Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
SWUTC/95/60012-1		

4. Title and Subtitle	5. Report Date
Dallas Area Rapid Transit LRT Starter Line Assessment Study Design	March 1995
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Gordon A. Shunk, Katherine F. Turnbull, and Nell Frazer Lindquist	Research Report 60012

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute The Texas A&M University System College Station, TX 77843-3135	11. Contract or Grant No. 0079

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Southwest Region University Transportation Center Texas Transportation Institute The Texas A&M University System College Station, TX 77843-3135	Final
	14. Sponsoring Agency Code

15. Supplementary Notes

Research supported by a grant from the Office of the Governor of the State of Texas, Energy Office

16. Abstract

Light rail transit (LRT) systems have recently been implemented in a number of urban areas throughout the United States and additional projects are in various stages of planning and development. Questions have been raised concerning the impact of these systems on ridership levels, transit operating costs, regional mobility, land use, economic development, energy, air quality, congestion levels, and other factors. The implementation of the Dallas Area Rapid Transit (DART) LRT starter line provides the opportunity to assess the impact of an LRT system in a Southwestern city in the United States.

This research project was undertaken to assist with the development of a comprehensive study design for assessing the effects of the DART LRT starter line. To accomplish this objective, a review was conducted of before-and-after studies of recent LRT, heavy rail, and high-occupancy vehicle (HOV) projects. The goals and objectives of the DART system were also reviewed and existing transportation-related data collection activities in the Dallas area were examined. This information was used to develop a preliminary study design for assessing the effects of the DART LRT starter line. This report documents the review of recent before-and-after studies and presents the preliminary study design for assessing the effects of the DART LRT starter line.

17. Key Words	18. Distribution Statement
Light rail transit, LRT, Transit Impacts, HOV, Before-and-after assessments	No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	71	

DALLAS AREA RAPID TRANSIT LRT STARTER LINE ASSESSMENT STUDY DESIGN

by

Gordon A. Shunk
Research Engineer

Katherine F. Turnbull
Research Scientist

Nell Frazer Lindquist
Assistant Research Scientist

Sponsored by

Southwest Region University Transportation Center
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

March 1995

ABSTRACT

Light rail transit (LRT) systems have recently been implemented in a number of urban areas throughout the United States and additional projects are in various stages of planning and development. Questions have been raised concerning the impact of these systems on ridership levels, transit operating costs, regional mobility, land use, economic development, energy, air quality, congestion levels, and other factors. The implementation of the Dallas Area Rapid Transit (DART) LRT starter line provides the opportunity to assess the impact of an LRT system in a Southwestern city in the United States.

This research project was undertaken to assist with the development of a comprehensive study design for assessing the effects of the DART LRT starter line. To accomplish this objective, a review was conducted of before-and-after studies of recent LRT, heavy rail, and high-occupancy vehicle (HOV) projects. The goals and objectives of the DART system were also reviewed and existing transportation-related data collection activities in the Dallas area were examined. This information was used to develop a preliminary study design for assessing the effects of the DART LRT starter line. This report documents the review of recent before-and-after studies and presents the preliminary study design for assessing the effects of the DART LRT starter line.

ACKNOWLEDGMENTS

This publication was developed as part of the University Transportation Centers Program which is funded 50 percent in oil overcharge funds from the Stripper Well settlement as provided by the Texas State Energy Conservation Office and approved by the United States Department of Energy. The study was also co-funded by Dallas Area Rapid Transit (DART). The contents of this report reflect the views of the authors who are responsible for the findings and conclusions presented herein. The contents do not necessarily reflect the official view or policies of the funding agencies. This report does not constitute a standard, specification, or regulation, and is not intended for construction, bidding, or permitting purposes. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

A number of TTI personnel assisted with this study. In addition to the authors, significant contributions were made by Rose Roberts, Graduate Assistant Research, Patricia Bass, Associate Research Scientist, Laura Higgins, Assistant Research Scientist, Pam Rowe, Technical Secretary, and Bonnie Duke, Administrative Assistant. The assistance of these individuals is acknowledged and greatly appreciated.

EXECUTIVE SUMMARY

Introduction

Dallas Area Rapid Transit (DART) is implementing a light rail transit (LRT) system in the Dallas area. The initial 20-mile LRT line, which is scheduled to open in 1996, will link West Oak Cliff, South Oak Cliff, downtown Dallas, and the Park Lane area. The DART LRT line represents the first LRT system to be implemented in Texas and, with the exception of California, the first system in the Southwestern United States.

In order to better understand the impacts of the LRT system on transit ridership levels, transit operating costs, land use, air quality and other elements, DART is considering conducting a before-and-after assessment of the LRT starter line. A first step in the development of such an evaluation is the identification of an assessment study design. The Texas Transportation Institute (TTI), a part of The Texas A&M University System, and the Center for Transportation Research (CTR) at the University of Texas at Austin, assisted DART with the development of the assessment study design. Funding for the study design was provided by the Southwest Region University Transportation Center (SWUTC) and DART.

Research Activities

A number of activities were conducted to assist in the development of the DART LRT Starter Line Assessment Study Design. These included a review of evaluation studies from other recent fixed-guideway transit systems, an examination of DART's goals and objectives, and a review of current transportation related data collection activities in the Dallas area. This information was used to develop a preliminary DART LRT Starter Line Assessment Study Design. An Advisory Committee comprised of local, state, and national experts also provided advice and guidance throughout the project.

A first step in the development of the DART Assessment Study Design was a state-of-the-art review of current rail transit impact studies and evaluations of recent fixed-guideway transit systems. The purpose of this analysis, which examined studies of LRT, heavy rail transit systems, and HOV facilities, was to identify common elements included in these evaluations, the criteria and measures of effectiveness utilized, the data collection methodologies and techniques employed, and any specific issues or problems encountered during the course of the studies. The results from this review were used to help focus the DART study design on the essential factors an LRT system may impact and the appropriate evaluation methods.

Second, the goals and objectives of the DART system and the starter LRT line were examined to help identify the key factors to be included in the assessment. Existing data collection activities in the Dallas area were also reviewed to identify information that could be used in the assessment and to avoid possible duplication of effort.

An Advisory Committee, comprised of individuals with experience conducting similar evaluations and representatives from local agencies, assisted with the development of the DART

Assessment Study Design. The Advisory Committee provided insights into various aspects of previous evaluation studies and assisted with the identification of the key elements to be included in the DART study.

DART LRT Starter Line Assessment Study Design

The recommended DART Assessment Study Design includes seven major components. These are the purpose of the assessment, the approach and phasing of the assessment, the focus areas for the assessment, a preliminary schedule, a preliminary budget, a suggested management approach, and the next steps in the process. Each of these components are briefly described.

Purpose of Assessment—The purpose of the DART LRT Starter Line assessment is to enhance the understanding of the principal effects of an LRT system in Dallas. Thus, the primary goal of the assessment is to provide information to local transportation professionals and decision makers on the impacts of the LRT Starter Line. In the short-term, this information can be used to expand and enhance the positive impacts of the system, and to address and mitigate any negative aspects. Over the longer term, the study results can be used in planning future LRT extensions and other related projects in the Dallas area.

On a secondary level, the results of the DART LRT Starter Line assessment will be of interest and of benefit at the state and national levels. Information from the DART study could be utilized by other cities in Texas considering LRT systems. Given the unique characteristics of Texas and other Southwestern cities, the results from the DART assessment will be of special value to other transit systems in these areas. Thus, the DART assessment study can assist in establishing an ongoing national database on LRT systems.

Approach and Phasing—A comprehensive approach, covering all time periods, is proposed for the DART LRT Starter Line Assessment. A five phased study design is proposed to accomplish this objective. The major component of the five phases—before, initial operation, full operation, after, and ongoing monitoring—are summarized below.

- **Before.** The before phase will document existing conditions for a wide range of factors. The before data will establish the base line against which future conditions will be measured. The before data collection should be initiated as soon as possible to assure that an accurate base line is established. Construction activities, especially those along the North Central Expressway, may have already influenced changes in travel patterns and traffic volumes. A good base line can still be developed, however, with special consideration given to the possible impacts of construction activities. The before assessment should be comprehensive to ensure that the base conditions are adequately documented. It may be better to err on the side of too much, rather than too little, before data.

