fare collection system is working for riders like you.

Since you are part of a relatively small number of riders being surveyed, your answers are very important to the accuracy of this study. Tri-Met has hired an outside research firm to gather this information. You can be assured that the information you give is *confidential*, and will only be used in combination with the answers from other riders.

We would like you to complete the white part of the survey while on the bus and return it to the surveyor or place it in the box near the rear door. The yellow portion is to be completed as soon as possible and mailed postage free to Tri-Met.

THANK YOU FOR YOUR TIME AND HELP.

1. How many bus trips on the average do you usually take each week for each of the following trip purposes? (PLEASE COUNT EACH DIRECTION AS A SEPARATE TRIP.) (Write your answer on the line. Put "0" if none.)
   - ______ NUMBER OF WORK TRIPS
   - ______ NUMBER OF SHOPPING TRIPS
   - ______ NUMBER OF SCHOOL TRIPS
   - ______ NUMBER OF SOCIAL/RECREATION TRIPS
2. At what time do you most often ride the bus? (Circle the one number next to your answer.)
   1 WEEKDAYS: RUSH HOUR (7-9 a.m. & 4-6 p.m.)
   2 WEEKDAYS: MID-DAY (9 a.m.-4 p.m.)
   3 WEEKDAYS: EVENING/NIGHT (6 p.m.-7 a.m.)
   4 SATURDAY OR SUNDAY (ALL DAY)
3. What three bus lines do you ride most often?

   NUMBER LINE NAME

   ______ ______________________

   ______ ______________________

   ______ ______________________
4. How do you usually pay your fare? (Circle the number under the proper column.)

CASH	BUS TICKET	PASS
1 $ .75 (1- or 2-zone)	1 $ 5.00 (1-zone)	1 $23 (1- or 2-zone)
2 $1.00 (3-zone)	2 $ 6.50 (2-zone)	2 $32 (3-zone)
3 $1.25 (All zone)	3 $ 9.00 (3-zone)	3 $40 (All zone)
4 $ .50 (Youth)	4 $11.00 (All zone)	4 $15 (Youth)
5 $ .25 (Honored Citizen)	5 24-Hour (All zone)	5 $ 6 (Honored Citizen)
6 Other	6 Other	6 Other

   IF YOU PAY CASH FARES, PLEASE GO TO QUESTION #7
5. Where do you usually buy your pass or bus tickets? (Circle the one number next to your answer.)
   1 DRUG STORE
   2 7-ELEVEN STORE
   3 BANK OR SAVINGS & LOAN OFFICE
   4 TRI-MET CUSTOMER ASSISTANCE OFFICE
   5 PLACE OF WORK
   6 BY MAIL FROM TRI-MET
   7 SCHOOL
   8 OTHER ______________ (PLEASE SPECIFY)
6. Are ticket and pass outlets more or less convenient for you than before self-service fare collection?
   1 MORE CONVENIENT
   2 SAME
   3 LESS CONVENIENT
   4 DON'T KNOW
7. How much discount, if any, do you think people should get for purchasing ten-ride tickets in advance?
   1 NO DISCOUNT
   2 5% (or 37¢ on ten 2-zone rides)
   3 10% (or 75¢ on ten 2-zone rides)
   4 20% (or $1.50 on ten 2-zone rides)
   5 DON'T KNOW

Figure B-1 (continued)

8. Please circle the rating number below which best describes your opinion of the following statements regarding fare collection.

	STRONGLY DISAGREE		UNDECIDED		STRONGLY AGREE
a. It is a bother to have the correct change.	1	2	3	4	5
b. I don't like waiting while other people search for their fare.	1	2	3	4	5
c. I am uncertain about time limits and when I should pay extra fare.	1	2	3	4	5
d. I'm uncertain about where zone boundaries are and when I should pay extra fare.	1	2	3	4	5
e. I have trouble understanding the information printed by the machine on my ticket.	1	2	3	4	5

8a. What problems, if any, do you have with the method of collecting fares? (Write "none" if you have no problems.)

