HOUSTON *SMART COMMUTER* IVHS OPERATIONAL TEST AND LOCAL EVALUATION PROGRAM

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Table of Contents

Houston *Smart Commuter* IVHS Operational Test
Local Evaluation Program

I. Introduction

The Houston *Smart Commuter* Intelligent Vehicle Highway Systems (IVHS) Operational Test is one of the federally sponsored IVHS projects currently being conducted in the United States. The Houston *Smart Commuter* Operational Test is being funded and implemented through the joint efforts of the Metropolitan Transit Authority of Harris County (METRO), the Texas Department of Transportation (TxDOT), the Federal Highway Administration (FHWA), and the Federal Transit Administration (FTA). The Texas Transportation Institute (TTI), a part of The Texas A&M University System, assisted with the development of the operational test concept design and is responsible for conducting the local evaluation and providing ongoing project support.

A significant component of the Houston *Smart Commuter* IVHS Operational Test is the local evaluation program. As outlined in this document, discussion of the local evaluation program includes the study design, the operational test objectives, the measures of effectiveness, the data collection and monitoring activities, the data reduction and analysis activities, and the distribution of local evaluation results. The local evaluation program is a critical part of the Houston *Smart Commuter* IVHS Operational Test. The local evaluation program will help ensure that the operational test is designed and implemented in such a way that the results can be evaluated and that an unbiased ongoing monitoring and evaluation program is conducted. The results of the local evaluation program will be used to analyze the costs, benefits, impacts, problems encountered and solutions utilized, and the overall effects of the Houston *Smart Commuter* IVHS Operational Test.

This document contains the local evaluation program for the Houston *Smart Commuter* IVHS Operational Test. The local evaluation program is presented in six chapters. Following this introduction, Chapter II provides an overview of the Houston *Smart Commuter* IVHS Operational Test. This overview includes a summary of the development of the project, the concepts being tested, the organization of the operational test, the roles and responsibilities of the different agencies, and the link with the national FTA evaluation program. Chapters III and IV present the detailed evaluation programs for the I-45 North and the I-10 West portions of the operational test. Each chapter outlines the selection of the sample and control groups, the objectives and corresponding measures of effectiveness, the data collection activities, potential confounding variables, and the timetable for conducting the different data collection activities. The fifth chapter describes the relationship between the Houston *Smart Commuter* IVHS Operational Test and the objectives of the Federal Transit Administration's Advanced Public Transit System (APTS) program. Finally, Chapter VI provides a summary of the major highlights of this document and the local evaluation program.

II. Overview of the Houston *Smart Commuter* Operational Test and the Local Evaluation Program

This chapter provides an overview of the development of the Houston *Smart Commuter* IVHS Operational Test and the local evaluation program. It includes a description of the background of the project and the concepts being tested in the operational test. It also summarizes the organization of the operational test, the roles and responsibilities of the different agencies, and the link to the national FTA evaluation program.

Background

Like many major metropolitan areas, traffic congestion continues to be a major problem in the Houston area, especially during the morning and afternoon peak-periods. Although recent improvements in the transportation system have reduced congestion levels in some corridors, Houston is still ranked as one of the top ten most congested cities in the country (1). The annual cost of this congestion, based on the costs associated with time delay and fuel, is estimated to be approximately $1.38 billion (1). Air quality and environmental issues are also major concerns. Houston is currently in severe violation of the Environmental Protection Agency (EPA) standards for ozone emissions. In order to meet requirements of the 1990 Clean Air Act Amendments, the area must develop measures to control growth in vehicle miles of travel, and initiate other programs.

In response to the combination of increasing demands on the system and limited resources, the agencies responsible for transportation in the Houston area have often utilized innovative approaches to address mobility and congestion problems. The regular development and publication of a multimodal Regional Mobility Plan, the extensive system of high-occupancy vehicle (HOV) lanes, park-and-ride lots, transit centers and express bus services, the expansion of the freeway and toll road system, the development of a strategic arterial street plan, and the commitment to a state-of-the-art traffic management center represent just a few of the approaches that are being utilized in Houston.

The development of these projects has occurred through the coordinated and cooperative efforts of the TxDOT, METRO, the City of Houston, Harris County, the Houston-Galveston Area Council (HGAC), and others. TTI has provided technical assistance on many of these projects. In preparing to move Houston forward into the 21st century, these agencies continue to work together to ensure that the transportation system will meet the needs of future generations. Incorporating advances in technology, such as those offered through the application of the *Smart Commuter* IVHS Operational Test, is an important part of this overall approach.

The Houston *Smart Commuter* IVHS Operational Test represents one example of this multi-agency approach. The development of the Houston *Smart Commuter* IVHS Operational Test was initiated in 1990. A planning and feasibility study, which was jointly funded by FTA, METRO, and TxDOT, was conducted by TTI in 1990 and 1991. This study examined the concepts behind the project, analyzed available literature on commuting behavior and mode choice selection, examined the market potential for the concepts through the use of focus groups and surveys, and reviewed potential technologies for providing the real-time traffic and transit information to individuals in their home and work place. A series of reports were prepared documenting the different elements of the study (2,3,4,5,6). The final report, *The Houston Smart Commuter IVHS Demonstration Project: Concept Design and Implementation Program Outline* (6), summarizes the major elements of the operational test and contains the project implementation program, budget, and preliminary evaluation approach.

This report was used as the basis for federal funding requests by METRO and TxDOT to FTA and FHWA respectively. A total of $5 million has been committed for the first phase of the multi-year $17 million Houston *Smart Commuter* IVHS Operational Test. Both METRO and TxDOT have committed $1,250,000 to fund the first phase, FTA has provided $500,000 in funding, and FHWA has provided $2,000,000. The concepts being tested in the *Smart Commuter* project are described next, followed by a more detailed discussion of the roles and responsibilities of the different groups involved in the project, and the link to the national evaluation.

The Houston *Smart Commuter* Operational Test is evaluating the potential for gaining more efficient use of major travel corridors through greater utilization of high-occupancy commute modes, shifts in travel routes, and changes in time of travel through the application of innovative approaches using advanced technologies. The test is based on the hypothesis that commuters who have quick and easy access to relevant, accurate, and up-to-date information on existing traffic conditions, bus routes, bus schedules, how to use the bus, and instant ridematching services in their home and workplace will be more likely to use public transportation and other high-occupancy commute modes. The travel time savings and travel time reliability offered by the Houston HOV lanes add further incentives for changing travel modes. In addition, individuals may alter their travel time or travel route based on this information.

The *Smart Commuter* Operational Test includes two different, but compatible, components. Both components are intended to make better use of the Houston HOV facilities. These facilities have been developed and funded as multi-agency projects. A diagram of the major freeway and HOV lane facilities in Houston is shown in Figure 1.

The first component of the *Smart Commuter* Operational Test, the bus component, focuses on the traditional suburb-to-downtown travel market in the I-45 North corridor. This element focuses on encouraging a mode shift from driving alone to using the bus, changing travel times, and shifting travel routes. These changes in travel decisions will result from the provision of current traffic and transit information to individuals in their home and workplace through state-of-the-art videotext and telephone technologies. Changes in travel behavior will be evaluated by comparing the sample group with a control group that does not receive the current traffic and transit information device.

The second component focuses on the suburb-to-suburb travel market in the I-10 West corridor to the Post Oak/Galleria area. This corridor, which is more difficult to serve with traditional, regular-route bus service, provides the opportunity to test the use of a comprehensive employer-based carpool matching service. This system will include the ability to provide real-time carpool matches and is structured to encourage a mode shift from driving alone to carpooling and also to encourage an increase from two to three person carpools.

The two components of the *Smart Commuter* Operational Test, the advanced traffic and transit information in the I-45 North corridor and the comprehensive employer based instant rideshare matching service in the I-10 West corridor, are being implemented and evaluated over a five year period. As noted, funding has been secured for the first phase of the operational test which includes finalizing the local evaluation plan, selecting the technology to be utilized to provide the real-time information to individuals in their home and work place, and implementing the operational test, and completing the first six month and first year evaluation.

The *Smart Commuter* Operational Test represents the first major test of the use of IVHS technologies to encourage an increase in average vehicle occupancy. It provides an opportunity to test the ability to collect, process, and transmit current traffic and transit information and instant rideshare matching services to individuals in their home and workplace through a variety

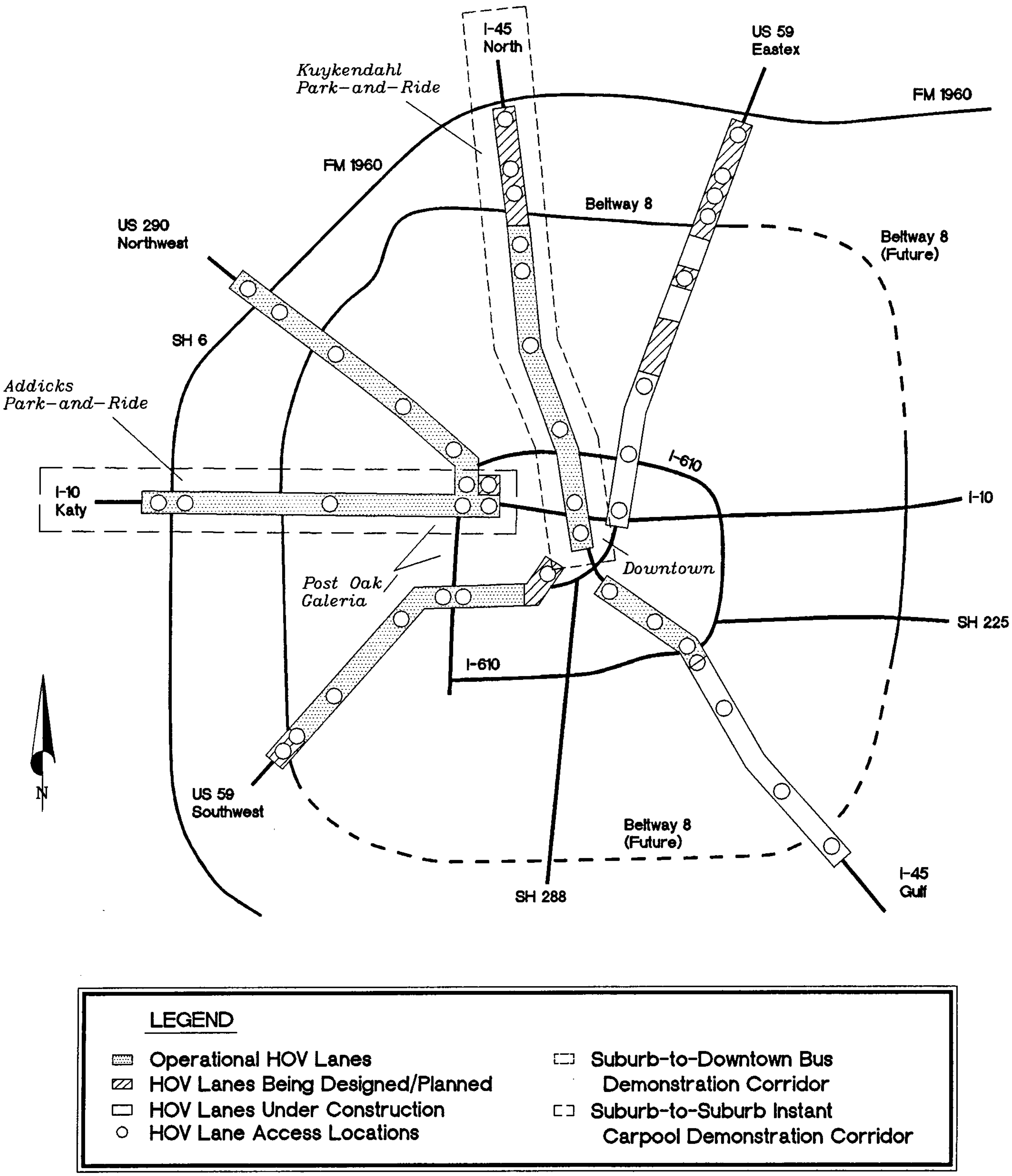

Figure 1. Major Freeway and HOV Lane Facilities in Houston

of advanced technologies. The *Smart Commuter* Operational Test also provides an opportunity for highway and transit interests to work together to better manage the overall transportation system through the innovative application of IVHS technology, enhanced information, and improved services.