- **Initial Operation.** The second phase of the assessment should occur after the system has been in operation for six months. The intent of this phase is to

provide an interim picture of the system shortly after opening. Data collection activities in this phase would be limited and would focus on operational factors.

- **Full Operation.** The third phase of the assessment should cover the full operation of the DART LRT Starter Line. The third phase would occur after at least a full year of operation and would involve more extensive data collection and analysis. In addition to operational measures, this phase would also examine mobility impacts and attitudinal changes.

- **After.** The fourth phase represents the major focus of the assessment. This phase would be conducted after the LRT Starter Line has been in operation for 3 to 5 years. Thus, the intent of this phase is to measure the impacts of a mature system. A comprehensive data collection and analysis program would be conducted in this phase, closely replicating the effort undertaken in the before phase. It is important that this phase be conducted before other LRT lines are opened.

- **Ongoing Monitoring.** An ongoing monitoring and evaluation program should be continued to measure the long-term impacts of the LRT line. This phase would focus on elements such as land use and development changes, as well as ongoing monitoring of transit ridership levels, travel patterns, and traffic conditions.

Focus Areas—Five focus areas, or principal areas of study, are proposed for the DART LRT Starter Line Assessment. These are mobility, development and land use, environment, costs, and community attitudes. Each of these contain a number of elements and will require a variety of data collection activities. In combination, they provide a comprehensive assessment of the possible impacts of the DART LRT Starter Line, however. The five focus areas are briefly described next, along with the major data collection and monitoring activities associated with each.

- **Mobility Impacts.** Elements to be examined in this focus area include transit ridership levels, traffic conditions, travel trends, and accessibility changes. The analysis will focus on the travel sheds served by the LRT lines and the control corridor.

- **Development and Land Use.** This focus area will monitor and document changes in development and land use patterns around DART LRT stations and in the LRT corridors. A comprehensive before survey of land uses and developments should be conducted in the LRT station areas and corridors should be initiated to develop the base line. Given the experience in other cities, the land use and development impacts of the DART LRT system can be expected to happen slowly over a period of years. Thus, an ongoing monitoring program is critical for this focus area.

- **Environment**. Three potential environmental impacts are proposed to be examined in this focus area. These are air pollution and air quality levels in station areas, noise levels in station areas and in LRT corridors, and crime in station areas.

- **Costs**. The capital and operating costs of the LRT Starter Line will be examined as part of the overall assessment. The focus of this effort will be on comparing the actual capital and operating costs with those estimated during the planning process. Any differences will be examined along with the factors influencing the changes. Although it is not anticipated that these elements will be examined in as much detail as other impacts, they can provide useful information for planning future extensions and for other cities considering LRT systems.

- **Community Attitudes**. The attitudes of riders, the community as a whole, developers and businesses, and decision makers will be examined in this step. The attitudes and perceptions of these groups toward the LRT system, and its impact, will be examined through a series of special surveys, interviews, and focus groups. It is realized that many of these perceptions may not be quantifiable, but they are important nonetheless.

Preliminary Schedule—A multi-year schedule is proposed for the DART LRT Starter Line Assessment. As discussed previously, this is necessary since many of the impacts of the LRT system will emerge over time. The before or base year inventory should be initiated as soon as possible to provide the best information on conditions before the final construction activities and opening of the system in 1996. It is realized that the schedule may change depending on the timing of the actual opening and different elements of the LRT system.

Estimated Budget—The estimated cost for the first three phases—before, initial operation, and full operation—is approximately $2 million.

Suggested Management Approach—Most of the fixed-guideway evaluation studies examined as part of this research project were managed by the metropolitan planning organization (MPO) or other regional organization. Although the transit agency and other agencies responsible for the fixed-guideway system were actively involved in the evaluation process, they were not responsible for the overall conduct of the studies. This approach helps ensure objectivity in the evaluations.

To help maintain objectivity with the DART Starter Line Assessment, it is suggested that TTI continue to take the lead role in the actual evaluation. This would be very similar to the role TTI plays in the ongoing assessment of the East R. L. Thornton HOV lane in Dallas and the HOV lane system in Houston. An interagency Advisory Committee and an expert Advisory Committee would be used to help guide the assessment and ensure coordination among the different agencies.

Next Steps—The next steps needed to initiate the assessment include securing the necessary funding, developing any interagency agreements that may be needed, organizing the interagency and expert Advisory Committees, and finalizing a more detailed work plan. DART, working with NCTCOG, FTA, and others can identify appropriate funding sources for the assessment. Grant applications and other agreements can then be developed. Once funding is secured, any needed interagency agreements can be developed, the various advisory committees can be established, a detailed work plan can be finalized, and the assessment can be initiated.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE—INTRODUCTIONS

Dallas Area Rapid Transit (DART) is in the process of developing a light rail transit (LRT) system in the Dallas area. The LRT system represents one component of the 20-year DART *Transit System Plan* (1). In addition to LRT, the plan includes high-occupancy vehicle (HOV) lanes, commuter rail, roadway improvements, and bus service enhancements. The initial 20-mile LRT line, which is scheduled to open in 1996, will link West Oak Cliff, South Oak Cliff, downtown Dallas, and the Park Lane area. The Dallas line represents the first LRT system to be implemented in Texas and, with the exception of California, in the Southwestern United States.

In order to better understand the impacts of the LRT system on transit ridership levels, operating costs, land use, air quality and other elements, DART is considering the development of a before-and-after assessment of the LRT starter line. A first step in this effort is the identification of the assessment study design. This step is necessary to help ensure that the analysis focuses on those factors most likely to be influenced by the LRT system and that valid measuring and monitoring techniques are used in the assessment. The Texas Transportation Institute (TTI), a part of The Texas A&M University System, and the Center for Transportation Research (CTR) at the University of Texas at Austin, assisted DART with the development of the assessment study design. Funding for the study design was provided by the Southwest Region University Transportation Center (SWUTC) and DART.

A number of activities were conducted to assist in the development of the DART LRT Starter Line Assessment Study Design. These included a review of evaluation studies from other recent fixed-guideway transit systems, an examination of DART's goals and objectives, and a review of current transportation related data collection activities in the Dallas area. This information was used to develop the preliminary study design outlined in this report. An Advisory Committee comprised of local, state, and national experts also provided advice and guidance throughout the project.

Background

Light rail transit and other fixed guideway transit systems have been and are continuing to be considered in Texas cities and in metropolitan areas throughout the country. Ongoing discussions have occurred in many of these areas over the potential impacts of LRT, heavy rail, and HOV facilities on transit ridership levels, transit operating costs, regional mobility, land use, economic development, energy, air quality, and congestion levels. A number of factors contribute to the uncertainty over the possible impacts of these systems. In some instances, no efforts have been made to try to measure potential impacts of new systems. In other cases, before-and-after evaluations have been conducted, but have provided inconclusive results. Some studies have suffered from focusing on impacts that are difficult or impossible to measure or evaluate. The lack of sustained ongoing efforts, which are necessary to determine impacts that may emerge over time, have also been an issue in some areas.

The implementation of the DART starter LRT line provides the opportunity to document the influences of the system on different elements of the transportation system, land use, and the environment. The results of this assessment will have both local and national benefits. At the local level, the assessment will provide DART, member municipalities, and others with a better idea of the effects of the starter LRT line on ridership levels, operating costs, land use, air quality, and other issues. This information will be of value in planning and implementing future segments of the system. At the state and national level, the assessment will contribute to expanding and enhancing the understanding of the impacts of LRT systems. The preliminary study design presented in this report may also be of use in other areas implementing new LRT and fixed-guideway transit systems.

A first step in the development of the DART Assessment Study Design was a state-of-the-art review of current rail transit impact studies and evaluations of recent fixed-guideway transit systems. The purpose of this analysis, which is documented in this report, was to identify common elements included in these evaluations, the criteria and measures of effectiveness utilized, the data collection methodologies and techniques employed, and any specific issues or problems encountered during the course of the studies. The results from this review were used to help focus the DART study design on the essential factors an LRT system may impact and the appropriate evaluation methods.

Second, the goals and objectives of the DART system and the starter LRT line were examined to help identify the key factors to be included in the assessment. Existing data collection activities in the Dallas area were also reviewed to identify information that could be used in the assessment and to avoid possible duplication of effort.