9. How many times in the last 30 days has your fare been checked by a Tri-Met Fare Inspector? ____________

10. Do you think fares should be checked more or less often?
 1 MORE OFTEN
 2 THE SAME
 3 LESS OFTEN
 4 DON'T KNOW

11. Do you think more people or fewer people pay the correct fare with self-service fare than with the old method of collecting fares?
 1 MORE PAY CORRECT FARES
 2 THE SAME
 3 FEWER PAY CORRECT FARES
 4 DON'T KNOW

12. With the new equipment and rear-door boarding, is getting on and off the bus faster or slower for you than with the old fare collection system?
 1 FASTER
 2 THE SAME
 3 SLOWER
 4 DON'T KNOW

13. In general, do you find self-service fare collection more or less confusing than the old method of collecting fares?
 1 MORE CONFUSING
 2 THE SAME
 3 LESS CONFUSING
 4 DON'T KNOW

14. *Overall*, is the new fare collection system better or worse for you than the old fare collection system?
 1 BETTER
 2 THE SAME
 3 WORSE
 4 DON'T KNOW

15. Are you:
 1 MALE
 2 FEMALE

16. What is your age?
 1 15 OR UNDER
 2 16 TO 24
 3 25 TO 44
 4 45 TO 64
 5 65 OR OVER

17. What was your approximate family income in 1982?
 1 UNDER $5,000
 2 $5,000 TO $9,999
 3 $10,000 TO $14,999
 4 $15,000 TO $24,999
 5 $25,000 OR OVER

AGAIN, THANK YOU! PLEASE TEAR OFF THE WHITE FORM AND RETURN IT TO THE PERSON WHO GAVE IT TO YOU OR PUT IT IN THE BOX NEAR THE REAR DOOR. PLEASE FILL OUT THE YELLOW FORM AS SOON AS POSSIBLE AND MAIL (POSTAGE-FREE) TO TRI-MET. WE APPRECIATE YOUR HELP!

Figure B-1. continued

13818

BUS RIDERS MAIL-BACK SURVEY

Your responses to the second portion of this survey will help us determine how well the fare collection system is working. Please fill out the following questions as soon as possible and return, free of postage, to Tri-Met. Thank you!

1. How do you usually pay your fare? (Circle the one number next to your answer.)
   1 CASH (PLEASE GO TO QUESTION #2.)
   2 BUS TICKET (PLEASE GO TO QUESTION #3.)
   3 BUS PASS (PLEASE GO TO QUESTION #3.)

2. Why do you pay by cash rather than buy a 10-ride ticket?
   1 DON'T RIDE THE BUS OFTEN ENOUGH TO TO BOTHER WITH A 10-RIDE TICKET
   2 DIDN'T KNOW 10-RIDE TICKETS WERE AVAILABLE
   3 TICKET OUTLETS ARE NOT CONVENIENT TO GET TO
   4 I DON'T KNOW WHERE TO BUY TICKETS
   5 TICKETS ARE TOO EXPENSIVE
   6 I LIKE USING CASH
   7 OTHER ______________________ (PLEASE SPECIFY)

3. Which of the following do you think should be considered in determining fares? (Circle all that apply.)
   1 DISTANCE OF TRIP (PAY BY THE MILE)
   2 TIME OF DAY (RUSH HOUR, NIGHT, WEEKEND)
   3 ABILITY TO PAY
   4 AGE (UNDER 6 YEARS, STUDENTS, ADULTS, OVER 65 YEARS)
   5 COST OF OPERATING THE ROUTE
   6 AMOUNT OF TIME FOR THE TRIP
   7 OTHER ______________________ (PLEASE SPECIFY)

4. Fares are set according to the distance traveled and the time it takes to make the trip. How many zones would you consider best? (Circle one choice.)
   1 ONE ZONE, the same fare for everyone
   2 TWO ZONES, for example (a) inside Portland; (b) outside Portland
   3 THREE ZONES, for example (a) downtown Portland; (b) inside Portland; (c) outside Portland
   4 FIVE ZONES, for example (a) downtown Portland; (b) inner-city; (c) outer-city; (d) suburbs (such as Beaverton or Gresham (e) outlying areas (such as Vancouver or Forest Grove)
   5 SEVEN OR MORE ZONES, based on actual miles and minutes traveled

5. Based on your answer to the last question, how much do you think fares should increase for each additional zone?
   1 $ .05 — 4 $ .20
   2 $ .10 — 5 $ .25
   3 $ .15 — 6 SHOULD NOT CHANGE

6. Has the fare collection equipment ever failed to work properly when you were on the bus?
   1 YES How many times in the last 30 days? ______
   2 NO
   3 DON'T KNOW

7. How many times in the last 30 days *did you not pay your fare* because the fare equipment did not work? (Enter 0 if this has not happened to you in the last 30 days or you use a pass) ______

8. Has non-working fare equipment caused a delay in your trip in the last 30 days?
   1 YES About how long? ______ minutes
   2 NO