Organization of the Houston *Smart Commuter* IVHS Operational Test

The development of the Houston *Smart Commuter* IVHS Operational Test has been accomplished through the joint efforts of METRO, TxDOT, FHWA, FTA, HGAC, and TTI. This multi-agency coordinated approach will also be used to implement, monitor, and evaluate the operational test. This section outlines the overall organization of the operational test. A more detailed description of the roles and responsibilities of the different agencies, especially as they relate to the evaluation, is provided in the next section.

METRO, TxDOT, FHWA, and FTA have agreed on the overall organizational structure for implementing and evaluating the Houston *Smart Commuter* IVHS Operational Test. METRO will provide the overall project management responsibility for the operational test and has appointed a project manager. TxDOT will be actively involved throughout the project and will participate in both the Executive Committee and the Project Management Team (PMT). FTA and FHWA will provide federal oversight. The management structure for the operational test is shown in Figure 2 and each element is briefly described next.

The Executive Committee. The Executive Committee is comprised of senior staff members from the various agencies involved in the project. It is responsible for executive oversight of the operational test.

The Project Manager. The Project Manager is responsible for the daily project management of the design, implementation, and operation of the *Smart Commuter* IVHS Operational Test. METRO is providing the Project Manager for the project. The Project Manager reports to the Executive Committee and is responsible for staffing the Project Management Team. This individual is overseeing and coordinating the various elements of the *Smart Commuter* IVHS Operational Test, including the I-45 North bus component and the I-10 West carpool component. The individual is also responsible for coordinating the *Smart Commuter* project with other programs and projects. To help manage the operational test, METRO is contracting with TTI for ongoing project assistance.

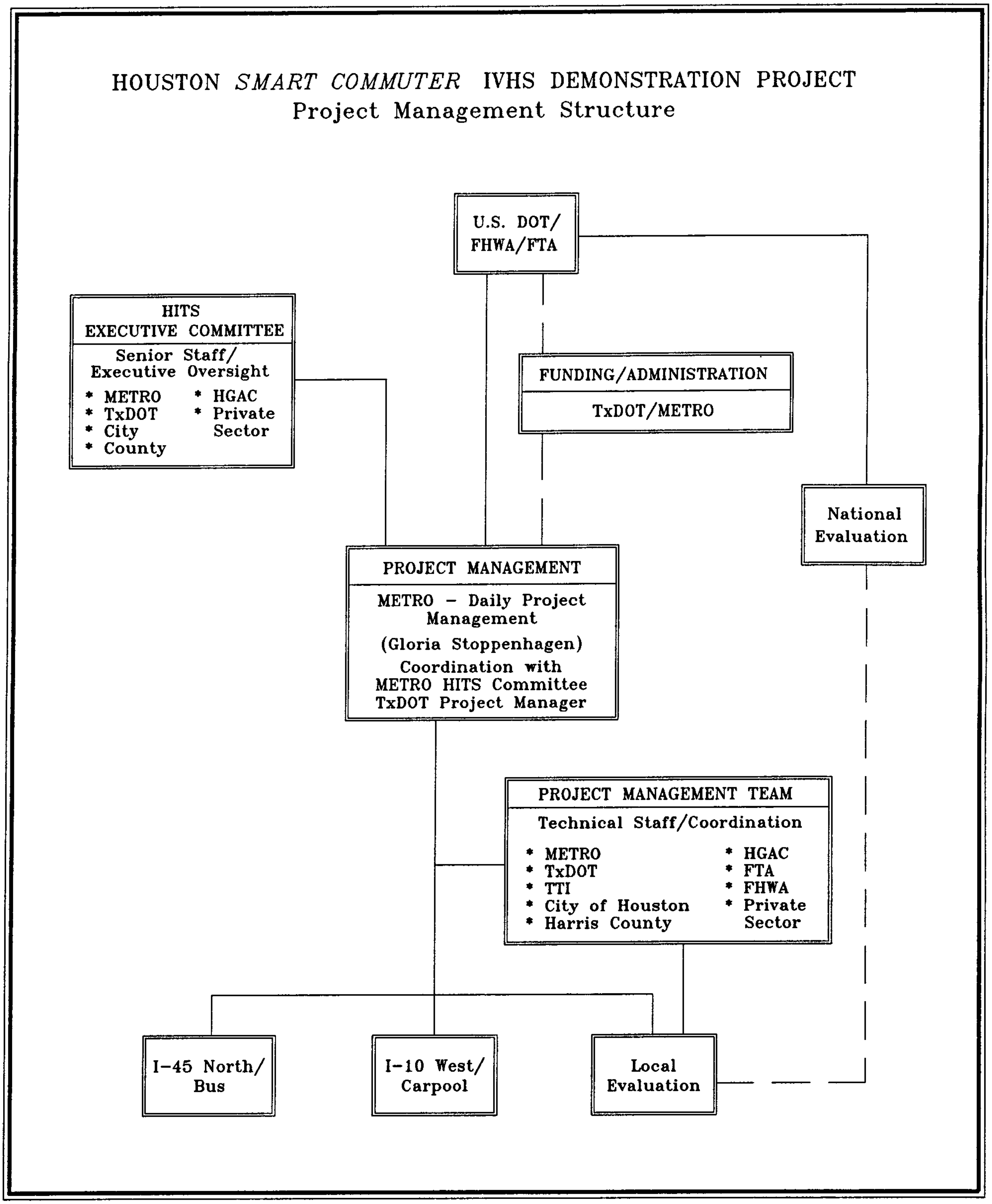

Figure 2. Houston *Smart Commuter* Project Management Structure

The Project Management Team (PMT). A Project Management Team (PMT), comprised of technical staff members from the various agencies in the Houston area, was used to assist with the development of the initial *Smart Commuter* project design. The PMT continues to play an integral part in the implementation and evaluation of the operational test. The PMT is responsible for ensuring coordination with other projects and programs, providing a link to agency activities, and assisting the Project Manager in obtaining needed support and responses from the different agencies.

U.S. DOT - FHWA and FTA. FHWA and FTA representatives provide federal oversight and guidance throughout the operational test and will participate in PMT meetings as appropriate. Although FTA has the overall federal monitoring responsibilities for this operational test, these responsibilities will be shared and coordinated with FHWA, especially the FHWA Austin office.

Local Evaluation. TTI is responsible for conducting the local evaluation of the operational test under contract to METRO and TxDOT. This includes finalizing the study design and local evaluation program, and completing the ongoing data collection, monitoring, and evaluation activities.

National Evaluation. The FTA is sponsoring national evaluations of the federally sponsored advanced public transportation systems (APTS) operational tests. These evaluations are being administered through the Volpe National Transportation Systems Center. The Volpe Center is utilizing the consulting firm Science Applications International Corporation (SAIC) and its subcontractor Castle Rock Consultants (CRC) to conduct the national evaluation of the Houston *Smart Commuter* IVHS Operational Test.

Agency Roles and Responsibilities Related to the Local Evaluation Program

The local evaluation of the Houston *Smart Commuter* IVHS Operational Test will be conducted using the same coordinated multi-agency approach that was followed in the development of the project. Although TTI is responsible for the local evaluation under contract with TxDOT and METRO, the PMT and other participating agencies are actively involved. The local evaluation is also being coordinated with the national evaluation sponsored by FTA.

TTI is also responsible for a number of activities related to the overall conduct of the local evaluation. First, as documented in this report, TTI is preparing the local evaluation program. This includes the local evaluation objectives and related measures of effectiveness, selection of the sample and control groups, identification of potential confounding variables, data collection activities, and the evaluation and data collection schedule. The draft *Local Evaluation Program* has been developed with input from the PMT and the draft and final plans have been reviewed by PMT members.

Second, TTI is also responsible for conducting the local evaluation. Following the program outlined in this document, TTI will complete the ongoing data collection, monitoring, and evaluation activities. The objectives, measures of effectiveness, and data needs that will be used to guide the evaluation are presented in this report. Further, TTI will be responsible for most of the specific data collection and survey activities. TTI will also coordinate the collection of other information provided by METRO and TxDOT. Based on the schedule outlined in the proposal and this document, TTI will complete evaluations after 6 months, 12 months, 24 months, and 36 months. The results of these evaluations will be documented in formal reports prepared by TTI and reviewed by the PMT. TTI will also be responsible for coordinating the local and national evaluation activities and communicating with the national evaluation consultants.

Both METRO and TxDOT will assist with different aspects of the evaluation. This will include reviewing the different reports, participating as part of the PMT, and providing information needed for different parts of the evaluation. For example, METRO will be responsible for providing information on bus assignment levels from the Kuykendahl park-and-ride lot and other supporting data.

Representatives from FHWA and FTA will also assist with the local evaluation. This will include reviewing the draft evaluation program and the evaluation reports, and participating in PMT meetings. In addition, representatives from both agencies will help ensure the ongoing coordination between the local and national evaluations. The Volpe Center is responsible for the national FTA evaluation which will be conducted by SAIC and CRC. Coordination of the local and national evaluation is described in more detail in the next section.

Link to the National FTA Evaluation

Development of the Houston *Smart Commuter* IVHS Operational Test local evaluation program is being coordinated with the national FTA APTS evaluation. Further, the ongoing local evaluation will continue to be coordinated with the national evaluation. This coordination and communication is occurring in a number of different ways.