An Advisory Committee, comprised of individuals with experience conducting similar evaluations and representatives from local agencies, assisted with the development of the DART Assessment Study Design. The Advisory Committee provided insights into various aspects of previous evaluation studies and assisted with the identification of the key elements to be included in the DART study. A listing of the members of the DART Assessment Study Design Advisory Committee is provided in Table 1.

The results of these activities are documented in this report, along with the recommended DART Assessment Study Design. The study design can be used to help guide a DART before-and-after assessment. It will also help ensure that the assessment focuses on the key characteristics and uses appropriate data collection, measurement, and evaluation techniques.

Table 1. DART Assessment Study Design Advisory Committee

Member	Representing
Ronald Thorstad	Dallas Area Rapid Transit (at time of the study)
Paul Bay	BRW, Inc.
Dennis Christiansen	Texas Transportation Institute
Robert Dunphy	The Urban Land Institute
Clifford Keheley	City of Dallas
Michael Morris	North Central Texas Council of Governments
Kenneth Mowill	Federal Transit Administration
John Sedlak	Metropolitan Transit Authority of Harris County
Joel Stone	Atlanta Regional Commission
C. Michael Walton	University of Texas at Austin

Organization of this Report

Following this introduction, the report is organized into three chapters. A description of the DART LRT starter line is provided in the next chapter, along with the agency's goals and objectives. Existing transportation-related data collection activities in the Dallas area are also highlighted in Chapter Two. Chapter Three presents a review of the main elements associated with recent evaluations of fixed-guideway transit systems. This analysis includes an examination of the elements included in recent before-and-after studies, data collection techniques, and the impacts documented to date. The report concludes with an outline of the DART LRT Assessment Study Design in Chapter Four and possible next steps in the evaluation process.

CHAPTER TWO—OVERVIEW OF THE DART LRT STARTER LINE AND CURRENT DATA COLLECTION ACTIVITIES

This chapter provides an overview of the DART LRT Starter Line, DART principles and key evaluation criteria, and the current transportation-related data collection activities in the Dallas area. This information helps establish the framework for an assessment of the DART LRT Starter Line. It also provides an indication of the ongoing monitoring efforts already underway in the Dallas area that may be used for the DART assessment.

DART LRT Starter Line

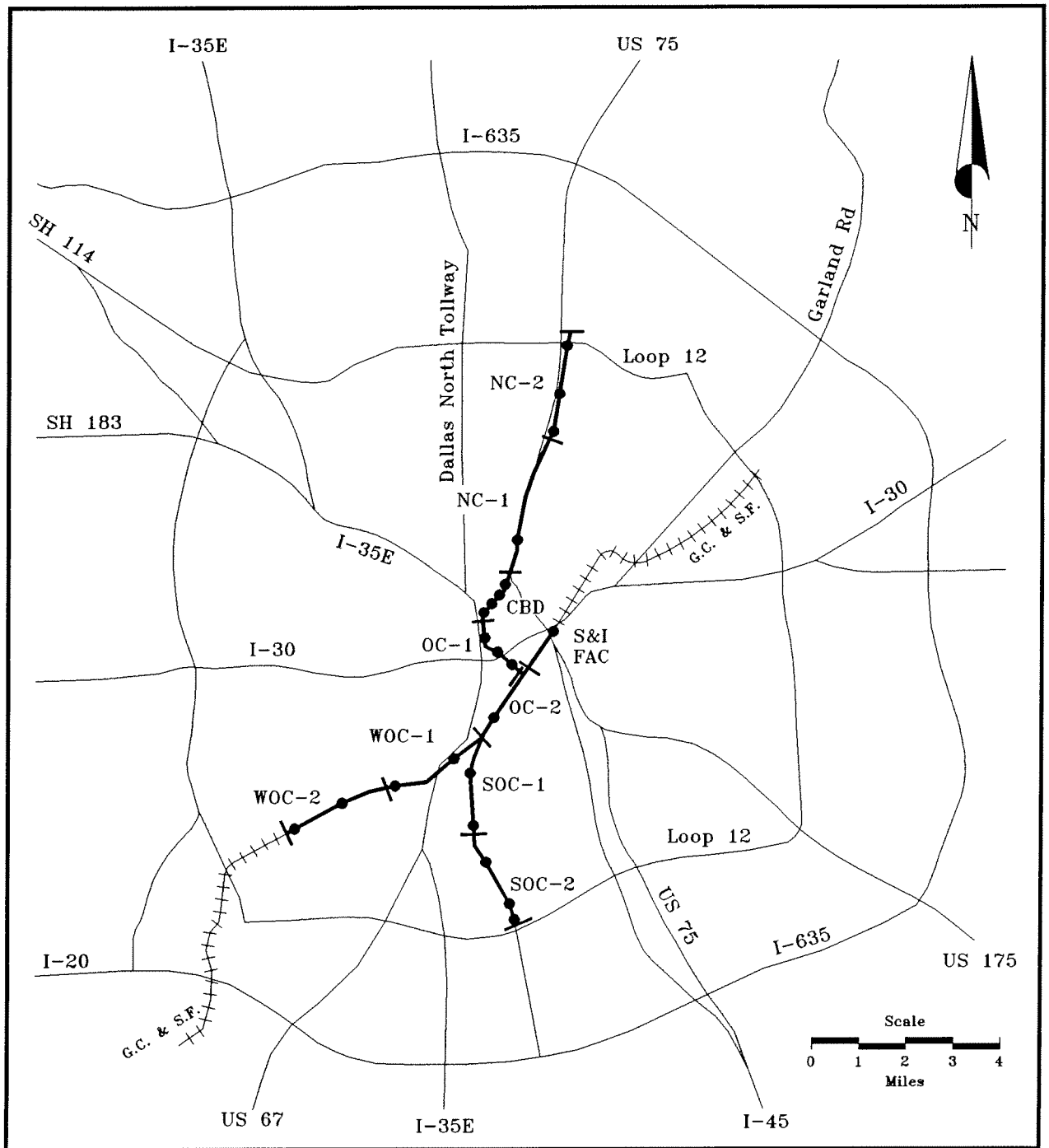
State legislation in Texas allows for the formation of regional metropolitan transit authorities (MTAs), which can be funded with up to a one-cent sales tax on approval of the voters. Dallas Area Rapid Transit (DART) was established in 1983. Residents of Dallas and the surrounding suburbs voted to create DART and approved a one-cent sales tax to fund the agency. Based on state legislation addressing MTAs, DART has broad powers to plan, design, construct, and operate a variety of transit services.

Exercising this authority, DART is moving forward with a 20-year *Transit System Plan* (1) for the Dallas metropolitan area. Elements of this plan include the LRT starter line, commuter rail between Dallas and Fort Worth, HOV lanes, bus service enhancements, and roadway improvements. The development of these components is funded on a "pay as you go" philosophy, with no long-term debt anticipated.

The 20-mile LRT starter line represents a major component of the 20 year plan. As illustrated in Figure 1, the initial system provides radially-oriented LRT lines connecting the Dallas Central Business District (CBD) with major activity centers to the north and to the south. The starter line is divided into five general segments; North Central, CBD, Oak Cliff, South Oak Cliff, and West Oak Cliff. Provisions for system expansion have also been provided. As shown in Figure 1, these include future lines to Garland, Richardson, and Pleasant Grove.

The LRT starter line includes both at grade and tunnel sections. Further, it includes LRT stations, 3 transit centers, and a vehicle maintenance building. The maintenance building will support DART rail and bus requirements. The new facility will allow for the consolidation of bus services, Handi Rides services, and the DART transit police, along with the LRT. Major elements of the system are highlighted next.

- **LRT Stations**. The LRT starter lines serves 18 stations and three major transit centers. Four stations serve the downtown area, with additional stations at the Convention Center and Union Station. The other stations are located at City Park, Mockingbird, Lovers Lane, and Park Lane along North Central Expressway Corridor; Corinth, Morrell, West, and the VA Hospital along the Oak Cliff section; and the Zoo, Tyler-Vernon, and Westmoreland along the West Oak Cliff section.