9. Based on your best estimate, of every 100 riders who get on the bus, how many do you think do not pay the correct fare?
   1 NONE (PLEASE GO TO QUESTION #12.)
   2 1 - 2
   3 3 - 5
   4 6 - 10
   5 11 - 20
   6 21 OR MORE

10. Of those persons who pay too little fare, why do you think they fail to pay the correct fare? (Circle all that apply.)
   1 THEY FORGET TO PAY
   2 THEY DON'T HAVE THE CORRECT CHANGE
   3 THEY ARE CONFUSED BY THE ZONE SYSTEM
   4 THEY SEE OTHERS CHEATING
   5 THEY THINK THEY WON'T BE CHECKED BY A FARE INSPECTOR
   6 THEY ARE DISHONEST PEOPLE
   7 THEY JUST DON'T HAVE THE MONEY
   8 THEY ARE UNHAPPY WITH SERVICE OR FARES
   9 OTHER ______________________ (PLEASE SPECIFY)

Figure B-1 (continued)

11. How do you think these people usually underpay their fares? (Circle all that apply.)
    1 INSUFFICIENT FARE FOR NUMBER OF ZONES TRAVELED
    2 INSUFFICIENT FARE FOR LENGTH OF TIME TRAVELED
    3 NO PAYMENT AT ALL
    4 MISUSE OF HONORED CITIZEN OR YOUTH PASS
    5 SLUGS, HALF DOLLAR BILLS, ETC.
    6 FORGED PASS
    7 OTHER ______________ (PLEASE SPECIFY)

12. Which word do you think best describes a fare inspector?
    1 FRIENDLY
    2 INTIMIDATING
    3 PROFESSIONAL
    4 HELPFUL
    5 NUISANCE

13. Overall, how well do you feel fare inspectors are doing their jobs?
    1 GOOD
    2 FAIR
    3 POOR. Why? ______________
    4 NO OPINION

- - - - - - - - - - Fold Here - - - - - - - - - -

14. What one penalty should there be for people who *did not know* they paid the wrong fare? (Circle the ONE number next to your answer.)
    1 NONE
    2 ASKED TO PAY THE CORRECT FARE
    3 ASKED TO LEAVE THE BUS
    4 ISSUED A WARNING
    5 FINED $5.00
    6 FINED $20.00
    7 FINED $50.00
    8 OTHER ______________ (PLEASE SPECIFY)

15. What one penalty should there be for people who did not pay the correct fare *on purpose*? (Circle the ONE number next to your answer.)
    1 NONE
    2 ASKED TO PAY THE CORRECT FARE
    3 ASKED TO LEAVE THE BUS
    4 ISSUED A WARNING
    5 FINED $5.00
    6 FINED $20.00
    7 FINED $50.00
    8 OTHER ______________ (PLEASE SPECIFY)

16. Are you:
    1 MALE
    2 FEMALE

17. What is your age?
    1 15 OR UNDER
    2 16 TO 24
    3 25 TO 44
    4 45 TO 64
    5 65 OR OLDER

THANK YOU!

- - - - - - - - - - Fold Here - - - - - - - - - -

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

Business Reply Mail

FIRST CLASS PERMIT NO. A-40 PORTLAND, OR

POSTAGE WILL BE PAID BY ADDRESSEE

Tri-Met Rider Survey
4012 S.E. 17th Avenue
Portland, Oregon 97202

Figure B-1 (continued)

DOWNTOWN CROSSING BUS PASSENGER SURVEY

№ 2996

Please COMPLETE and RETURN this questionnaire before leaving the bus. This survey is being conducted for the Boston Redevelopment Authority (BRA) in order to evaluate the recent changes made in the routing of this bus to serve the Downtown Crossing Project. Your cooperation is appreciated.

Please hand your questionnaire to the person who gave it to you when you leave the bus. If this is not convenient, drop it in any mailbox (we will pay the postage). It is NOT necessary to sign this form or otherwise identify yourself.