First, the local evaluation for the *Smart Commuter* Operational Test is being coordinated with the objectives of the national evaluation, as outlined by the Volpe National Transportation Systems Center in the *Evaluation Guidelines for the Advanced Public Transportation Systems Operational Tests* (7). This document provides a framework for the coordination of the national and local evaluations, and focuses on key elements central to the Federal Transit Administration's Advanced Public Transportation Systems (APTS) program. The national evaluation framework and the national APTS program objectives were reviewed in the development of the local evaluation plan for this operational test. A more detailed discussion concerning the specific APTS elements and the objectives addressed in the *Smart Commuter* Operational Test are discussed in Section V.

Second, both groups - the local agencies and the Volpe Center and national consultants - are providing input to the development of the local evaluation program and the national evaluation plan. Representatives from the Volpe Center, SAIC, and CRC attended an August, 1993 PMT meeting in Houston to initiate coordination of the local and national evaluations. The national consultants will review the draft local evaluation program and the PMT will have the opportunity to review the national evaluation framework and the more detailed national evaluation plan.

Third, the local evaluation process will provide most, if not all of the data necessary to complete the national evaluation. It is anticipated that all of the data needed for the national evaluation has been identified in the local evaluation program. Additional data needs may arise to support the national evaluation, however. These will be addressed as necessary and the appropriate data collection methods, as well as any additional funding, will be agreed to among all groups. TTI will be responsible for coordinating the sharing of information between the local and national evaluations.

Finally, ongoing communication between the local and national evaluations will occur through periodic meetings as well as regular telephone calls and faxes. All groups realize that ongoing coordination among all involved agencies, both local and national, will be necessary to ensure the successful completion of the local and national objectives. The PMT recognizes the need for cooperation and is committed to working together to meet the common goals of the operational test.

III. I-45 North

Selection of Sample and Control Groups

The sample and control groups for the I-45 North Bus Component will each consist of approximately 700 participants recruited from downtown employers. The sample size of 700 employees for both the sample and control groups was selected based on estimates of acceptable levels of statistical significance and statistical power. Acceptable levels of statistical significance and statistical power reflect the tolerance for of Type I (alpha) and Type II (beta) statistical error.

Both sample and control group participants must live in the Kuykendahl park-and-ride lot market area and work downtown. Potential downtown employers will be identified by METRO through involvement on other projects, such as the ridesponsor program, and with the assistance of the Greater Houston Partnership and other organizations. Participating employers will be asked to identify employees who live in the zip code zones comprising the Kuykendahl market area. The area employees will be selected from is shown in Figure 3. This area includes zip code zones 77014, 77068, 77073, 77090, 77373, 77379, 77380, 77381, 77385, 77386, 77388, 77389, and 77390. These employees will be invited to participate in the operational test. A variety of informational brochures are being prepared to help explain the program to perspective participants -- both employers and employees. These will be used to explain the operational test and the activities required as part of participating in the project to employers and employees. All of the employees from each company who agree to participate in the operational test will be randomly divided into two groups, half will be assigned to the control group, and half to the test group. Participants in the test group will have access to real-time traffic and transit information through a machine that will be provided to them free of charge. Test group participants will have access to traffic and transit information both at home and at the office.

Objectives and Measures of Effectiveness

Four major objectives have been identified for the I-45 North corridor operational test. These objectives, along with the corresponding measures of effectiveness (MOEs) and data sources, are shown in Table 1 and discussed below.

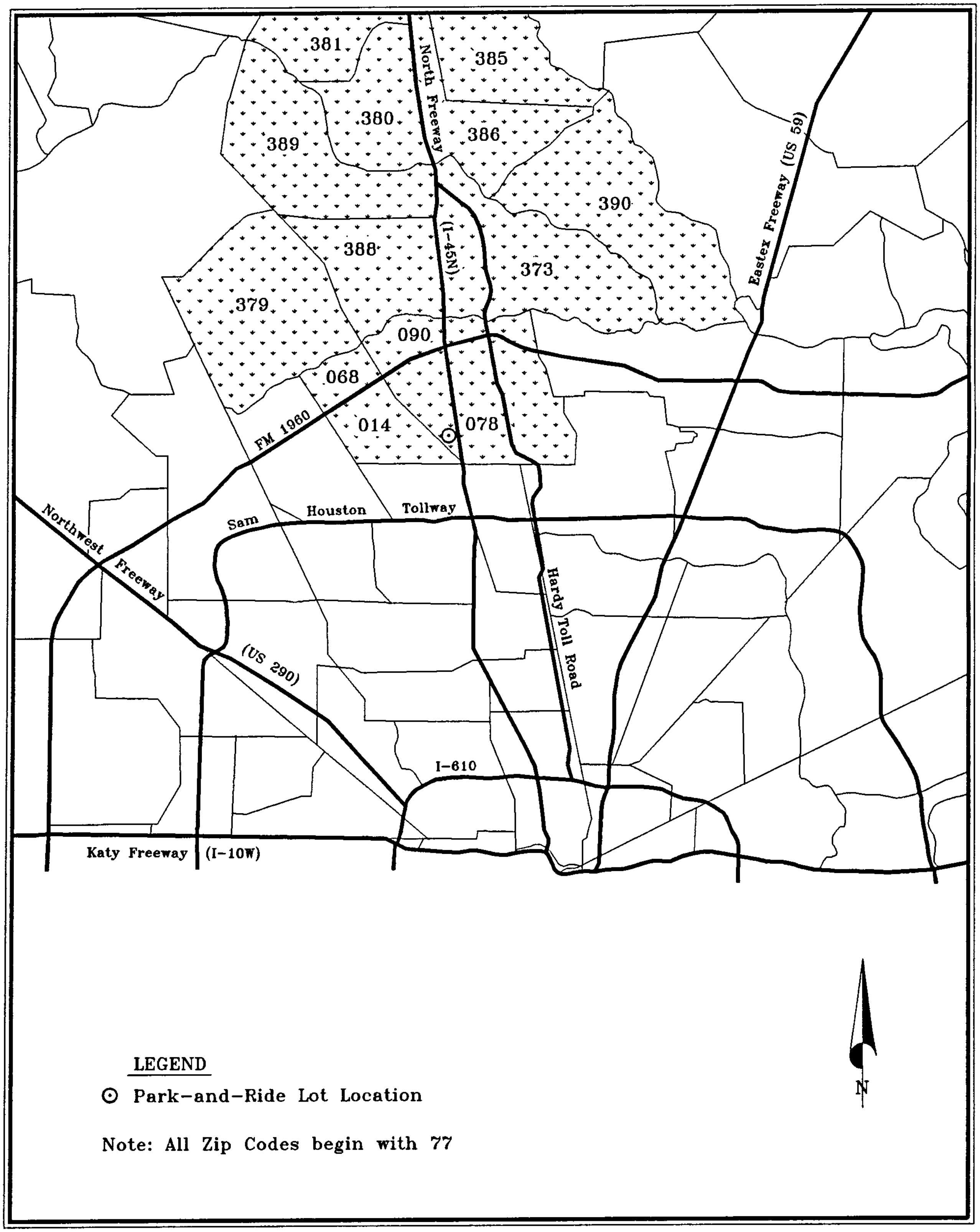

Figure 3. Residential Zip Codes of Participants in I-45 North Component

Table 1. Operational Test Objectives and Measures of Effectiveness

Objective 1: Identification and quantification of the effects of the provision of real-time information on commuter behavior in the suburb-to-downtown commute.	
Measure of Effectiveness	Data Source
Quantification of information provided • Number of inquiries per day • Time of inquiries • Kind of information requested	Recorded by information device in home and office and compiled and analyzed by TTI
Quantification of travel characteristics for both control group and participants • Number of commuters traveling by mode • Average travel time by mode • Travel route • Time of travel • Number of trips made	Surveys and travel diaries administered and analyzed by TTI, and possible use of AVI and other advanced technologies to help monitor changes
Extrapolation of changes in travel characteristics and its correlation with receipt of information • Number of commuters who change mode • Number of commuters who change travel route • Number of commuters who change time of travel • Number of trips eliminated • Average occupancy of participant group and control group • Correlation between information inquiry and propensity to change commuting behavior (mode, route, time of travel, or elimination of trip)	Calculations performed by TTI

Objective 2: Evaluation of the net effect on corridor operations due to changes in commuter behavior.	
Measure of Effectiveness	**Data Source**
Quantification of transit characteristics on I-45 North • Vehicle assignment levels • Transit operating costs	METRO - Scheduling and Finance
Quantification of transit utilized on I-45 North • Bus ridership by month • Passenger fare revenues • Transit pass sales • Park-and-ride lot utilization levels	METRO - Planning and Finance, and TTI surveys
Evaluation and comparison of traffic and operating characteristics for HOV and general purpose lanes on I-45 North • Person movement by mode • Vehicle movement by mode • Average peak hour speed • Average travel time • Accident rate per lane • Efficiency per lane (product of the average speed times the number of persons moved)	Calculated by TTI

Objective 3: Assessment of the effectiveness of the technology used.	
Measure of Effectiveness	Data Source
Measurement of machine performance • Reliability - Failure rate per machine per year • Other problems with machines	Reported by users, vendor, or others and monitored by TTI
Evaluation of Human Factors • System ease of use • Visual display or audio recording clarity • System "menu" set-up (logical progression, easy to follow, etc.) • Access to system (convenient or difficult) • Attitude towards selected system technologies • System training required	Reported by users in surveys and focus groups

Objective 4: Dissemination of the information acquired during the planning and implementation of the operational test.	
Measure of Effectiveness	Data Source
Appraisal of technology transfer • Professional reports • Articles for periodicals • Papers and presentations for professional conferences	Monitored by TTI

Objective One. The first objective is to evaluate the effects on commuter behavior due to the provision of current traffic and transit information at home and at the workplace. The major focus of the demonstration is to monitor changes in travel mode - from driving alone to using bus service. Other possible behavior changes will also be monitored, including changes in time of travel, and the elimination of trips. MOEs that will be used to gauge the effects on commuter behavior include the number of times the real-time information is accessed, reported changes in behavior, and actual changes in behavior. First, the number, the time, and the kind of inquiries for current traffic and transit information made by commuters in the sample group, both at home and at the workplace, will be monitored. It is anticipated that the ability to collect this information will be built into the selected device. This information will be correlated with the propensity of the commuter to alter his/her behavior, as demonstrated by a change in mode, time of travel, route, or the elimination of a trip. Travel behavior, and changes in travel behavior, will be monitored through travel diaries and surveys scheduled at regular intervals throughout the test. In addition, the potential to monitor actual changes in travel behavior through the use of automatic vehicle identification (AVI) tags or other technologies is being explored. For example, participants in the control group could be given AVI tags for their vehicles, which could then be read by readers located at the park-and-ride lot and along the corridor to determine possible changes in commuter behavior.