Key	Description	Status
NC-2	North Central Section 2	Under Construction
NC-1	North Central Section 1	Under Construction
S&I FAC	Service & Inspection Facility	Under Construction
OC-1	Oak Cliff Section 1	Under Construction
OC-2	Oak Cliff Section 2	Under Construction
CBD	Central Business District	Under Construction

Key	Description	Status
WOC-1	West Oak Cliff Section 1	Under Construction
WOC-2	West Oak Cliff Section 2	Under Construction
SOC-1	South Oak Cliff Section 2	Under Construction
SOC-2	South Oak Cliff Section 1	Under Construction
SOC-2A	South Oak Cliff Section 2A	Combined to Bid Mid 1994
SOC-2B	South Oak Cliff Section 2B	
●	Station Site	
———	Under Construction	

Figure 1. DART LRT Starter Line

- **Three Transit Centers**. Three LRT/Bus Transit Centers are being constructed as part of the project. The Illinois, Hampton, and Ledbetter Transit Centers include enclosed passenger waiting areas, bus bays, rest rooms, and park-and-ride lots. Parking spaces for 350 will be provided at the Illinois Transit Center, with 500 spaces at the Hampton Center and 400 spaces at the Ledbetter Center. The Illinois and Hampton Centers will operate as bus transit stations until the LRT system is open, while bus and LRT service will start at the same time at the Ledbetter Center.

- **Facility Maintenance Building**. The LRT Service and Inspection (S&I) facility will be located just south of I-30E to the east of I-45. The facility will support both LRT and bus maintenance requirements. It will allow all bus, LRT, HandiRide, and transit police functions to be consolidated in one building.

Construction on the LRT starter line began in 1990, with the relocation of San Jacinto Street. Major construction activities were initiated in 1992 with the tunnel along the North Central Expressway and the bridge over the Trinity River. The first LRT vehicles will be delivered in 1995, and the system is scheduled to begin operation in 1996.

DART Principles and Key Evaluation Criteria

DART's *New Directions* work plan includes 15 guiding principles and 11 evaluation criteria. These elements are to be used in examining new services, re-evaluating existing services, and considering other projects. The guiding principles and the key evaluation criteria are summarized next (2).

New Directions Guiding Principles

- Ensure maximum community participation
- Continue improving bus operations, increasing ridership, reducing costs, and adding new services where appropriate.
- Preserve current DART city and county memberships, and invite additional regional memberships.
- Cooperate with all regional transportation organizations to identify all regional mobility solutions.
- Promote more effective integration of planning, programming, and funding of regional mobility solutions.
- Develop an evaluation framework to include mobility indicators, land-use objectives, and environmental impacts.
- Develop a long-term plan to provide public transit service to the most people at the least cost.

- Fit technologies to the size and nature of the need within each corridor.
- Develop short-range and long-range solutions incrementally to take advantage of changes in mobility patterns and advances in technologies.
- Develop early action public transit projects (busways, HOV lanes, light rail, commuter rail, bus priorities, demand-responsive services, etc.).
- All modes and alignments within the corridors adopted in the 1983 Service Plan, and as legally amended from time to time, are subject to the FTA's Alternatives Analysis process.
- Develop a financial plan with local funds on a "pay-as-you-go" basis using short-term borrowing, and available state and federal funds.
- Retain the one-cent sales tax, but consider using a portion of revenue for general mobility projects.
- Preserve right-of-way options for future transportation improvements.
- Upon approval of the New DART System Plan, and within five years, implement an operational fixed guideway starter line in the service area.

Key Evaluation Criteria

- Ridership Forecasts
- Cost Estimates (Life-cycle capital and operating)
- Added Cost Per Added Rider
- Service to Employment Centers
- Travel Time Savings
- Impact on Traffic Congestion
- Environmental Sensitivity
- Flexibility to Expand and Upgrade
- Private Contribution Potential
- Proven Technology
- Public Acceptability

The guiding principles, key evaluation criteria, and other related information were reviewed by the Advisory Committee. Those elements relating to the LRT Starter Line were identified and discussed in greater detail. Suggestions were also provided on how principles, criteria, and other elements could be used to help guide the development of the DART LRT Starter Line Assessment Study Design.

Transportation-Related Data Collection Activities in the Dallas Area

A number of different agencies in the Dallas area collect and analyze transportation-related information. These include regular ongoing monitoring activities, as well as special studies and one-time efforts. A few of these activities are highlighted in this section.

The North Central Texas Council of Governments (NCTCOG) is responsible for a number of regional transportation data collection activities. Examples of recent and ongoing efforts include the following.

- **Regional Traffic County Program**. The NCTCOG produces an annual estimate of vehicle miles of travel (VMT) in the region. This estimate is based on 24-hour vehicle count data from approximately 600 randomly-selected locations.

- **Workplace Travel Survey**. A survey was conducted at approximately 270 workplace locations throughout the metropolitan area in 1994. A total of some 20,000 visitor interview records and 9,000 employee surveys were completed as part of this process. The results of these surveys should be available in late 1995.

- **External Travel Survey**. A survey was conducted in 1994 of the 38 highest volume external stations along the perimeter of the region. Approximately 28,000 driver interview records were completed. These surveys are being analyzed, and the preliminary results should be available in late 1995.

- **Household Travel Survey**. Approximately 4,000 residents will be included in an activity-based household travel survey to be conducted in the fall of 1995.

In addition to these surveys, NCTCOG maintains the census data for the region and other transportation, socio-economic, and land use information. NCTCOG publishes reports and ongoing newsletters highlighting much of this information.

DART collects a wide range of transit-related information on a regular basis. This includes monitoring ridership levels, service levels, on-time performance, farebox revenues, and other performance measures. DART also conducts special studies periodically, such as on-board ridership surveys and detailed assessments of a specific route.

The Texas Department of Transportation (TxDOT) and DART are funding the ongoing monitoring of the East R. L. Thornton HOV lane. This effort, which is being conducted by TTI, includes vehicle counts, vehicle occupancy counts, travel times, and other surveys. This information is being collected for both the HOV lane and the general-purpose lanes. Similar data collection activities have also been initiated on the Stemmons and LBJ Freeways. TxDOT also conducts many special studies, such as the 1994 24-hour traffic counts taken at numerous locations throughout the metropolitan area. Traffic accident records are maintained by the Department of Public Safety (DPS) and local police departments.

Many local jurisdictions have ongoing traffic monitoring programs. For example, many communities regularly collect data on traffic volumes, turning movement volumes, and vehicle occupancy levels. Additional information may be collected for special studies and projects.

CHAPTER THREE—REVIEW OF SELECTED TRANSIT FIXED-GUIDEWAY BEFORE-AND-AFTER EVALUATION STUDIES

Before-and-after evaluations have been conducted on a number of fixed-guideway transit projects over the last 20 years. These include assessments of new LRT, heavy rail, and HOV lanes. The approaches utilized with these studies have varied considerably, however, as have the data collection methods, analysis techniques, and results. In some cases, lack of available resources have limited data collection efforts. In other cases, initial evaluations were completed shortly after implementation of the systems, but little or no ongoing data collection or evaluation studies were conducted. As a result of these issues, evaluating the impact of new fixed-guideway systems has been difficult.

This chapter examines before-and-after evaluations conducted on fixed-guideway transit systems. Projects with evaluation studies were identified and examined in greater detail. Table 2 lists evaluation efforts initiated with the 12 heavy rail, LRT, and HOV lane projects reviewed as part of this study. A more extensive review was made of recent heavy rail and LRT evaluation studies, as a similar study of HOV evaluations was previously conducted by TTI (3). Two of the best examples of comprehensive before-and-after evaluations of HOV lanes are provided from this study, along with the Seattle bus tunnel.

The information presented in this chapter is based on a review of available reports, journal articles, and other data provided by the transit systems. For each case study, a brief description of the project is provided first, followed by a discussion of the evaluation process, project objectives, evaluation measures and criteria, and data collection techniques. Any unique features or issues associated with the evaluations are also highlighted.

Table 3 identifies the agency sponsoring the evaluation study and provides a summary of the main elements examined in each study.