1. Where did you board this bus? (Please give nearest street intersection or landmark.)

   ______ Street Intersection or Landmark

2. How did you get to this bus? (PLEASE CHECK AS MANY AS APPLY)

   - ☐ Walked
   - ☐ In a car
   - ☐ Taxi
   - ☐ Commuter Train
   - ☐ MBTA Bus
   - ☐ MBTA Rapid Transit
   - ☐ Other (specify) ______

3. Where did you come from before boarding this bus?

   - ☐ Home
   - ☐ Work
   - ☐ School
   - ☐ Shopping
   - ☐ Personal Business
   - ☐ Social/Recreational
   - ☐ Medical/Dental
   - ☐ Other ______

4. The place you came from is located at:

   ______ Street Address or Nearest Intersection

   ______ City or Town

5. How will you get to your final destination after leaving this bus? (PLEASE CHECK AS MANY AS APPLY)

   - ☐ Walk
   - ☐ In a Car
   - ☐ Taxi
   - ☐ Commuter Train
   - ☐ MBTA Bus
   - ☐ MBTA Rapid Transit
   - ☐ Other ______

6. Where will you go after leaving this bus?

   - ☐ Home
   - ☐ School
   - ☐ Work
   - ☐ Shopping
   - ☐ Personal Business
   - ☐ Social/Recreational
   - ☐ Medical/Dental
   - ☐ Other: ______

7. Your final destination after leaving this bus is located in:

   ______ City or Town (If Boston, please specify the neighborhood)

8. How many days per week do you normally ride this bus (a bus on this route)?

   - ☐ Not on a regular basis
   - ☐ 1 day a week
   - ☐ 2 days a week
   - ☐ 3 days a week
   - ☐ 4 days a week
   - ☐ 5 or more days a week

9. On September 1, 1978, the routing of this bus was changed to better serve the Downtown Crossing area. Before the routing change was made, how many days a week did you normally ride this bus?

   - ☐ Never rode the bus
   - ☐ Not on a regular basis
   - ☐ 1 day a week
   - ☐ 2 days a week
   - ☐ 3 days a week
   - ☐ 4 days a week
   - ☐ 5 or more days a week

10. Before September 1, 1978, how did you travel to and from the place from which you are now travelling? (CHECK AS MANY AS APPLY)

    - ☐ Did not make the trip
    - ☐ Same bus
    - ☐ Another MBTA bus
    - ☐ MBTA Rapid Transit/Trolley
    - ☐ In a car
    - ☐ Taxi
    - ☐ Walked
    - ☐ Other: ______

11. Before September 1, 1978, how often did you travel to the place from which you are now coming?

    - ☐ Less often than you do now
    - ☐ More often than you do now
    - ☐ About the same as you do now

12. What type of fare will you pay on this bus today?

    - ☐ Adult cash fare
    - ☐ Student half-fare
    - ☐ Student transfer
    - ☐ Elderly half-fare
    - ☐ Handicapped half-fare
    - ☐ Prepaid MBTA Pass:

      ↳ Which type of pass do you have? (look for the letter on the left side of your pass and CHECK ONE)

      ☐ A ☐ B ☐ C ☐ D ☐ E ☐ F

      Other: ______

13. Are you employed in the downtown area of Boston? (DO NOT INCLUDE BACKBAY AS PART OF DOWNTOWN BOSTON)

    ☐ YES ☐ NO

14. What is your age?

    - ☐ Under 16
    - ☐ 16 - 24
    - ☐ 25 - 44
    - ☐ 45 - 59
    - ☐ 60 - 64
    - ☐ 65 or older

15. What is the combined annual income of your entire household?

    - ☐ Less than $ 6,000
    - ☐ $ 6,000 - $10,999
    - ☐ $11,000 - $15,999
    - ☐ $16,000 - $27,000
    - ☐ Over $27,000

16. We are very interested in any stores, restaurants, or other business establishments that you visited in Boston today. Would you please give the establishment name, street address, or nearest intersection, and the value of any purchases that you made?

Name and Location of Establishments	Value of Purchases	No Purchases Made
a. ______	$ ______	☐
b. ______	$ ______	☐
c. ______	$ ______	☐

THANK YOU FOR YOUR COOPERATION. We welcome your suggestions for ways in which this bus service can be improved. Please use the space provided below or the reverse side of the card for your comments.

Questions 1 through 7 in Figure B-2 present recommended question formats and response categories for the measures of travel behavior that are likely to be included in most user and non-user surveys. These recommendations are based on a review and evaluation of questions asked in past surveys (including U.S. Census Journey-to-Work) and are directed to the five basic types of surveys (See Table B-1). In designing a survey for a particular demonstration, the evaluator should follow these guidelines to the extent consistent with the scope and objectives of the survey.