Objective Two. The second objective of this component of the operational test is to evaluate the net effect on bus and corridor operations due to changes in commuter behavior. Changes in bus ridership, bus scheduling efficiency and effectiveness, and changes in HOV and general purpose lane traffic and operating characteristics will all be monitored. The implications of any changes on air quality and other environmental factors will also be addressed. Given the relatively small size of the test, encompassing only about 700 participants, it is expected that the net effect on the operations of the corridor will be small. It is important to examine these impacts however, to help determine the potential influence of more wide-spread application of the *Smart Commuter* concepts. It is also important to examine the overall influence of the real-time information in relationship to any potential confounding variables that may also impact commute behavior changes.

MOEs that will be used to evaluate the impacts that changes in commuter behavior have on bus and corridor operations include bus ridership, bus scheduling efficiency and effectiveness, and changes in HOV and general purpose lane traffic and operating characteristics. Specific MOEs that will be used to assess the effects on transit include bus ridership levels by route and time of day, bus vehicle assignment levels and operating costs, passenger fare revenues, transit pass sales, and park-and-ride lot utilization levels. Specific MOEs that will be used to assess the effects on the HOV and general purpose lanes include HOV lane person and vehicle movement by type of vehicle (carpool, vanpool, and bus); and general purpose and HOV lane use characteristics, including volume per lane, peak hour speed, travel times, accident rate per lane (injury accidents per 100 M vehicle miles), and efficiency (persons moved times vehicle speed). It is anticipated that all MOEs will be collected and analyzed for the peak periods only.

Objective Three. The third objective of this component of the operational test is to assess the technologies used. The technologies utilized for the collection and processing of data and information, and the technologies used to present the information to the commuter in the home and at the workplace will all be assessed. The technologies will be evaluated with respect to their ability to meet both user and system needs, reliability, and accuracy. Areas for technological improvement or enhancement will be identified, along with any problems or issues.

One MOE that will be used to assess machine performance is the failure rate per machine per year. Other aspects of technology that will be evaluated include human factors aspects, which will be evaluated through surveys and focus groups and will address the problems encountered or the ease with which the information was obtained.

Objective Four. A fourth objective of the I-45 North component of the *Smart Commuter* IVHS Operational Test is to report the results of the test to interested parties. This includes other transit systems, communities, state departments of transportation, FTA, FHWA, national organizations, and other groups. Results of this test will be used to expand the knowledge base of transportation professionals at the local, state, and national level.

The achievement of this final objective, the dissemination of information acquired during this operational test, will not be quantified by traditional MOEs but will be documented through a variety of technology transfer activities. Professional reports, papers and articles for professional conferences and periodicals, and presentations will be used to share the knowledge and experience gained through the *Smart Commuter* Operational Test.

Other MOEs. In addition to the specific MOEs that will be used to evaluate the attainment of the four objectives, additional information will be provided by feedback from both participants and employers. Focus groups may be used to informally discuss reactions to the project and assess areas for improvements. Overall community reaction will also be monitored. Newspaper, television, and other local media will be monitored for relevant articles; and calls and letters to TxDOT and METRO will be monitored.

Confounding Variables

There are factors that are outside the span of control of the Houston *Smart Commuter* Operational Test which may have an impact on the results of the I-45 North portion of the operational test. Efforts will be made to identify and track these variables, so that their effects on test results will be recognized and documented. Possible confounding variables include:

gasoline prices and availability, congestion trends, employment and economic trends, participant turnover rates, and changes in participant residence. Other factors which may affect the study results include construction, natural disasters such as hurricanes, media attention to transportation issues, and employer incentives offered to increase vehicle occupancy rates in response to the requirements of the 1990 Clean Air Act Amendments.

For example, a drastic increase in gasoline prices or a decrease in gasoline availability may result in an increase in transit use by commuters, or other changes in travel behavior. To account for this possible effect, gasoline prices and availability will be monitored throughout the duration of the study. Similarly, congestion trends will also be monitored, because an increase in congestion on the general purpose lanes may cause a shift to an HOV mode.

Other factors which may affect the results of this element of the operational test include employee turnover and changes in residential locations. If a participant either moves out of the Kuykendahl park-and-ride lot market area, or changes location of employment, then participation in the test is infeasible. While some attrition from the initial sample and control groups is expected, the reasons for attrition will be monitored. New participants may join the project to offset participants lost through attrition, however. If participants are added over the course of the test, the analysis will consider the length of time the commuter has participated as another independent variable.

While all of these confounding variables may affect commuter behavior, and thus will be monitored, it is important to note that all of these factors will affect the control and sample groups equally. Thus, the influence of the provision of current traffic and transit information may be seen when the sample group is compared to the control group.

Timetable for Data Collection Activities

A number of data collection activities will be performed by a variety of agencies to support the data needs of this element of the *Smart Commuter* IVHS Operational Test. Data collection will be ongoing, and will address the objectives and measures of effectiveness discussed previously. Table 2 summarizes the data collection activities and the schedule for conducting the different activities.

As shown in Table 2, the timetable for the completion of the operational test must reflect the quantification of MOEs prior to the study, as well as throughout the duration of the study. Historical data for many of the MOEs are available through other TxDOT, METRO, and TTI projects; this information will be used for comparison and for trend analysis. The "before" study conditions will be collected in early 1994; data collection activities at this time will include participant travel diaries, as well as transit, general purpose lane, and HOV lane utilization levels and operating characteristics. Data collection will then occur at 6 months, 12 months, 24 months and 36 months after the implementation of the operational test. The same data collection activities will be conducted at these intervals. The ongoing category in Table 2 indicates that the information will be recorded each time the participant uses the in-home or in-office device.

Table 2. Data Collection Activities

Objective 1: Identification and quantification of the effects of the provision of real-time information on commuter behavior in the suburb-to-downtown commute						
Measures of Effectiveness	Ongoing	Before	Months After Implementation			
			6	12	24	36
Number of inquiries per day	X					
Time of inquiries	X					
Kind of information requested	X					
Number of commuters traveling by mode		X	X	X	X	X
Average travel time by mode		X	X	X	X	X
Travel route		X	X	X	X	X
Time of travel		X	X	X	X	X
Number of trips made		X	X	X	X	X
Number of commuters who change mode		X	X	X	X	X
Number of commuters who change travel route		X	X	X	X	X
Number of commuters who change time of travel		X	X	X	X	X
Number of trips eliminated		X	X	X	X	X
Average occupancy of participant group and control group		X	X	X	X	X

Objective 2: Evaluation of the net effect on corridor operations due to changes in commuter behavior.						
Measures of Effectiveness	Ongoing	Before	Months After Implementation			
			6	12	24	36
Vehicle assignment levels		X	X	X	X	X
Transit operating costs		X	X	X	X	X
Bus ridership by month		X	X	X	X	X
Passenger fare revenues		X	X	X	X	X
Transit pass sales		X	X	X	X	X
Park-and-ride lot utilization levels		X	X	X	X	X
Person movement by mode		X	X	X	X	X
Vehicle movement by mode		X	X	X	X	X
Average peak hour speed		X	X	X	X	X
Average travel time		X	X	X	X	X
Accident rate per lane		X	X	X	X	X
Efficiency per lane (product of the average speed times the number of persons moved)		X	X	X	X	X

Objective 3: Assessment of the effectiveness of the technology used.						
Measure of Effectiveness	Ongoing	Before	Months After Implementation			
			6	12	24	36
Failure rate per machine per year	X					

Objective 4: Dissemination of the information acquired during the planning and implementation of the operational test.						
Measure of Effectiveness	Ongoing	Before	Months After Implementation			
			6	12	24	36
Professional reports	X					
Articles for periodicals	X					
Papers and presentations for professional conferences	X					
Calls and letters to TxDOT and METRO	X					
Community reaction and media reports on *Smart Commuter* project	X					

IV. I-10 West

Selection of Sample Group

During the first phase of the Houston *Smart Commuter* IVHS Operational Test, the I-10 West carpool component will focus on one or two large employers in the Post Oak/Galleria area. This approach is being taken to test the concept with a smaller initial sample. The sample group for the I-10 West carpool component will consist of approximately 800 to 1200 participants recruited from one or two employers in the Galleria/Post Oak area. Potential employers will be identified by METRO through involvement on other projects, such as the ridesponsor program, and with the assistance of the Uptown Association and other organizations. Participating employers will be asked to identify employees who live in the zip code zones comprising the Addicks park-and-ride lot market area along the I-10 West corridor. The area employees will be selected from is shown in Figure 4. This area includes zip code zones 77079, 77084, 77094, 77423, 77441, 77449, and 77450. These employees will be invited to participate in the operational test. A variety of informational brochures are being prepared to help explain the program to prospective participants, both employers and employees. The participants will then be included in the database for instant carpooling. No control group will be used in this component of the operational test, because the main focus is to test the viability of the concept. Additionally, all participants are needed in the sample group to increase the likelihood of a carpool match at any given time.

Objectives and Measures of Effectiveness

Four major objectives have been identified for the I-10 West component of the Houston *Smart Commuter* IVHS Operational Test. These objectives, along with the corresponding measures of effectiveness (MOEs) and data sources are shown in Table 3 and discussed below.

Objective One. The first objective is to evaluate of the effect of real-time carpool matching services on carpool formation. Specific changes in travel behavior from a single occupancy mode to a carpool, and shifts from two person carpools to three person carpools will be monitored.