Table 2. Selected Fixed-Guideway Assessments

Type of Project	Location	System Name or Agency
Heavy Rail	Atlanta	Metropolitan Atlanta Regional Transit Authority (MARTA)
	Baltimore	Mass Transit Administration - METRO
	Boston	Massachusetts Bay Transportation Authority (MBTA) - RedLine Extension
	Chicago	Chicago Transit Authority (CTA) - Extension to O'Hare International Airport
	San Francisco	Bay Area Rapid Transit District (BART)
	Washington, D.C.	Washington Metropolitan Area Transit Authority (WMATA) - METRO
LRT	Calgary	Calgary Transit-Light Rail Transit System (C-Train)
	Portland	Tri-County Metropolitan Transportation District (Tri-Met) - MAX
	San Diego	Metropolitan Transit Development Board (MTDB) - San Diego Trolley
HOV Lanes	Houston	I-10W, I-45N, I-45S, U.S. 290, and U.S. 59 HOV Lanes - Metropolitan Transit Authority of Harris County (METRO) and Texas Department of Transportation (TxDOT)
	Minneapolis	I-394 HOV Lanes - Minnesota Department of Transportation (MnDOT)
	Seattle	Municipality of Metropolitan Seattle (METRO) - Downtown Bus Tunnel

Table 3. Major Elements of Selected Fixed-Guideway Assessments

Project	Responsible Agency	Major Elements								
		Transit Impacts	Transit Costs	Travel Times	Mode Selection	Traffic Configuration	Land Use	Attitude Surveys	Environmental	Special Studies
MARTA	Atlanta Regional Commission	X	X	X	X	X	X	X		X
MTA-METRO	Regional Planning Council	X		X	X		X	X		
MBTA-RedLine Extension	Central Transportation Planning Staff	X	X		X	X	X			X
CTA-O'Hare Extension	Chicago Area Transportation Study	X					X			X
BART	Metropolitan Transportation Commission	X	X	X	X	X	X	X	X	X
WMATA-Metrorail	Metropolitan Washington Council of Governments	X	X	X	X	X	X			X
C-Train	City of Calgary	X			X	X	X	X		X
Tri-Met-MAX	Tri-Met	X					X			X
MTDB-San Diego Trolley	San Diego Association of Governments	X		X	X					
Houston HOV Lanes	Texas Department of Transportation and Metropolitan Transit Authority of Houston County	X		X	X	X	X	X		

Table 3. Major Elements of Selected Fixed-Guideway Assessments (continued)

Project	Responsible Agency	Major Elements								
		Transit Impacts	Transit Costs	Travel Times	Mode Selection	Traffic Configuration	Land Use	Attitude Surveys	Environmental	Special Studies
I-394 HOV Lane	Minnesota Department of Transportation	X		X	X	X	X	X		X
Seattle Bus Tunnel	Puget Sound Council of Governments	X	X	X	X	X				X

Metropolitan Atlanta Regional Transit Authority (MARTA)

The Metropolitan Atlanta Regional Transit Authority (MARTA) was formed by the Georgia State legislature in 1971. Based on the 1972 voter authorization in DeKalb and Fulton Counties, MARTA purchased the privately owned Atlanta Transit System and began operating bus service. Planning for a rapid rail system was also initiated, and in 1979, the first 7 miles of the MARTA heavy rail system opened. Today, the system encompasses 33 miles with east-west and northeast-south lines. The four lines intersect at Five Points Station in downtown Atlanta. Service is also provided to Hartsfield Airport to the south, major suburban shopping and employment centers, universities, and cultural and recreational facilities. The downtown portion of the system, which comprises approximately 20 percent of the total, is in subway. Some 50 percent of the system operates at grade in separate rights-of-way, while the remaining 30 percent is elevated. Extensions to the system are in the planning, design, and construction stages.

In 1976, the Atlanta Regional Commission (ARC), the metropolitan planning organization (MPO), initiated the Transit Impact Monitoring Program (TIMP). This was a special multi-year monitoring and evaluation program, partially funded by the Urban Mass Transportation Authority (UMTA—now Federal Transit Administration, FTA). The TIMP, which focused on examining the impacts of the rail system, grew out of the Transit Station Area Development Studies conducted by ARC during the planning and development of the MARTA system. These studies, which were also funded by UMTA, resulted in the adoption by local governments of development plans for many areas surrounding MARTA stations (4). The ARC identified the following four major purposes of the Transit Impact Monitoring Program (5).

- To monitor the short term impacts of MARTA.
- To examine long-term impacts that result in changes in land use patterns.
- To assess the effects of rapid transit on the transportation system and travel behavior.
- To evaluate the performance of the integrated rail-feeder bus system and determine if operational changes are warranted which would improve transit service.

In order to accomplish these goals, an ongoing monitoring program was outlined to assess the impact of the MARTA rail system. Sixteen major tasks or evaluation elements were identified in the TIMP work program to be included in the monitoring program. The following items represent the 16 work tasks (5).

- Travel time surveys.
- On-board surveys of residents.
- Telephone surveys of residents.
- Traffic volume surveys.

- Station area studies.
- MARTA operations analysis.
- Network analysis to estimate changes in accessibility and energy consumption.
- Residential attitude surveys.
- Monitoring transit station area development implementation.
- MARTA relocation program analysis.
- Residential land activity analysis.
- Commercial land activity analysis.
- Activity center case study analysis.
- Report preparation.
- Develop and apply in-house computer graphics capability.

Between 1976 and 1987 some 25 reports were prepared and published by ARC as part of the TIMP. These included both annual summary reports and the results of specific monitoring activities. Since the TIMP was initiated prior to the opening of first rail line, a pre-rail system base line was established for many elements of the analysis. Although portions of the program have continued, the major TIMP elements were discontinued in 1984 due to funding limitations. Thus, the TIMP represented an extensive and fairly comprehensive examination of the impacts associated with the initial implementation of the MARTA rail system.

A variety of evaluation methods, data collection activities and analysis techniques were used to conduct the various studies completed as part of the TIMP. The approaches used with some of the evaluation components are described next, along with the results.

Travel Time. Travel time studies were conducted on roadways adjacent to the east-west line in an attempt to measure the impact of the rail line on automobile travel. Changes in door-to-door travel times for home-to-work trips were examined for both transit trips and auto trips on arterial streets paralleling the rail line. Travel time data were collected prior to the opening of the rail line and again after the opening of the system (6,7).

Fourteen residential neighborhoods along the east-west line were selected for the analysis of changes in transit travel times. Six of these were identified as in-town neighborhoods and eight were suburban neighborhoods. Three downtown destinations were selected and bus travel times from each neighborhood to each destination were recorded. After the rail system was implemented, the same analysis was conducted using the new feeder bus and rail connections. In two of the suburban neighborhoods, both feeder bus and auto access modes were examined. A total of 40 origin-destination pairs were monitored and analyzed in this analysis.

The results of this study indicated that MARTA had a mixed impact on transit travel times. A decrease in the total peak-hour travel times were realized for slightly over half of the trips after the opening of the rail line. No significant changes in travel times were recorded for ten trips, while increases in travel time were experienced for nine trips. Improvements in travel times were more common with trips from suburban neighborhoods. The analysis included an examination of the wait, walk, and in-vehicle times associated with the different components of

the transit trip before-and-after implementation of the rail system. While the average in-vehicle travel times tended to decrease, waiting and walking times increased with the rail system (6).

Automobile travel times were also monitored on five arterial streets parallel to the rail line in the east and west corridors to identify possible impacts on the roadway system. Inbound peak-hour travel times were monitored before the rail system opened and again in 1982. This comparison indicated that travel times did not change significantly for 54 percent of the miles tested. Overall, travel times decreased on three routes, increased on two routes, and did not change significantly on 5 routes (6).

Mode Selection. Three sources were used to gauge the effect of the rail system on commuter mode choice in the east-west corridor. These were a 1980 work place survey of 80,000 workers in the corridor, a 1980 on-board bus and rail survey, and special traffic counts. The results of the 1980 work place survey indicated a number of trends relating to the impact of the rail system on mode choice. First, approximately 14 percent of those surveyed who drove alone before MARTA opened, indicated they had changed to using the rail system. Based on the survey results, it appeared that approximately 40 percent of downtown workers commute by MARTA (7).

Cordon counts were taken at a screen line along the east line to examine vehicle and person trips by mode. Counts from 1971 were compared with those taken in 1979, before the opening of the rail line, and in 1980 after the opening of the line. Identifying trends from these counts was difficult due to confounding external factors such as the energy crisis and the resulting increase in gasoline prices. Overall, the analysis concluded that the opening of the rail line increased total corridor capacity and contributed to an increase of about 16,500 daily person-trips crossing the screen line (8).