Attitudinal Measures

Attitudinal items will be used in many surveys to measure the respondent's evaluation of the BRT service provided, specifically in terms of such characteristics as speed, reliability, convenience, attractiveness, and safety. Attitudinal questions may also be used, if applicable, to determine what factors have influenced a modal change. Construction of such items requires careful design and will lengthen the survey's administration time. Occasionally, attitudinal questions may be used to obtain a profile of the community in which the transit service is being provided. An entire survey would then be designed explicitly for the purpose of determining the opinions of the general population in the BRT service area to such things as the role of government, environmental issues, adequacy of transportation facilities, and desirability of travel by alternate mode.

Examples of attitudinal questions appear throughout the aforementioned Figure B-1, and also in Questions 8 and 9 in Figure B-2. The results of Question 8 can be used both to measure users' and non-users' evaluations of the BRT transit service and the factors that have influenced their modal choices. In combination with responses to Question 9, one can put respondents' opinions about the different travel characteristics into proper perspective. For example, if several respondents indicated that "car" had a very high status and "bus" had a very low status, it might at first appear that the status of the automobile might deter the use of bus transit. However, the responses would be considerably less significant if these same respondents indicated that the "status" travel characteristics were rather unimportant to them.

There are no specific recommendations for the format of attitudinal questions, since the design of such questions is entirely dependent on the particular attitudes being measured (e.g., opinions of a very subjective item or perceptions about items which are independently measurable) and on the overall survey context. However, the following discussion presents some general informative guidelines regarding the treatment of responses to attitudinal questions.

There are three types of response categories that can be used for attitudinal questions: nominal, ordinal, and interval scales. Nominal data consists of mutually exclusive categories with no implied rating of the responses (e.g., questions with "yes," "no" answers). Responses such as "like very much," "dislike," "dislike very much" represent ordinal level data, with an implied rank ordering. Interval data involves the use of numerical scales (e.g., asking people to indicate their opinions on a scale of 1 to 5). Since interval scales require prior validation and careful application, it is recommended that attitudinal questions be limited to nominal or ordinal response categories. Moreover, it is recommended that the survey data be represented in the form of frequency distributions, rather than statistics such as means which have an implied ranking.

Social and Demographic Measures

The inclusion of certain social/demographic questions in surveys serves the dual purpose of (1) providing data on respondent characteristics which might show a correlation (perhaps even a causal relationship) with measured behavioral attributes, and (2) providing data about respondents which can be used in conjunction with U.S. Census data to check survey accuracy, determine non-response bias, and extrapolate survey findings to other areas.

The amount and nature of social/demographic information collected depends on a number of factors, in particular, the desired length of the survey and the extent to which the data will be correlated with behavioral data and used for extrapolation purposes. It is recommended that the following items be included in every survey: respondent's sex, age, household income, the number of autos in the respondent's household, and availability of an auto for the particular trip(s) made on project service (user surveys only). Depending on the survey objectives, scope, and administration format, the following are some of the additional items that might be included: whether the respondent has a driver's license, the general (regular) availability of an auto for a particular trip type (e.g., work, educational level completed, occupation, and length of residence and employment at present location).

Examples of questions on social/demographic variables appear throughout Figure B-1. Questions 10 through 18 in Figure B-2 present a suggested question formats and response categories for most of the social/demographic measures listed above. It is considered important to collect and code this type of data in categories which are equivalent to, or collapsible into, U.S. Census categories, so as to facilitate comparisons with the same type of U.S. Census data for the survey area (for accuracy check purposes),[18] or to permit the use of other types of U.S. Census data to amplify survey findings (with the collected data serving as a bridge between the survey population and the U.S. Census population). Special purpose surveys may require a greater amount of detail about a particular social/demographic measure, but the stratification should be compatible with commonly used Census breakdowns.[19]

NON-RESPONSE BIAS

Use of the guidelines presented in this Appendix to design and execute a survey does not insure that the responses obtained will accurately reflect the characteristics, travel behavior, and/or attitudes towards the BRT demonstration of the entire sample selected even though the sample itself is unbiased and totally representative of the population from which the sample was selected. It is possible that the characteristics, behavior, and

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[18] Census tract or block data on family income will be a good check on reporting accuracy.

[19] See U.S. Census, Volume I: Characteristics of the Population, Part II, Appendix B for a detailed discussion on the format of questions. See also "1990 Census User Guide," U.S. Department of Commerce, Bureau of the Census, Washington, DC, June, 1993.

attitudes of the part of the sample that did not respond to the survey are different from those of the part that did respond, hence producing non-response bias.