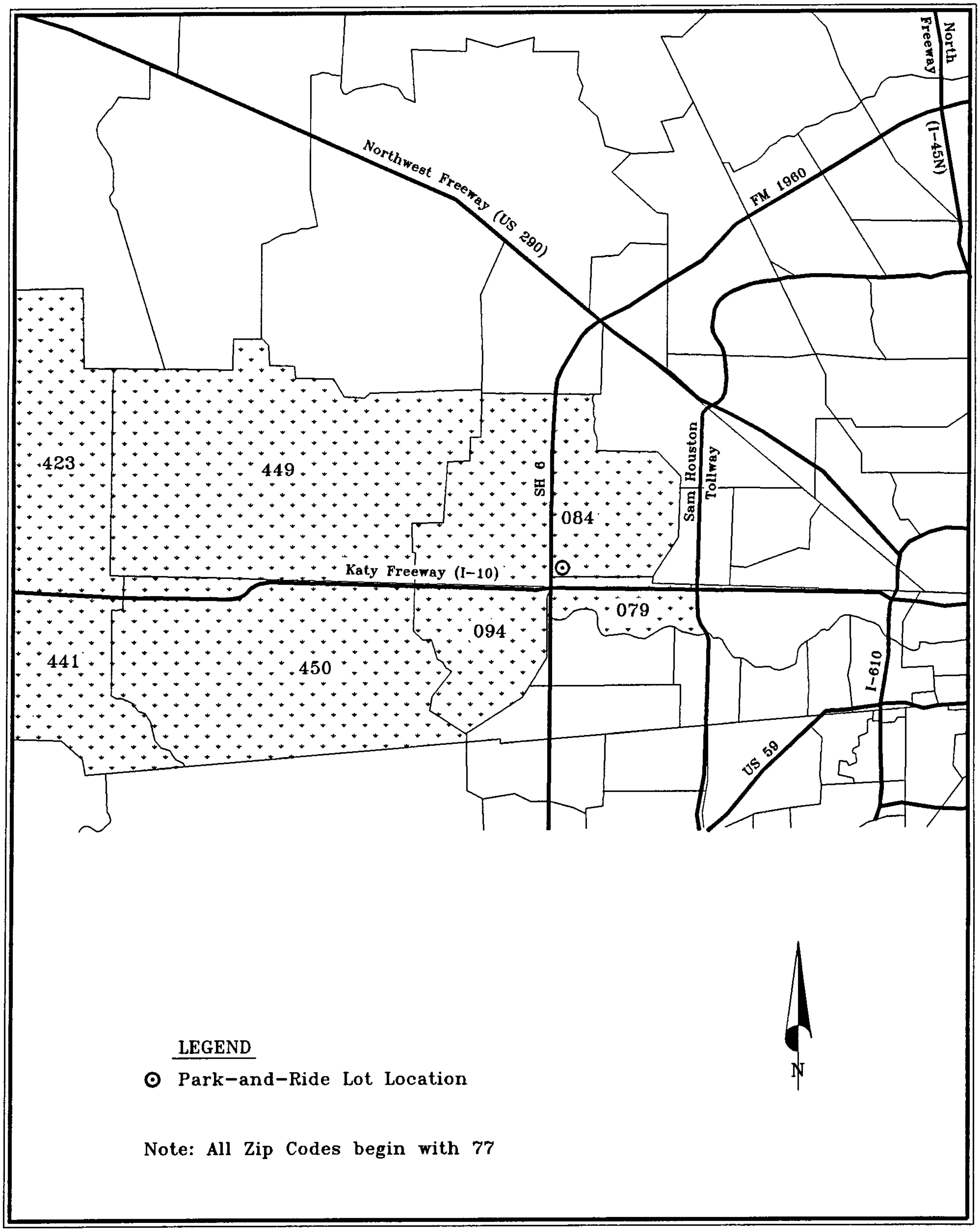

Figure 4. Residential Zip Codes of Participants in I-10 West Component

Table 3. Operational Test Objectives and Measures of Effectiveness

Objective 1: Identification and quantification of the effects of the provision of instant carpool matching services on commuter behavior in the suburb-to-suburb commute.	
Measure of Effectiveness	Data Source
Quantification of information provided • Number of matches requested per day and time of requests	Recorded by real-time ridematching system
Quantification of travel characteristics • Number of participants commuting by single occupancy vehicle • Number of participants commuting by 2 person carpools • Number of participants commuting by 3+ person carpools • Average occupancy of carpool • Average travel time for single occupancy commuters • Average travel time for carpools	Surveys administered and analyzed by TTI
Extrapolation of changes in travel characteristics • Change in average occupancy level • Change in travel time • Correlation between rideshare request and propensity to carpool	Calculations performed by TTI

Objective 2: Evaluation of the net effect on corridor operations due to changes in commuter behavior.	
Measure of Effectiveness	Data Source
Quantification of carpool utilization on I-10 West HOV lane • Park-and-ride lot utilization levels • Number of 2 person carpools • Number of 3+ person carpools	Surveys and field counts administered by TTI
Evaluation and comparison of traffic and operating characteristics for HOV and general purpose lanes on I-10 West • Person movement by mode • Vehicle movement by mode • Average peak hour speed • Average travel time • Accident rate per lane • Efficiency per lane (product of the average speed times the number of persons moved)	Calculations performed by TTI

Objective 3: Assessment of the effectiveness of the technology used.	
Measure of Effectiveness	**Data Source**
Measurement of machine performance • Ability to provide timely matches • Failure rate of system per year	Recorded by ridematching system and analyzed by TTI
Evaluation of Human Factors • System ease of use • Visual display or audio recording clarity • System "menu" set-up (logical progression, easy to follow, etc.) • Access to system (convenient or difficult) • Attitude towards selected system technologies • System training required	Reported by users in surveys and focus groups

Objective 4: Dissemination of the information acquired during the planning and implementation of the operational test.	
Measure of Effectiveness	**Data Source**
Appraisal of technology transfer • Professional reports • Articles for periodicals • Papers and presentations for professional conferences	Monitored by TTI

An assessment of the effects of instant carpool matching services will be conducted throughout the operational test. MOEs that will be used to gauge commuter behavior include the number of requests for carpool matches - either as a rider or as a driver - made by commuters in the sample group. This information will be recorded by the instant ridematching system. This information will be correlated with the propensity of the commuter to alter his/her behavior, as demonstrated by a change from driving alone to carpooling or from a 2 person to a 3 person carpool. Although less of a focus than in the I-45 North bus component, changes in time of travel, travel route, or the elimination of a trip will also be examined. Travel behavior, and changes in travel behavior, will be monitored through travel diaries scheduled at regular intervals throughout the test.

Objective Two. The second objective of the operational test is to evaluate the net effect on corridor operations due to changes in commuter behavior. Changes in carpool formation, and changes in operating characteristics of the HOV and general purpose lane traffic will be monitored. The implications of any changes that will affect air quality and other environmental factors will also be addressed. Given the relatively small size of the test, encompassing only about 800 to 1200 participants during the first phase, it is expected that the net effect on the operations of the corridor will be small. It is important to examine these impacts however, to help determine the potential influence of more wide-spread application of the *Smart Commuter* concepts. It is also important to examine the overall influence of the real-time carpool matches in relationship to any potential confounding variables that may also impact commute behavior changes.

MOEs that will be used to evaluate the impacts that changes in commuter behavior have on corridor operations include changes in carpool formation and changes in HOV and general purpose lane traffic and operating characteristics. Specific MOEs that will be used to assess the impact on carpool formation include the number of 2 person and 3+ person carpools using the I-10 West HOV lane, as well as utilization levels at the Addicks park-and-ride lot. Specific MOEs that will be used to assess the effects on the HOV and general purpose lanes include HOV lane person and vehicle movement by type of vehicle (carpool, vanpool, and bus); and general purpose and HOV lane use characteristics, including volume per lane, peak hour speed, travel times, accident rate per lane (injury accidents per 100 M vehicle miles), and efficiency (persons moved times vehicle speed). All MOEs will be collected and analyzed for the peak periods only.

Objective Three. The third objective of this aspect of the operational test is to assess the technologies utilized. The technologies used to support the real-time ridematching system, including the matching system and the connection to individual homes and places of work will all be addressed. The technologies will be evaluated with respect to their ability to meet both user and system needs, reliability, and accuracy. Areas for technological improvement or enhancement will be identified, along with any problems or issues.

MOEs that will be used to assess the performance include the matching response time and machine failure rate. Other aspects of technology that will be evaluated include human factors aspects, which will be evaluated through surveys and focus groups and will address the problems encountered or the ease with which the information was obtained.

Objective Four. A fourth objective of the I-10 West Carpool Component of the Houston *Smart Commuter* IVHS Operational Test is to report the results of the test to interested parties. This includes other transit systems, communities, state departments of transportation, FTA, FHWA, national organizations, and other groups. Results of this test will be used to expand the knowledge base of transportation professionals at the local, state, and national level.

The achievement of this final objective, the dissemination of information acquired during this operational test, will not be quantified by traditional MOEs but will be documented through a variety of technology transfer activities. Professional reports, papers and articles for professional conferences and periodicals, and presentations will be used to share the knowledge and experience gained through the *Smart Commuter* Operational Test.

Other MOEs. Additional information will be provided by feedback from both participants and employers. Focus groups may be used to informally discuss reactions to the project and assess areas for improvements. Overall community reaction will also be monitored. Newspaper, television, and other local media will be monitored for relevant articles; and calls and letters to TxDOT and METRO will be monitored.

Confounding Variables

There are factors that are outside the span of control of the I-10 West component of the *Smart Commuter* Operational Test which may have an impact on the operational test results. Efforts will be made to identify and track these variables, so that their effects on test results will be recognized. Possible confounding variables include: gasoline prices and availability, congestion trends, employment and economic trends, participant turnover rates, and changes in participant residence. Other factors which may affect study results include construction, natural disasters such as hurricanes, media attention to transportation issues, and employer incentives offered to increase the vehicle occupancy rates in response to requirements of the 1990 Clean Air Act Amendments.

A drastic increase in gasoline prices or a decrease in gasoline availability may result in an increase in carpool use by commuters, or other changes in travel behavior. To account for this possible effect, gasoline prices and availability will be monitored throughout the duration of the study. Similarly, congestion trends will also be monitored, because an increase in congestion on the general purpose lanes may cause a shift to an HOV mode.

Other factors which may affect the results of the operational test include employee turnover and changes in residential locations. If a participant either moves out of the Addicks market area, or changes location of employment, then participation in the test is infeasible. New participants may join the project to offset participants lost through attrition, however. Further, additional employers and employees may be recruited to participate in the I-10 West carpool component in the second phase of the operational test.

Timetable for Data Collection Activities

A number of data collection activities will be performed by a variety of agencies to support the data needs of *Smart Commuter* IVHS Operational Test. Data collection will be ongoing, and will address the objectives and measures of effectiveness discussed previously. Table 4 summarizes the data collection activities, and the schedule for conducting the different activities.

As shown in Table 4, the timetable for the completion of the operational test must reflect the quantification of MOEs prior to the study, as well as throughout the duration of the study. Historical data for many of the MOEs are available through other TxDOT, METRO, and TTI projects; this information will be used for comparison and for trend analysis. The "before" study conditions will be collected in early 1994; data collection activities at this time will include participant travel diaries, as well as carpool, general purpose lane, and HOV lane utilization levels and operating characteristics. Data collection will then occur at 6 months, 12 months, 24 months and 36 months after the implementation of the operational test. The same data collection activities will be conducted at these intervals as more employers and employees area are added to the I-10 West Carpool Component after the first phase. The ongoing category in Table 4 indicates that the information will be recorded each time the participant uses the real-time ride matching service.