Traffic Changes and Congestion Levels. As part of the TIMP, the ARC also conducted a traffic monitoring program around MARTA transit stations and on major arterial streets in 1979-1980 and 1984-1985. The east-west line was examined in 1979 and 1980, while monitoring was conducted on the northeast-south line in 1984 and 1985. Traffic counts were taken around rail stations and at screen lines. Data was collected before the rail system was opened, and again after the system had been in operation for approximately one year, to measure changes in traffic volumes.

The results of the monitoring program were inconclusive. In two of the four corridors the total daily volumes decreased slightly, but the peak-period volumes increased slightly. One corridor experienced increased total daily volumes, while one remained approximately the same. Traffic volumes around stations also showed mixed trends, with most experiencing some increases and a few experiencing slight declines (7). The ARC analysis noted a number of external factors which may have influenced these results. These external factors included the significant increase in gasoline prices experienced from 1979 to 1980, highway construction activities, restructuring of the bus system, and MARTA fare increases in 1979, 1980, and 1981 (7).

Land Use. The TIMP included a number of tasks to monitor the effect of both construction and operation of the rail line on areas around stations and along segments of the rail line. The purpose of these activities was to help determine if the system produced economic benefits through land use and other changes, if there were any social and attitudinal changes, and if the types and intensities of development that were expected and planned by the public and private sectors actually occurred (5).

Three types of activities were used to monitor and evaluate these possible changes. First, new public and private developments were monitored to determine the extent to which transit station area plans were being implemented. Second, special studies were conducted to determine the social and economic impacts of the system. Third, annual data collection and monitoring of residential and commercial activities were conducted.

The 1982 TIMP Annual Report, the last annual report prepared under the program, provided a summary of land use and development activities around MARTA stations between 1975 and 1982. The report documents the major public and private developments under construction, as well as those in the planning stages. Most of the new development activities were occurring adjacent to stations in the downtown area and along the north line. The report also identifies the public policy actions that were taken to support and encourage development associated with the rail system. These included the new zoning ordinance adopted by the City of Atlanta and the MARTA policy dealing with the disposition of surplus property.

In addition to the ongoing monitoring of development activities, a variety of other special studies were conducted to determine land use, economic, and employment impacts. This included a special case study of the Brookhaven Station area, surveys to obtain information on residential and business attitudes, studies of station area employment levels, and monitoring of MARTA's commercial and residential displacement and relocation programs.

The Brookhaven station case study included an inventory of land uses before MARTA was opened. This information was to serve as the base line for comparison of changes after the opening of the rail line. These changes could then be compared to the desired results as outlined in the *Brookhaven Rapid Transit Station Area Development Plan* prepared by DeKalb County. The after analysis was not completed, however, due to funding limitations.

Three residential attitude surveys were conducted by ARC as part of the TIMP. Two of these surveys, in the East Lake and Hightower neighborhoods, were conducted after rail service had been implemented. A third survey, in the Brookhaven neighborhood, was conducted during the initial stages of land acquisition. In general, the two post-rail surveys identified similar positive reactions among residents toward the MARTA system. One negative factor, relating to noise, was identified by respondents in the East Lake area. The pre-rail survey in the Brookhaven neighborhood provided a base line of perceptions relating the impact of construction and the operation of the rail line (9,10).

Another special study focused on the impact of the rail system on employment. A sample of 23 station areas, 20 within the City of Atlanta, were selected for this study and 1970, 1975,

and 1980 employment levels were analyzed. The trends in these locations, which showed a decline in employment between 1970 and 1975, and an increase between 1975 and 1980, reflect those experienced by the city. However, the areas outside the city experienced increases in employment over the 10 year period. Changes in the types of jobs and employment classifications were also examined (9,10).

A variety of information was collected and examined on an annual basis relating to commercial and residential land activity in station areas. Data collected included the number and price of housing sales, apartment rental rates, residential building and demolition permits, sales information commercial, industrial and vacant land, office space supply and leasing, commercial building and demolition permits, and rezoning proposals (9,10).

MARTA Operating Costs. As part of the TIMP, MARTA operating data were examined on the east-west line to identify the impact the rail line and the restructured feeder bus service had on overall operation costs, revenues, and service levels. This analysis focused on patronage, vehicle miles, and operating costs before-and-after implementation of the rail system (11).

Baltimore Metro Impact Study

Bus, heavy rail and LRT service in the Baltimore area is provided by the Mass Transit Administration (MTA), a division of the Maryland Department of Transportation. The heavy rail system serves the corridor from downtown Baltimore to the northwestern suburbs in Baltimore County. The 31-mile heavy rail line was opened in two segments. The first phase, which runs from the downtown area to the city limits, was opened in 1984. The second phase, which extended the line to Ouing Mills in Baltimore County, was opened in 1987. The system operates in a subway in the downtown area and is either elevated or at-grade in the suburban corridor.

The Metro Impact Study was designed to measure and evaluate the transportation, demographic, environmental, and land use effects of the initial 8 mile segment of the Metro system. The study was intended to provide information to improve the ongoing operation of the system, to assist in planning future extensions, and to support the transportation planning activities of state and local government agencies in the Baltimore region (12).

The Metro Impact Study was conducted as a joint effort of the Regional Planning Council (RPC), the Mass Transit Administration (MTA), and the Baltimore City Planning Department. The RPC, the MPO for the Baltimore metropolitan area, took the lead role in developing the work program for the evaluation, conducting many of the surveys and data collection activities, and completing the summary reports. The Baltimore City Planning Department conducted much of the land use analysis and employer focused surveys. The MTA assisted with the energy analysis and other transit related impacts.

The Metro Impact Study work program identified 13 major tasks to be conducted as part of the program. As noted below, these focused on examining the impact on transit users, the MTA, traffic levels, and land use and development patterns.

- On-board surveys
- Work place surveys
- Station area studies
- Traffic volume analysis
- Travel time surveys
- Environmental analysis
- Residential land activity analysis
- Commercial land activity analysis
- Shoppers surveys
- Monitoring transit station area development studies (TSADS)
- Residential attitude surveys
- Metro center activity analysis
- Report preparation

A variety of information was collected and analyzed before the opening of the initial northwest rail segment in November 1983. These data, which were summarized in a 1985 report by the RPC, provided a baseline of the pre-rail demographic, travel, and land use characteristics in the corridor. In addition, environmental considerations were examined and special surveys conducted to identify residents' perceptions and attitudes toward Metro. Finally, the report outlined the next steps in the evaluation process and the agencies responsible for the different activities (12).

Due to funding limitations, the extensive monitoring, data collection, and evaluation program initially envisioned for the Metro system was not completed. A limited amount of data collection and analysis activities were conducted, however. The results of these activities were summarized in a 1987 ARC staff paper. The major elements examined in this document focused on transit use and mode choice, travel times, land use, and employee and shopper attitudes. The paper notes that while some impacts appear to be closely tied to the implementation of the rail line, determining the influence of others is not possible without significantly more study (12).

Transit Use and Mode Selection. On-board ridership surveys taken one year after the opening of the northwest rail line, indicated that approximately 22 percent of the riders had previously driven alone, while 68 percent had previously used the bus, and 10 percent were new trips. The large number of former bus riders was attributed to the fact that the initial rail segment served a transit-dependent, in-town, urban setting, where well utilized bus service had been in operation (13).

Cordon counts were taken in 1981 and in 1984 to examine changes in mode choice and the mode split in the rail corridor and in other corridors. The results of this analysis indicated that vehicular traffic entering the central business district (CBD) from the northwest corridor declined by 15 percent while other corridors exhibited a 7 percent increase. On the other hand, transit ridership in the northwest corridor increased by 42 percent, while it declined by 13 percent in other corridors. The mode split for transit in the northwest corridor increased from 32 percent to 43 percent, while it decreased from 21 percent to 18 percent in the other corridors (13).

Travel Times. A comparison of transit travel times before and after implementation of the northwest rail line indicated mixed results. In general, radial trips to the CBD experienced shorter travel times after the opening of the rail system. Travel times increased for some of the longer distance trips, however, which required the use of feeder buses and transfers to Metro. Travel times for some of these trips were shortened with the opening of the second phase of the rail line. The overall impact of Metro on transit travel times in the corridor appeared to vary depending on whether a transfer was required (13).