Pretesting of the survey instrument may or may not reveal this problem when it exists. Even if pretesting does reveal the problem, there may be no effective means of eliminating it. This is especially true if there is a systematic refusal to participate in a survey by certain segments or personality types in the population. It is recommended here that an attempt be made in every survey to determine whether or not non-response bias exists and how it might affect the validity of results.

Ascertaining the existence and the extent of non-response bias is problematic because it requires additional resources, but it is important because the non-respondents may differ systematically from the respondents in a way that would affect the accuracy and interpretation of the survey results. In mail surveys, one approach to obtain an indication of the direction of bias is to do a third mailing (assuming a second mailing/reminder were part of the original survey design) to non-respondents. A small number of this group will respond, and the case can be made that they are somewhat more representative of the remaining non-respondents than the respondents to the first two mailings. Their responses may be compared to returns of the previous two mailings for significant differences. Telephone follow-up calls are more effective than a third mailing, but also more expensive, and accomplish the same purpose of gauging the views of non-respondents. Where surveys are handed out in person, a rough indicator of differences in the respondent and non-respondent populations can be ascertained by the surveyors' observations of the refusals. They need to be aware of any obvious characteristics of the non-respondents that might bias the results, such as people getting off a bus at a particular stop, male versus female, age, etc. These observations, while not quantitative, might shed some light on results during the analysis phase of the survey. The evaluator should attempt to devise a specific methodology for determining whether non-response bias exists in the survey responses obtained from the surveys being conducted.

INTERVIEWS WITH TRANSPORTATION AGENCY PERSONNEL

There are situations where it may be useful to conduct interviews with transit company personnel (e.g., drivers, dispatchers, mechanics, management personnel from the agency operating the project service). In some cases, interviews could be used to develop ideas for questions and sets of responses for surveys of users and non-users. In other cases, interviews could be used as a check of the validity of collected data and survey responses.

Agency personnel may be able to provide first-hand insight on whether a BRT feature performed as expected from a functional perspective. For example, drivers and mechanics could provide information on the operating and maintenance characteristics of smart vehicle and smart card systems. Management could provide insight into the enforcement problems associated with exclusive bus lanes. Dispatchers could provide insight into the operating characteristics of an AVL system. It is up to the evaluator to decide whether interviews with transit company personnel would provide information needed to perform the particular evaluation, and to design the appropriate survey technique. Individual interviews and focus groups are other practical methods of obtaining information from agency personnel.

Figure B-2. Suggested Formats for Survey Questions

1. Boarding and Alighting Points (User Surveys Only)

Where did you board this vehicle? ________________________________
Nearest Street Intersection

Where will you (did you) get off this vehicle? ________________________
Nearest Street Intersection

Respondent should specify nearest street intersection. Coders can then translate street address to codes representing bus stops or, if a less fine-grained analysis is required, zonal codes.

2. Trip Origin and Destination

Where did this trip begin? ____________________________________
Street Address, City, Zip Code

Is this place (check one)

- ❑ Home
- ❑ Place of employment
- ❑ School
- ❑ Retail/commercial establishment
- ❑ Social/recreational facility
- ❑ Medical facility
- ❑ Personal business site
- ❑ Other (specify) ____________________________________

If the main purpose of this question is to distinguish work from non-work trips, then the categories can be condensed to

- ❑ Home
- ❑ Place of employment
- ❑ Other

Respondent should specify street address. Coders can then translate street address to zonal codes, or addresses can be geocoded using the Census Bureau's TIGER files and address program.

3. Trip Destination

What is (was) the final destination of this trip? _________________________
Street Address, City, Zip Code

Is this place (check one)

- ❑ Home
- ❑ Place of employment
- ❑ School
- ❑ Retail/commercial establishment
- ❑ Social/recreational facility
- ❑ Medical facility
- ❑ Personal business site
- ❑ Other (specify) ____________________________________

Figure B-2 (continued)

If the main purpose of this question is to distinguish work from non-work trips, then the categories can be condensed to

- ❑ Home
- ❑ Place of employment
- ❑ Other

Respondent should specify street address. Coders can then translate street address to zonal codes, or addresses can be geocoded using the Census Bureau's TIGER files and address program.

Another option, for interview surveys, is to have the interviewer show the resondent a map with numbered zones superimposed, and ask the respondent to identify the destination zone.

A question classifying the nature of the trip destination, in combination with a question classifying the nature of the trip origin, is a better indicator of trip purpose than a question explicitly asking trip purpose, which can be confusing to persons making a multi-purpose trip.