Table 4. Data Collection Activities

Objective 1: Identification and quantification of the effects of the provision of instant carpool matching services on commuter behavior in the suburb-to-suburb commute.						
Measure of Effectiveness	Ongoing	Before	Months After Implementation			
			6	12	24	36
Number of requests for real-time matches	X					
Time of request	X					
Number of participants commuting by single occupancy vehicle		X	X	X	X	X
Number of participants commuting by 2 person carpools		X	X	X	X	X
Number of participants commuting by 3+ person carpools		X	X	X	X	X
Average travel time for single occupancy commuters		X	X	X	X	X
Average travel time for carpools		X	X	X	X	X

Objective 2: Evaluation of the net effect on corridor operations due to changes in commuter behavior.							
Measure of Effectiveness	Ongoing	Before	Months After Implementation			
			6	12	24	36
Park-and-ride lot utilization levels		X	X	X	X	X
Number of 2 person carpools		X	X	X	X	X
Number of 3+ person carpools		X	X	X	X	X
Person movement by mode		X	X	X	X	X
Vehicle movement by mode		X	X	X	X	X
Average peak hour speed		X	X	X	X	X
Average travel time		X	X	X	X	X
Accident rate per lane		X	X	X	X	X
Efficiency per lane (product of the average speed times the number of persons moved)		X	X	X	X	X

Objective 3: Assessment of the effectiveness of the technology used.						
Measure of Effectiveness	Ongoing	Before	Months After Implementation			
			6	12	24	36
Ability to provide timely matches	X					
Failure rate of system		X	X	X	X	X

Objective 4: Dissemination of the information acquired during the planning and implementation of the operational test.						
Measure of Effectiveness	Ongoing	Before	Months After Implementation			
			6	12	24	36
Professional reports	X					
Articles for periodicals	X					
Papers and presentations for professional conferences	X					
Calls and letters to TxDOT and METRO	X					
Community reaction and media reports on *Smart Commuter* Project	X					

V. Coordination with the National FTA Evaluation

The local planning, implementation, and evaluation procedures for the Houston *Smart Commuter* IVHS Operational Test are being coordinated with the objectives of the Federal Transit Administration's Advanced Public Transportation Systems national evaluation program (7). The Houston *Smart Commuter* IVHS Operational Test incorporates a number of elements central to the FTA APTS program, an integral part of the U.S. Department of Transportation IVHS effort. Table 5 illustrates the components from the FTA APTS Program that are central to the Houston *Smart Commuter* Operational Test.

The Houston *Smart Commuter* Operational Test addresses one of the primary goals of the APTS Program, to enhance the ability of public transportation to satisfy customer needs. This objective will be met by providing customers with real-time traffic and transit information, and access to carpool matching services. The Houston *Smart Commuter* IVHS Operational Test also addresses several other goals and objectives of the FTA APTS Program. The goals and objectives of the FTA APTS program addressed by the Houston Smart Commuter IVHS Operational Test are highlighted in Table 5 and 6, and briefly summarized next.

As noted in Table 5, the Houston *Smart Commuter* IVHS Operational Test will demonstrate two of the concepts central to the FTA APTS program. These are the testing of a dynamic or real-time ridematching system in the I-10 West corridor and the provision of real-time traffic and transit information to commuters in the I-45 North corridor. Both of these elements focus on the use of IVHS technologies to encourage a change in commute mode from driving alone to carpooling, vanpooling or using the bus. Enhancing all types of transit services and encouraging greater use of HOV modes is central to the federal APTS program. In addition, the Houston *Smart Commuter* IVHS Operational Test may utilize AVL and AVI technologies in later phases, supporting additional components of the federal program.

The Houston *Smart Commuter* IVHS Operational Test further addresses a number of specific objectives of the FTA APTS program. As shown in Table 6, the four specific objectives are enhancing the quality of on-street service, improving system productivity, enhancing the contribution of the public transportation system to overall community goals, and expanding the knowledge base of transportation professionals. Thus, the Houston *Smart Commuter* IVHS Operational Test supports and enhances the goals and objectives of the federal APTS program.

Table 5. APTS Elements Incorporated in Houston *Smart Commuter* IVHS Operational Test

APTS Element	Houston *Smart Commuter* Applications
Dynamic ridesharing systems using real-time communication methods with the aid of touch-tone telephone, television, radio, and videotext systems.	Providing quick and easy access to up-to-date information to aid an individual in arranging a carpool or vanpool the same day or evening before a trip.
Passenger information systems using audio, visual, interactive devices at home and at the workplace.	Supplying passengers with real-time information on routes, schedules, cancellations, delays, rerouting, traffic conditions and other aspects of service to make travel easier.
	Supplying potential passengers with public transportation information, in addition to traffic information, in order to encourage the use of alternatives to the automobile mode.
Automated vehicle location (AVL) systems and computerized dispatching techniques.* * As METRO implements an AVL system this may provide the opportunity to test this aspect.	Controlling and monitoring the use of vehicles.
	Estimating vehicle positions to assist dispatchers in improving on-street schedule adherence.
	Assisting in the development of more realistic schedules.
	Facilitating the assignment of individuals to shared ride, demand response services.
	Assisting in the preparation of daily driver logs.

Table 6. APTS Objectives Met by Houston *Smart Commuter* IVHS Operational Test

APTS Objective	Houston *Smart Commuter* Attribute
Enhance the quality of on-street service to customer.	Improve the quality, timeliness, and availability of customer information in the home and at the workplace.
Improve system productivity and job satisfaction.	Improve incident detection and response; and increase the timeliness and accuracy of operating data for service planning and scheduling.
Enhance the contribution of public transportation systems to overall community goals.	Increase the utilization of high occupancy vehicles, with an emphasis on reducing the use of single occupant vehicles.
Expand the knowledge base of professionals concerned with APTS innovations.	Conduct thorough evaluation of operational test and disseminate evaluation information.

The measures of effectiveness outlined in this report for use in evaluating the objectives of the operational test are in concurrence with those outlined for the national evaluation. These measures, as well as the related categories from the national evaluation, are shown in Table 7. All of the measures identified are either quantitative or qualitative. Quantitative measures are expressed in terms of counts, measurements, or other physical units. Qualitative measures are expressed in terms of people's attitudes, perceptions, or observations (7). Further, Table 7 indicates whether the measures are collected, or derived. Collected measures are obtained by measurement, counting, surveying, or from agency records. Derived measures utilize mathematical formulas or analytic models and are based on collected measures (7).

As discussed previously, the local and national evaluations on the Houston *Smart Commuter* IVHS Operational Test will be closely coordinated. The local evaluation will provide the data necessary to complete the national evaluation. Further, the ongoing monitoring and evaluation will appraise local and national agencies of the progress of the operational test, and will provide feedback for operating the test. Examination of these preliminary results may suggest opportunities for modification in the project or the evaluation procedures to increase the utility of the operational test.

Table 7. Measures Used in the Houston *Smart Commuter* IVHS Operational Test

APTS National Evaluation Category	Houston *Smart Commuter* Measure	Type of Measure[1]	Collected /Derived[2]
User acceptance	Actual level of usage at home and at work	Qt	C
	User perceptions of utility	Ql	C
	Results of usage (change in behavior, e.g. mode shift)	Qt	C
Transit system effectiveness	Total passengers	Qt	C
	Mode shift	Qt	C
	Passengers per veh-mi or veh-hr	Qt	D
	Operating cost per passenger or passenger mi	Qt	D
	Operating revenue as percent of operating cost	Qt	D
	Revenue per veh-mi or veh-hr	Qt	D
	Number of incidents or accidents per 100,000 veh-mi or veh-hr	Qt	D
Human factors	Extent to which information device was designed for ease of use by commuters	Ql	C
Institutional	Increase coordination between transit agency, state DOT, and other participating agencies	Ql	C

1 Ql = Qualitative, Qt = Quantitative

2 C = Collected, D = Derived

VI. Conclusions

The Houston *Smart Commuter* Operational Test provides the opportunity to demonstrate and evaluate a number of important concepts relating to IVHS and APTS. This test examines the ability of the application of IVHS technologies to influence a mode change among commuters through the provision of real-time traffic and transit information and the provision of real-time carpool matching services to individuals in their home and workplace. This test also explores possible influences on changes in time of travel, travel route, and not making a planned trip. This test explores the potential and limitations of the delivery of real-time traffic and transit information, as well as provides valuable information concerning the development and operation of such a system.

The results from the I-45 North transit project will enhance the current understanding of the impact the provision of real-time traffic and transit information may have on commuter mode choice, route choice, and travel-time behavior. These results will assist in better understanding the complex factors that influence individual commute behavior.

The results from the I-10 West carpool matching project will likewise provide useful information on the ability to provide real-time carpool matching capabilities and the consumer response to this type of service. As a potentially viable approach to serving suburb-to-suburb travel markets, the results of this portion of the demonstration could have widespread application.

The detailed evaluation of the Houston *Smart Commuter* Operational Test will provide valuable information on the benefits and costs associated with the use of IVHS technology to influence changes in commute mode, commute route, and time of travel. The results will be of benefit to local, state, and national groups interested in the potential benefits of IVHS technology and will be directly applicable in other areas considering similar projects.

This report has presented the local evaluation program for the Houston *Smart Commuter* Operational Test. Additional work is still needed to finalize the surveys, trip diaries, and focus groups that will be used throughout the operational test. These instruments will be finalized through the involvement of both the PMT and with input from the national evaluation consultants.

References

1. Hanks, James W. and Timothy J. Lomax. *Roadway Congestion in Major Urban Areas 1982 to 1988.* College Station, Texas: Texas Transportation Institute, 1990.

2. Texas Transportation Institute. *Houston Smart Commuter IVHS Demonstration Project: Review of Existing Market Research Information.* College Station, Texas: Texas Transportation Institute, October 1990.

3. Texas Transportation Institute. *Houston Smart Commuter IVHS Demonstration Project: Bus and Carpool Concept Definition.* College Station, Texas: Texas Transportation Institute, February 1991.

4. Gelb Consulting Group, Inc. *Exploratory Research on the Smart Commuter Concept.* College Station, Texas: Texas Transportation Institution, March 1991.

5. Texas Transportation Institute. *Houston Intelligent Transportation System.* College Station, Texas: Texas Transportation Institute, April 1991.

6. Turnbull, Katherine F. *Houston Smart Commuter IVHS Demonstration Project: Concept Design and Implementation Program Outline.* College Station, Texas: Texas Transportation Institution, June 1991.

7. Casey, Robert F., and John Collura. *Evaluation Guidelines for the Advanced Public Transportation Systems Operational Tests.* Washington D.C.: U.S. Department of Transportation, Federal Transit Administration, John A. Volpe National Transportation Systems Center, December 1993.

Appendix A

Data Collection Activities

The specific data collection activities that will be a part of the Houston *Smart Commuter* Operational Test can be divided into categories based on the data source. As discussed in this document, data collection activities will focus on obtaining information from participants and monitoring transit, rideshare, and HOV lane use in the I-45 North and I-10 West corridors. The specific data collection activities are outlined in more detail in this appendix.