Land Use. Residential and commercial building permits were monitored for the northwest corridor and the city as a whole. Between 1983 and 1985 the northwest corridor exhibited a steady increase in the rate of new residential building permit applications. This contrasted with slower rates of growth in other parts of the city. Commercial building activity exhibited mixed trends during the same two year period. In 1984, non-residential construction increased throughout the city, with the exception of the northwest corridor. However, in 1985 this trend was reversed, with more activity reported in the northwest (13).

Employee and Shopper Surveys. Special surveys were conducted of both shoppers and employees at two retail malls located along the northwest rail line before the opening of Metro and after the system had been in operation for a year. The results of these surveys provided a variety of information on transit use, travel, demographic, and socio-economic characteristics of shoppers and employees. In general, the results of these surveys indicated that transit use by employees and shoppers had increased at both malls after the implementation of the rail line (13).

Massachusetts Bay Transportation Authority (MBTA) - Red Line Extension

The Massachusetts Bay Transportation Authority (MBTA) operates bus, heavy rail, and light rail transit systems in the Boston metropolitan area. In late 1984, a 3.2-mile extension of the Red Line was opened between Harvard Square and the Alewife area in Cambridge. The extension included 3 new stations, the reconstructing of the Harvard Square Station, a parking garage for 2,200 vehicles at the Alewife Station, and the re-orientation of the feeder bus network.

A before-and-after evaluation was conducted on the Red Line extension to measure its impact on a number of elements. The evaluation was designed to examine the transportation and land use changes that occurred in the corridor over a five to six year period before-and-after implementation of the rail line. The evaluation was conducted to provide an enhanced understanding of the impact rail extensions have on the surrounding area and to assist with future planning efforts (14).

The evaluation was conducted by the Central Transportation Planning Staff, an interagency transportation-planning staff created and directed by the metropolitan planning organization. Agencies participating in the Central Transportation Planning staff include the Executive Office of Transportation and Construction, the Massachusetts Bay Transportation Authority, the Massachusetts Department of Public Works, the Massachusetts Bay Transportation

Authority Advisory Board, the Massachusetts Port Authority, and the Metropolitan Area Planning Council.

A total of four reports were prepared as part of the evaluation. These covered preliminary rail and feeder bus ridership and vehicular volumes around stations, feeder bus operations and ridership, changes in land use and value in the vicinity of the three new stations, and transportation-related changes. A variety of data collection and monitoring activities were conducted to obtain the information necessary for the evaluation. The following major data collection activities were included as part of the program (14,15).

- On-board surveys
- Rail passenger counts
- Feeder bus passenger counts
- Parking garage vehicle counts at the Alewife station
- Park-and-ride lot license plate surveys
- Transit operating costs and revenues
- Traffic volume counts around stations
- Sales prices of residential property around stations
- Vacancy rates and rental rates around stations
- Land use changes by categories around stations
- Major developments and stations
- Demographic and socio-economic data

Transit Usage. The results of the passenger counts indicated that the Red Line extension generated new transit riders. Overall ridership levels were above the projected levels. Based on the on-board survey results, 35 percent of the Red Line riders previously rode the system, while 65 percent were new riders. Of the new riders, 30 percent used to make the same trip by a different mode, while 35 percent did not previously make the trip. Among continuing riders, 44 percent changed their mode of access. The use of park-and-ride and kiss-and-ride facilities increased, as did access by walking. Conversely, the use of feeder buses as an access mode decreased (14,15).

Traffic and Vehicle Miles of Travel Changes. The study examined the impact of the extension on traffic conditions around the Alewife Station, as well as into Harvard Square and the overall corridor. Traffic counts and information from the passenger surveys were used in this analysis. This information indicated that the extension did slightly slow the net growth in traffic into Harvard Square (14). The analysis further estimated that the growth in regional daily vehicle miles of travel (VMT) was reduced by approximately 13,800 due to travelers diverting from driving alone to using the rail extension or making shorter trips. In addition, approximately 1,500 daily automobile trips were diverted from going into Boston and Cambridge (14).

Land Use. Land use changes were monitored in the areas surrounding the three new rail stations along the extension. The highest levels of new construction were recorded around the Alewife station. This was partially due to the rezoning of 400 acres of under-utilized land from industrial to office use. This change, which was recommended in a pre-extension Alewife Urban

Design Study, resulted in the construction of approximately one million square feet of office space and the creation of some 2,000 jobs over an eight year period. Changes around other stations were also noted. Overall, the percentage of land used for industrial purposes declined significantly in areas surrounding the new stations between 1978 and 1986. The largest increase in land use was recorded in office space, parking, and open space. Small increases in residential uses were recorded at two of the stations (14,15).

Housing prices were also monitored in the neighborhoods surrounding the three stations between 1980 and 1985. Information on the median sale prices for homes over this period indicated that in two station areas prices increased faster than the overall city averages, while prices rose at approximately the same or a slightly lower rate in the third station area. The two locations where prices increased faster than the city averages started with the least expensive prices in the base year, however, which may have influenced the trends (14,15). The analysis indicates that while many of these land use changes would have occurred even without the extension, the new service encouraged and quickened much of the development (15).

Demographic Changes. Changes in the demographic and socio-economic characteristics of neighborhoods surrounding the new rail stations were also monitored as part of the study. Population, housing, and economic data were examined for each of the neighborhood areas and comparisons were made to regional trends. The analysis was not able to document any significant changes due to lack of available data. It was recommended that additional studies be conducted once the 1990 census data were available (15).

MBTA Operating Cost and Revenues. The impact of the Red Line Extension and the reconfiguration of the feeder bus network on MBTA operating costs and revenues were analyzed as part of the study. The combined effect of the extension and the feeder bus rerouting increased overall MBTA operating costs and revenues. Although the level of service on many feeder bus routes increased, the vehicle service hours remained essentially the same and the peak vehicle requirements declined. This resulted in a minor decrease in operating costs for the feeder bus system. The combined bus and rail impact resulted in an increase in variable operating costs that exceeded the increase in farebox revenues. Thus, the MBTA's operating deficit increased as a result of the Red Line extension. However, the ratio of passenger revenue to variable operating cost for the feeder routes and the rail extension remained relatively stable before and after the extension. Before the extension, the ratio of passenger revenues to variable operating cost for the bus routes in the area was approximately .476. After the extension, the combined ratio for the feeder buses and the rail segment was .466 (14,15).

Chicago Transit Authority (CTA)-Extension to O'Hare International Airport

Bus, heavy rail, and commuter rail services are all provided in the Chicago area. In 1984, the Chicago Transit Authority (CTA) extended the west/northwest heavy rail line to O'Hare International Airport. This provided a link to the airport from downtown Chicago. The extension was opened in two phases. The first connection to the River Road in Rosemont was opened in February, 1983, and the final segment to the airport was opened in September, 1984.

An evaluation study of the impact of the rail extension to O'Hare Airport was initiated in 1982 by CTA and the Chicago Area Transportation Study (CATS), the MPO for the area. A multi-agency task force was organized to develop the study design. The task force was comprised of representatives from 16 local, state, and federal agencies. The task force recommended that before, interim, and after studies be conducted to determine the effect of a new rapid transit line on a heavily traveled corridor which already had several transportation alternatives. The focus of the study was further intended to provide information on changes in travel mode, reverse commuting, and land use (16).

In order to accomplish these objectives, a cooperative data collection and analysis program was developed among the agencies participating in the task force. The following listing of work tasks and data collection activities were conducted by the different agencies prior to the opening of the rail extension. This information provided the base line data for comparison of changes after the rail extension opened (16).

- Expressway ramp counts
- Intersection delay studies
- Rail boarding counts
- Rail station access mode
- Taxi passenger counts
- Commuter parking lot usage
- City sticker or state license plate surveys
- Roadway volume machine counts
- Airport parking and passenger levels
- Convention attendance
- Land use inventories
- Bus route passenger counts and ridership levels
- Tollway volume counts

An interim study was conducted after the opening of the initial segment of the extension to the River Road. This partial evaluation was designed to measure selected elements, to provide an initial indication of the changes caused by the extension, and to identify any problems requiring operational changes. The full evaluation study was conducted over a five month period from July through November 1985; approximately 10 months after the opening of the complete extension.