4. Trip Start and End Times

What time did you begin this trip? ____________________AM/PM

What time did you arrive at your destination? _________________________AM/PM

Depending on the survey objectives, beginning and ending times can be used as given to compute total trip times, or they can be coded using categories such as AM peak, midday, PM peak, nighttime.

5. Access Mode to Transit Vehicle

How did you get from the place where this trip began to the place where you boarded this vehicle?

How will you (did you) get to your destination after leaving this vehicle?

Recommended response categories:

- ❑ Park and Ride
- ❑ Carpool
- ❑ Kiss and ride
- ❑ Bus
- ❑ Subway, Elevated Train, Railroad
- ❑ Walked
- ❑ Taxi
- ❑ Bicycle or Motorcycle
- ❑ Other

This list needs to be adjusted to the demonstration site.

Figure B-2 (continued)

6. When Present Mode Was First Used

For User Surveys:

When did you first use (specify BRT service)?
Month________________ Year________________

For Non-user Surveys:

How long have you used your current mode of transportation for the type of trip you are now taking?
Since: Month________________ Year________________

7. Former Transportation Mode

How did you make this trip before (specify BRT service)?

Recommended response categories:

- ❑ Park and Ride
- ❑ Carpool
- ❑ Kiss and ride
- ❑ Bus
- ❑ Subway, Elevated Train, Railroad
- ❑ Walked
- ❑ Taxi
- ❑ Bicycle or Motorcycle
- ❑ Other

This list needs to be adjusted to the demonstration site.

8. Attitudes on Travel by Transit and Auto

On the scales below, please indicate your general opinion of cars and buses for local travel. Base your opinion on what you have experienced or have heard about local travel by each mode from the user's viewpoint. Even though you may not use the bus, you probably have some perceptions of what this form of travel is like; you don't need to have tried something in order to be able to express some general opinions.

To indicate your opinion, look at the descriptive scales below, each of which allows for a range of opinions on a particular characteristic, such as "comfort". Then, mark what you consider to be the single most appropriate description on each scale by circling the relevant number. For instance, on the "comfort" scale, if you thought cars were a very comfortable for local travel, you would circle "1" on the scale on the line for cars; however, if you thought they were a slightly uncomfortable form of travel, you would circle "4", and so forth.

Figure B-2 (continued)

Travel Characteristic								
Cost	Inexpensive	Car	1	2	3	4	5	Expensive
		Bus	1	2	3	4	5	
Enjoyableness	Enjoyable	Car	1	2	3	4	5	Unenjoyable
		Bus	1	2	3	4	5	
Speed	Fast	Car	1	2	3	4	5	Slow
		Bus	1	2	3	4	5	
Convenience	Convenient	Car	1	2	3	4	5	Inconvenient
		Bus	1	2	3	4	5	
Status	High Status	Car	1	2	3	4	5	Low Status
		Bus	1	2	3	4	5	
Comfort	Comfortable	Car	1	2	3	4	5	Uncomfortable
		Bus	1	2	3	4	5	
Modernity	Modern	Car	1	2	3	4	5	Old-fashioned
		Bus	1	2	3	4	5	
Safety	Safe	Car	1	2	3	4	5	Unsafe
		Bus	1	2	3	4	5	
Simplicity	Simple to use	Car	1	2	3	4	5	Complicated
		Bus	1	2	3	4	5	
Punctuality	On-time	Car	1	2	3	4	5	Late
		Bus	1	2	3	4	5	

9. Opinion on Transportation and Personal Travel

Below are listed a number of statements relating to transportation facilities and personal travel; you will probably agree with some of them and disagree with others. Please answer by circling the latter which best represents your feeling about each of the statements, according to the following codes:

A: Strongly Agree
B: Somewhat Agree
C: Neither Agree nor Disagree
D: Somewhat Disagree
E: Strongly Disagree

I much prefer driving a car to being a passenger in one.	A B C D E
It's time measures were taken to discourage auto usage in downtown.	A B C D E
I really can't see much of a future for public transportation.	A B C D E

Figure B-2 (continued)