One source of data will be the information device in participants' homes and offices. This device will have the capability to record data, and transmit this data to the *Smart Commuter* central system. This device will record the number of inquiries per day, the time of inquiries, and the kind of information requested. Data collected by the information device will be collected constantly throughout the duration of the operational test.

A second source of data will be travel diaries and travel surveys completed by participants in the control and sample groups. This data will be collected at various points in the operational test, including before the test, and then six months, twelve months, twenty-four months, and thirty-six months after the operational test has begun. This data will provide information about the participants in the control and sample groups in the I-45 corridor and the participants in the I-10 West element. Data on the number of participants traveling by each mode, the travel route, the time of travel, the number of trips made, the number of commuters who change their travel mode, route, or time of travel, and the average occupancy. Because this data will be collected throughout the operational test, it will facilitate the evaluation of the changes in travel behavior of the sample groups. Samples of a typical travel diary and travel survey are shown in Figures A-1 and A-2; these samples were used in a travel study conducted by the City of Boulder Research & Evaluation Division, as published in the document *Modal Shift in the Boulder Valley, 1990 to 1992*, by Michelle A. Miller and Thomas I Miller. The exact survey to be used in the *Smart Commuter* Operational Test will be developed prior to the before data collection activities.

It will also be necessary to collect data on corridor operations, in an effort to determine the relationship between changes in commuter behavior and corridor operating conditions. Corridor operating conditions are reflected by a number of measures, including bus assignment levels, bus ridership, park-and-ride lot utilization levels, person movement by mode, vehicle movement by mode, transit operating costs, passenger fare revenue, transit pass sales, average peak hour speed, average travel time, accident rate per lane, efficiency per lane (product of average speed and the number of persons moved). Vehicle assignment levels, transit operating costs, passenger fare revenue, and transit pass sales are all data that are routinely collected by METRO. The remaining data listed above generally require manual data collection; the methods of collection are discussed below, and are based on research conducted by the Texas Transportation Institute, as published in *Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities*, by Katherine F. Turnbull, Russell H. Henk, and Dennis L. Christiansen. The methods discussed generally follow those outlined in the Institute of Transportation Engineers' *Manual of Traffic Engineering Studies*, and the Transportation Research Board's *Traffic Data Collection and Analysis: Methods and Procedures*.

City of Boulder Research & Evaluation Division
P.O. Box 791
Boulder, CO 80306
441-3139
September 1992

Please read the instructions before filling out the diary.

ID#:______

TRAVEL DIARY

Please record all your trips whether you are a passenger, driver or pedestrian.

NAME: ______________________
ADDRESS: ______________________
____
DIARY DATE: ___/___/___ (MO DAY YR)

STARTING POINT ADDRESS
Street Address: ______________________
City/State: ______________________

If using motor vehicle, list odometer reading at:
Beginning of Day : ________
End of Day: ________

I did not leave the house today: ☐

TRIP #	DESTINATION	START TIME HOUR	START TIME MIN	START TIME AM/PM	END TIME HOUR	END TIME MIN	END TIME AM/PM	TRIP PURPOSE	TRAVEL METHOD	EST. TRIP MILES	# PERSONS IN VEHICLE
1	Address, Building or Nearest Intersection: ________ ________			__am __pm			__am __pm	1. Go home 2. Personal Business 3. Shopping 4. School 5. Work/Business 6. Social/Recreation 7. Change travel mode 8. Drive a passenger 9. Eat a Meal 10. Other ________	1. Car (driver) 2. Car (passenger) 3. Bus (transit) 4. School Bus 5. Motorcycle 6. Taxi (passenger) 7. Truck (driver) 8. Truck (passenger) 9. Bicycle 10. Walk only 11. Other ________		
2	Address, Building or Nearest Intersection: ________ ________			__am __pm			__am __pm	1. Go home 2. Personal Business 3. Shopping 4. School 5. Work/Business 6. Social/Recreation 7. Change travel mode 8. Drive a passenger 9. Eat a Meal 10. Other ________	1. Car (driver) 2. Car (passenger) 3. Bus (transit) 4. School Bus 5. Motorcycle 6. Taxi (passenger) 7. Truck (driver) 8. Truck (passenger) 9. Bicycle 10. Walk only 11. Other ________		
3	Address, Building or Nearest Intersection: ________ ________			__am __pm			__am __pm	1. Go home 2. Personal Business 3. Shopping 4. School 5. Work/Business 6. Social/Recreation 7. Change travel mode 8. Drive a passenger 9. Eat a Meal 10. Other ________	1. Car (driver) 2. Car (passenger) 3. Bus (transit) 4. School Bus 5. Motorcycle 6. Taxi (passenger) 7. Truck (driver) 8. Truck (passenger) 9. Bicycle 10. Walk only 11. Other ________		
4	Address, Building or Nearest Intersection: ________ ________			__am __pm			__am __pm	1. Go home 2. Personal Business 3. Shopping 4. School 5. Work/Business 6. Social/Recreation 7. Change travel mode 8. Drive a passenger 9. Eat a Meal 10. Other ________	1. Car (driver) 2. Car (passenger) 3. Bus (transit) 4. School Bus 5. Motorcycle 6. Taxi (passenger) 7. Truck (driver) 8. Truck (passenger) 9. Bicycle 10. Walk only 11. Other ________		

Figure A-1. Typical Travel Diary

ID# __________

City of Boulder Research and Evaluation Division
P.O Box 791
Boulder, CO 80303
441-3139
September 1992

HOUSEHOLD TRAVEL SURVEY

Please complete the following survey regarding your household. The survey should only take a few minutes and can be completed before or after you complete your diary. This survey is important because it will help the City's research staff look at how representative the people who participate in the diary study are of Boulder Valley residents as a whole. **Your answers to this survey will be kept in strict confidence and only used in the aggregate.**

As soon as you have completed your travel diary and survey, please return them promptly in the enclosed postage paid envelope. A prompt response on your part will alleviate the need for the City's research assistants to call you and ask for your diary information and the survey.

Thank you again for your time and help.

GENERAL TRAVEL INFORMATION

1. How many passenger cars, vans, and light trucks does your household own or normally have use of? ____

   1a. How many bicycles does your household own? _____

2. For all adult full-time or part-time workers living in your home, please check the box that indicates the city nearest which their jobs exist. Please include yourself as Person 1.

	Person 1	Person 2	Person 3	Person 4	Person 5
Boulder					
Louisville					
Lafayette					
Other					

	Person 1	Person 2	Person 3	Person 4	Person 5
Longmont					
Broomfield					
Denver					

3. Please check only one travel mode to indicate how each full or part time adult worker or student in this household usually gets to work or school. Choose only one mode per person. Include yourself as Person 1.

MOST FREQUENT MODE OF TRAVEL:	Person 1	Person 2	Person 3	Person 4	Person 5
In Auto with no passengers					
In Auto with at least one other adult					
Bicycle					
Bus					
Walk					
Other (please explain)					

4. About how close is the nearest bus stop to your residence?

_____ A. Less than 1 block
_____ B. 2 - 5 blocks
_____ C. 6 -10 blocks
_____ D. 11 - 15 blocks
_____ E. 16 - 20 blocks
_____ F. More than 20 blocks
_____ G. Don't know

(Please Continue on Reverse Side)

Figure A-2. Typical Travel Survey

HOUSEHOLD INFORMATION

5. Check the one choice listed below which best describes the kind of residence in which you now live.

a. A detached single family home		e. A mobile home	
b. A duplex or triplex		f. An apartment in a formerly single family home	
c. An apartment in a complex with four or more units		g. Group quarters (Dorm, Greek house, nursing home)	
d. A condominium or townhouse		h. Other (Please describe):	

6. Record the number of household members in each of the following age categories. Please include yourself.

AGE	NUMBER	AGE	NUMBER
0 - 6 years old		36-45 years old	
7-14 years old		46-55 years old	
15-17 years old		56-65 years old	
18-25 years old		Over 65 years old	
26-35 years old			

7. Do any of the household members have access problems due to mobility impairment?

A. No ____ B. Yes ____ If yes, how old is the person(s)? ___ ___ ___

8. Do you have any University of Colorado students living in your household?

A. No ____ B. Yes ____

If yes, how many are full-time? ____ part-time? ____

Are you one of these students? A. No ____ B. Yes ____

INDIVIDUAL INFORMATION

Please check the appropriate gender and age for yourself:

9. Gender

Male: ____ Female: ____

10. Age

16-25 ____ 26-35 ____ 36-45 ____ 46-55 ____ 56-65 ____ Over 65 ____

Please check the line that comes closest to describing your ethnicity and the education you have completed.

11. Ethnicity

White ____
Black ____
Asian ____
Native Amercian ____
Hispanic ____
Other ____

12. Education

0 to 11 years ____
Completed High School ____
1-3 years of College ____
4 years of College ____
5+ years of College ____

Thank you very much for taking the time to complete this survey. Please return this with your diary in the postage paid envelope provided.

Figure A-2. Typical Travel Survey (Continued)

Vehicle and occupancy counts will be taken on the freeway mainlanes, on the HOV lanes, and on the freeway frontage roads. Vehicle and occupancy counts will be performed manually during the morning and afternoon peak periods on the HOV lanes, and on the freeway mainlanes in the peak direction. Counts will be taken at one location for the freeway mainlanes on I-45 North, at two locations for the freeway mainlanes on I-10 West, and at two locations for the HOV lanes on I-10 West and I-45 North. An additional count location is used on the I-45 North HOV lane to account for the different access points. The count sites were selected based on their provision of an unobstructed view of the freeway, allowing the observers to clearly and accurately see vehicles in both the morning and afternoon from the site. Count sites were also selected with consideration given to the safety afforded to the observers. While the HOV lane and freeway count locations are in the same general vicinity, they are not always at the exact same location, due to safety concerns. For both I-45 North and I-10 West, at least one count location will be used to collect vehicle and occupancy information for both the HOV lane and the freeway mainlanes. Vehicle and occupancy count locations are shown in Figure A-3.

Vehicle and occupancy counts will be conducted in 15 minute intervals on both mainlanes and HOV lanes. On freeways, vehicle classification and occupancy counts are taken only on the middle lane. Only vehicle counts and general classification (automobile or commercial) are taken in the other lanes. The occupancy data obtained for the middle lane, with the exception of buses and vanpools, have been shown to provide a reasonable representation of occupancy characteristics for vehicles utilizing the freeway mainlanes in the peak direction of flow (based on historical data for the Houston freeway system). This reduces the need to collect occupancy data for cars and commercial vehicles on the remaining freeway lanes. The occupancy rates observed in the middle lane are then applied to the vehicles in the other lanes to produce the overall person volume estimates for the entire freeway in the peak direction of flow. Data sheets for the vehicle and occupancy information from the middle lane, and vehicle and classification information from the other lanes, are shown in Figures A-4 and A-5.

With respect to vehicle classification on the mainlanes, automobiles, pick-up trucks, minivans, and motorcycles will be classified as cars. Commercial vehicles include taxi cabs, commercial vehicles (delivery trucks, dump trucks, etc.), large emergency vehicles, and large trucks. Since buses and vanpools exhibit occupancy rates that are significantly higher in range and magnitude than those of cars or commercial vehicles, making inferences about the occupancy rates of the other lanes based on those observed in the middle lane could produce serious errors. To reduce this risk, the occupancy rates of buses and vanpools utilizing the other lanes will be individually recorded on the data sheet shown in Figure A-4.

The observed general bus passenger levels are translated into specific occupancy rates based on the utilization levels identified in Table A-1. A person-carrying capacity of 50 persons will be used for all standard size buses, including standard Metro buses, school buses, and charter buses, while the capacity of articulated buses will be estimated to be 70 persons. Since it is often difficult to observe passenger levels through the tinted bus windows, the accuracy of this procedure will be checked periodically by counting the number of individuals boarding buses at selected locations. These detailed counts will be compared to the survey results, and adjustments to the estimating process will be made as needed.

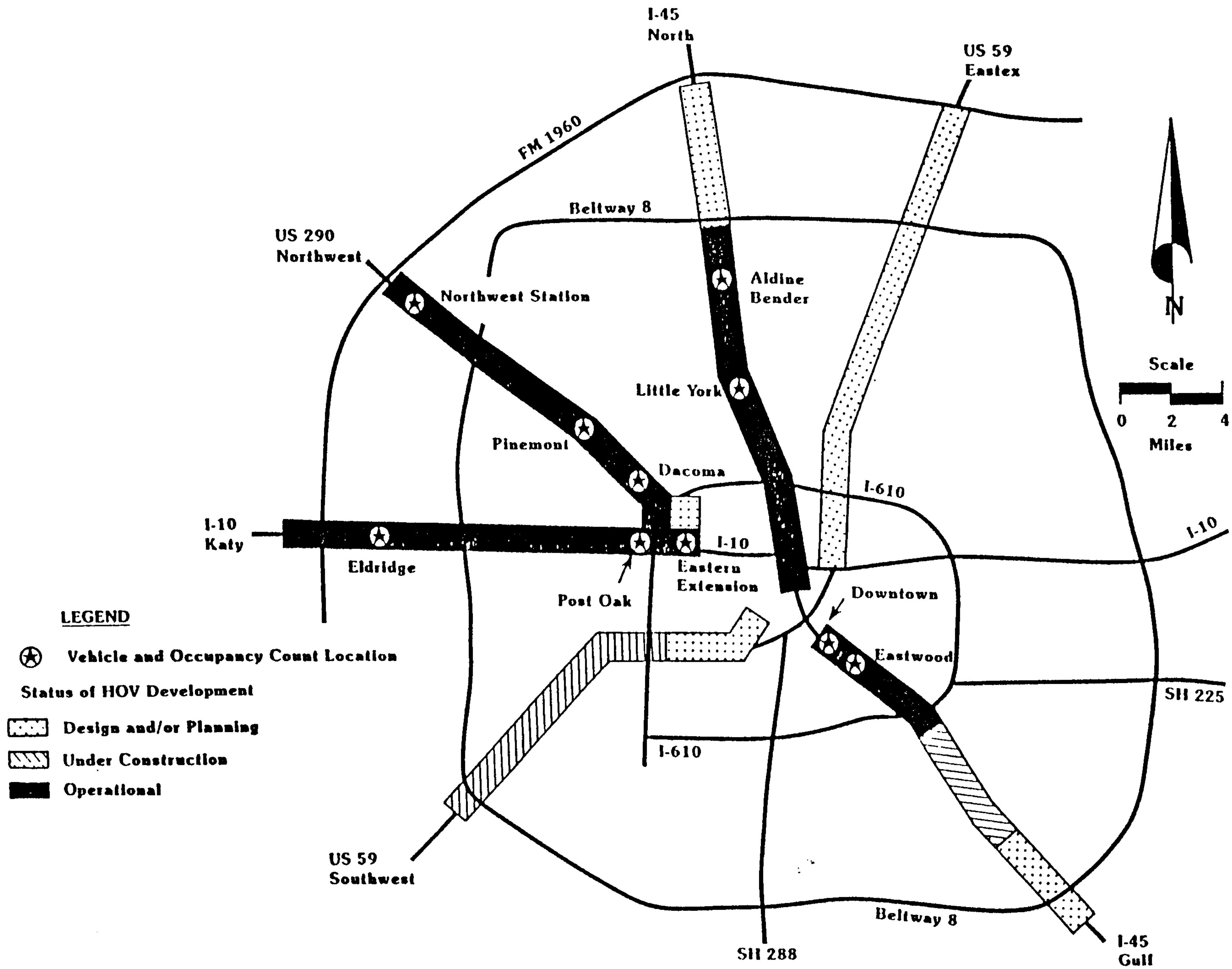

Figure A-3. Vehicle and Occupancy Count Locations

TTI VEHICLE OCCUPANCY DATA

Facility: ______________ Weather: ______________

Time: ______________ Recorder: ______________

Date: ______________ Lane: ______________

Vanpools

1-3	
4-6	
7-9	
10-12	
13+	

Buses

Empty	
1/4 Full	
1/2 Full	
3/4 Full	
Full	
Full+	

Pickups/Passenger Cars

1	
2	
3	
4+	

Commercial

1	
2	
3	
4+	

Motorcycles

Frontage Road Volumes

Trucks 18-Wheelers

1	
2	
3	

Taxi Cabs

1	
2	
3	
4+	

Figure A-4. Vehicle Occupancy Data Sheet, Freeway Mainlanes

TTI BY LANE VEHICLE VOLUMES (Freeway)

FACILITY: ____________________ WEATHER: ____________________

DATE: ____________________ RECORDER: ____________________

Begin Time	Code Time	Lane ______		Lane ______		Lane ______	
		Cars	Commercial	Cars	Commercial	Cars	Commercial
3:30	15						
3:45	16						
4:00	17						
4:15	18						
4:30	19						
4:45	20						
5:00	21						
5:15	22						
5:30	23						
5:45	24						
6:00	25						
6:15	26						
6:30	27						
6:45	28						

Figure A-5. Vehicle Volume Data Sheet, Freeway Mainlanes

Table A-1. Bus Person Volume Estimates for Different Passenger Utilization Levels

Type of Bus	General Status of Bus Occupancy[1]	Estimated Number of Persons Aboard Bus[2]
Standard Size[3]	Empty	1
	1/4 Full	10
	1/2 Full	20
	3/4 Full	30
	Full	40
	Full +[4]	50
Articulated[5]	Empty	1
	1/4 Full	15
	1/2 Full	30
	3/4 Full	45
	Full	60
	Full +[4]	70

1 Estimated portion of bus that is occupied by passengers.

2 Corresponding estimate of the number of passengers based on a seating capacity of 40 persons for standard size buses and 60 persons for articulated buses.

3 Includes Metro buses, school buses, and charter buses.

4 Refers to the ultimate capacity of the bus: all seats full and passengers standing in the aisle.

5 Refers to Metro buses that are longer than standard size buses and that have a permanent hinge near the center which enhances maneuverability.

Vehicle and occupancy counts for the HOV lane will be taken during the same periods as the freeway counts, in 15 minute intervals, utilizing the data sheets shown in Figure A-5. Vehicles utilizing the HOV lane are classified as carpools, vanpools, and buses. Only full-sized vans will be considered to be vanpools, minivans will be classified as carpools. The same approach described for the freeway counts will be used with the HOV lane counts. The general bus passenger levels that are observed will be translated into specific occupancy rates using the values provided in Table A-1.

With respect to park-and-ride lot utilization, counts of parked vehicles will be conducted during the midday at both the Kuykendahl and Addicks park-and-ride lots. These counts will be performed on a monthly basis. The number of vehicles parked at each facility will recorded during the middle of the day on weekdays. The data sheet shown in Figure A-7 will be used to record this information. Information on bus assignment levels, transit operating costs, passenger fare revenue, and transit pass sales will be provided by METRO.

Travel time and speed data for the mainlanes and HOV lanes will be gathered using the automatic vehicle identification (AVI) system currently in place. This system identifies automobiles that have a transponder as they pass AVI readers along I-10 West and I-45 North. A computer program, which is currently in place, can then automatically calculate the travel time and speed on the facility (travel times are screened to eliminate vehicles that exited the freeway between AVI readers). Travel times and speeds will then be relayed to the *Smart Commuter* central system, so this information can be disseminated to participants at their homes and offices. Accident data and construction information, for both the freeway mainlanes and the HOV lanes, will also be provided to the *Smart Commuter* central system for dissemination to participants. Accident and construction information will be provided by the Greater Houston Traffic Management Center.

Finally, in order to evaluate the effectiveness of the information device, participants in the sample groups will be surveyed to attain their evaluation of the information devices. This survey will attempt to ascertain qualitative aspects that reflect the success of the human factors elements of design such as ease of use, and the clarity of the information provided. In addition to the utilization of maintenance records, participants will be queried on more objective aspects of the device's utility, such as machine malfunction/reliability.

HOV OCCUPANCY SUMMARY

DATE: ____________

LOCATION: ____________ OBSERVER: ____________

TIME	Buses						Vanpools					Carpools				
	E	1/4	1/2	3/4	F	F+	1-3	4-6	7-9	10-12	13+	1	2	3	4	5+
3:30PM																
3:45PM																
4:00PM																
4:15PM																

Figure A-6. Vehicle Occupancy and Classification Data Sheet, HOV Lanes

Month:
Project:

Freeway Corridor	Name of Lot	Number of Parked Vehicles	Date
Katy (I-10W)	1. Kingland		
	2. Fry		
	3. Addicks		
	4. West Belt		
	5. Mason		
	6. Barker-Cypress		
North (I-45N)	1. N Sheperd		
	2. Kuykendahl		
	3. Spring		
	4. Seton Lake		
	5. Woodlands		
Gulf (I-45S)	1. Edgebrook		
	2. Bay Area		
Southwest (US 59S)	1. Sharpstown		
	2. West Loop		
	3. Westwood		
	4. Alief-Boone		
	5. Missouri City		
Eastex (US 59N)	1. Kingwood		
	2. Eastex		
Northwest (US 290N)	1. NW Station		
	2. W Little York		
	3. Pinemont		
I-10E	1. Maxey		

Figure A-7. Data Collection Sheet for Park-and-Ride Lot Counts