I could manage without a car for a few months if I had to.	A B C D E
People would use public transportation a lot more if fares were lower.	A B C D E
I'd much rather people saw me arriving at work by car than getting off a bus.	A B C D E
I've never really bothered to find out details of what public transportation services are available around here.	A B C D E
A lot of my friends and acquaintances judge people by the type of car they drive.	A B C D E
It's important that my home be close to good public transportation.	A B C D E
Government investments in mass transit are a good way to help reduce air pollution.	A B C D E
I've go bad memories of public transportation.	A B C D E
Everyone has a right to drive his car just as much as he wants.	A B C D E
Public transportation is no use at all for journeys outside commute hours.	A B C D E
I enjoy driving very much.	A B C D E
It would hardly seem proper for someone in a top job to commute by bus.	A B C D E
I hate to be tied to fixed schedules for traveling.	A B C D E
I might use public transportation more often if it were simpler to obtain information about routes and schedules.	A B C D E
Traveling by public transportation is so much more relaxing than driving.	A B C D E
I often worry about being involved in a bad car accident.	A B C D E
I'd never travel regularly by any form of public transportation, no matter how much they improved the service.	A B C D E
The idea of carpooling doesn't appeal to me.	A B C D E
There should be a greater emphasis on developing improved public transportation systems and less on building freeways.	A B C D E
I'm always glad of an excuse to take my car out for a drive.	A B C D E

Figure B-2 (continued)

10. Respondent's Sex

For Self-administered Surveys:

Are you

- ❑ Male
- ❑ Female

For Interview Surveys:

Respondent's sex is noted by the interviewer.

11. Respondent's Age

To what age group do you belong?

- ❑ Under 20
- ❑ 20-44
- ❑ 45-64
- ❑ 65 and Over

These categories may be split into finer age groupings according to the nature of the BRT demonstration.

12. Respondent's Income

What is the combined annual income of all members of your household?

- ❑ Less than $10,000
- ❑ $10,000 to $19,999
- ❑ $20,000 to $29,999
- ❑ $30,000 to $39,999
- ❑ $40,000 to $49,999
- ❑ $50,000 to $59,999
- ❑ $60,000 to $69,999
- ❑ $70,000 to $79,999
- ❑ $80,000 to $89,999
- ❑ $90,000 to $99,999
- ❑ $100,000 and Greater

These categories may be further subdivided or combined depending on the survey objectives and expected income distribution of the respondent population.

It is important to use the word "annual" or "yearly" in order to obtain responses on a consistent basis. Moreover, if deemed appropriate, the question can be phrased to refer to the most recently ended calendar.

Figure B-2 (continued)

13. Auto Availability

Was a car available to you for this trip?

- ❑ Yes, but without inconvenience to others
- ❑ Yea, but with inconvenience to others
- ❑ No

Information on the availability of a car for a specific trip or time period is the most direct way of determining auto availability and its possible influence on mode used.

14. Auto Ownership

How many cars (including vans, SUV's, pickup trucks, and other passenger vehicles) are owned or operated by members of your household?

- ❑ None
- ❑ 1
- ❑ 2
- ❑ 3 or more

15. Whether Respondent Has Driver's License

Are you a licensed driver?

- ❑ Yes
- ❑ No

16. Respondent's Occupation

Are you:

- ❑ Employed
- ❑ Student
- ❑ House spouse
- ❑ Retired
- ❑ Other

If you are employed, describe briefly the kind of work you do:

____

The second question should be included in the survey only when there is a specific need for using employment data. To perform the coding for this question, it is necessary to obtain a description of the type of work actually done as well as job title. The coder may use the following codes for the open-ended question:

Figure B-2 (continued)

Professional, technical and kindred workers
Managers and administrators, except farm
Salesworkers
Clerical and kindred workers
Craftsmen and kindred workers
Operatives, except transcripts
Transport equipment operators
Laborers, except farm
Farmers and farm machinery
Farm laborers and farm foremen
Service workers, except private household
Private household workers

17. Respondent's Educational Level

What is the highest level of education you attained?

- ❑ No formal schooling
- ❑ Grade school
- ❑ Some high school
- ❑ High school
- ❑ Some college
- ❑ College degree
- ❑ Some graduate work or graduate degree

18. Length of Residence

When did you move to your present residence?
Year__________

REFERENCES

The following are considered to be excellent references on the subject of survey execution, experimental design, and associated issues, concepts, and techniques:

- General Accounting Office, *Designing Evaluations*, Washington, D.C., May 1991.
- Mohr, L., *Impact Analysis for Program Evaluations*, Brooks-Cole, Monterey, California, 1988.
- Rossi, Peter H., James D. Wright and Andy B. Anderson, *Handbook of Survey Research*, Academic Press, San Diego, California, 1983.

The last two may be purchased through Amazon.com, while the first is available through the Government Printing Office.