Transit Ridership. A major focus of the before-and-after analysis was on the impact of the extension on bus and rail ridership levels in the corridor. A variety of data collection activities and surveys were used to determine the nature and magnitude of these changes. These included passenger counts, on-board ridership surveys, employee surveys at major activity centers, and surveys of park-and-ride lot users. Ridership data were collected on all the bus and rail services operated in the corridor. With multiple operators, this proved to be a major effort.

The after study found that within a year of completion of the O'Hare extension, ridership on the line had increased by 75 percent. According to on-board passenger surveys, 45 percent

of the respondents were new travelers in the corridor and 55 percent had switched from some other means of transportation or were boarding the line at a new station. Former automobile drivers accounted for 17 percent of the new riders who had switched modes, while 45 percent previously used another rail station, 14 percent had used commuter rail service, 15 percent had used CTA and suburban bus users, and 7 percent formerly used taxis or airport bus services. Monitoring indicated that the morning peak hour boardings on the two Metro commuter rail lines operating in the corridor declined by about 20 percent after the extension was opened (16).

Land Use. Information on new construction and vacant land was collected for all land use zones within the corridor. The period from May 1980 to April 1985 was used for the after monitoring. This corresponded to the planning, construction, opening and first 10 months of operation for the extension. Over this time period, the amount of vacant land within a one mile radius of the rapid transit stations decreased by an average of 44 percent. Office and industrial uses experienced the largest increases, with a number of major new developments constructed (16).

A number of trends were identified in the before-and-after comparison. First, during the ten year period from 1970 to 1980, the average annual total square feet of new construction for the area was approximately 723,000. The average for the five year period from 1980 to 1985 was 746,000. Thus, the area appeared to be developing at a relatively constant rate over the 15-year period. There was a change in the type of new construction between the two periods, however. During the before study, approximately 64 percent of the new construction was residential. In the after study, only 7 percent of the new development was residential (16). The report cautions that the changes in land use and new development can not be attributed solely to the rail extension, however. The presence of major freeways, freeway interchanges, the airport, and other factors, also contribute to and influences these changes (16).

San Francisco Bay Area Rapid Transit District - BART

The San Francisco Bay Area Rapid Transit District (BART) was established to develop and operate a heavy rail system in the San Francisco Bay area. The initial BART system was opened in five stages from September 1972 to September 1974. Currently, BART is a 71.5 mile, automated system with thirty-four stations located along four lines of double track. Extensions to the system are in different planning and design stages. The initial goals of the BART system were to:

- to increase travel capacities in Bay Area travel corridors
- to mitigate traffic congestion
- to reduce the need for further highway construction
- to divert a substantial number of travelers from automobiles

The Metropolitan Transportation Commission (MTC), with funding from the U.S. Departments of Transportation and Housing and Urban Development, began the BART Impact Program in 1972. The purpose of the study was to monitor BART's impact on transportation and travel behavior, the environment, land use and urban development, and economics and

finance. The BART Impact Program produced fifteen reports addressing different elements and a final summary report. The reports covered the period from 1972 to 1978. For the purposes of this project, the final summary report was reviewed and summarized.

A Sponsor's Note at the beginning of the final report cautions that the BART impacts should be viewed within the circumstances and the setting in which BART was planned and built, and the conditions under which the analysis was conducted. Some of the early interpretations of the study results were negative and the note points out many of the factors affecting the early stages of operation of the BART system. These factors include the extensive public transportation system already in place in the area, the fact that BART was intended primarily to serve suburban to downtown commuters, and the fact that BART was developed as a separate institution without full coordination among existing transportation and planning agencies. In addition, the BART system was not operating at its full service levels during the period covered by the evaluation, and BART had only been in operation a short time when the impacts were studied. Thus, BART's impacts in many areas, particularly land use and urban development, would be difficult to measure until the system had matured (17).

Travel and Transportation Impacts. Travel impacts measured by the study include mode choice, ridership levels, riders' characteristics, impacts on transbay travel, and impacts on local bus services. A passenger survey conducted in 1976 indicated that BART patrons were about equally divided between former bus riders and former drivers. This survey also provided information on the socio-economic characteristics of BART passengers. These results indicated that many BART riders are choice users, that is they have an automobile available, but choose to take BART rather than driving (18).

The impact study found that BART had significantly increased the capacity of the central transbay travel corridor and had absorbed most of the growth in the corridor since the opening of the transbay tube. It also found that BART had not had a lasting effect on the volume nor the speed of traffic in the transbay corridor (17).

Economic Development Impacts. The BART study examined the economic impacts of the construction and operation of the system, as well as the tax burden resulting from BART, and the system's impact on regional economic development. The role of the transportation service provided by BART in regional economic activities and development was also examined. The study results indicated that in 1978 the economic growth of the area as a whole was not significantly affected by BART (17).

The study did identify that the construction of the BART system had a modest impact on the regional economy. The total sales and income generated by the construction was estimated to be $3.1 billion during the thirteen year construction and procurement period. Additionally, the construction of BART directly and indirectly generated 75,000 person-years of employment. BART's direct peak-year employment was 5,000 construction jobs, or approximately 0.3 percent of regional employment (17).

Land Use Impacts. The BART Impact Program examined the system's effects on the distribution of new construction and on workplace and residence location decisions, development decisions, shopping patterns, retail sales, land uses near BART stations, real estate speculation, and property prices and rents. The impact study found that BART affected land use patterns in the Bay Area in a number of ways. First, BART influenced land use patterns directly by its physical presence and its service areas. In other cases, BART served as a catalyst for public policies and projects which helped influence land use changes (17).

Relatively little new urban development could be attributed to BART during the study period, but the system appeared to have influenced the direction and pace of existing growth patterns. BART's most notable land use impacts were found to be in downtown San Francisco and in Oakland where the system had some influence on the concentration of new office construction around stations. The study cited the example of downtown San Francisco, where 22.5 million square feet of the office space built since 1965 was close to four downtown BART stations. BART also provided the impetus for a $35 million street beautification program, the Market Street development project, and a new zoning ordinance (17).

Interviews were used to try to determine the impact of BART in the location decisions of employers, worker, retailers, and shoppers. The results of this analysis indicated that the system had little effect on Bay Area residents' decisions on where to work, shop, and locate businesses. BART's influence was slightly more evident in residential development and residential location decisions. Two-thirds of the 26 developers interviewed for the study stated that BART was a consideration in development decision process. Further, BART may have helped to accelerate residential development in two suburban fringe areas that had previously been beyond reasonable commuting distances (18).

Residential property prices and rents were largely unaffected by the BART system. Office rents near a few BART stations increased, but the study was unable to isolate BART's influence from other factors which might have effected such changes (17).

Environmental Impacts. The study attempted to investigate how the construction, operation, and structures of the BART system affected the environment of Bay Area residents. Due to BART's location in a largely urban areas, its biggest impacts appeared to be people rather than the natural environment. The assessment of construction impacts on businesses and residents were based mostly on anecdotal evidence. The greatest impacts were found in San Francisco, Oakland and Berkeley where construction of the subway section resulted in disruption of traffic, reduced parking, and created dirt and noise. Some retailers reported lost revenues because of decreased accessibility during construction. A review of sales tax data from stores near BART construction sites corroborated these reports (17).

The study evaluated the impacts of BART's operations on noise and air quality levels, as well as the visual impacts of associated structures. Noise impacts were measured by surveys of residents, as were visual impacts. Visual impacts were also examined by a survey of urban design professionals. Air quality impacts were measured by emissions. Train noise was found

to be most noticeable along a stretch of aerial trackway where residences were located close to the line and where background noise was low (17).

The professional urban designers examining the visual impacts of BART structures indicated that they were generally unobtrusive in commercial and industrial areas. The visual impacts of BART stations and structures on residential areas were found to vary, however. Stations with small, well-landscaped parking lots were less obtrusive than those with large, open expanses of parking. In contrast to the evaluations of the design professionals, most local residents found the visual impacts of BART stations and parking lots to be either pleasing or negligible (17).

A less extensive update of the BART Impact Study was completed in 1984 (18). This study examined trends in BART service and patronage levels, transbay traffic conditions, and other factors. The results of this analysis indicated that although ridership on BART has continued to increase, so has vehicle traffic in the transbay corridor. The system was also found to have positive longer term impacts on land use and development activities in many station areas (18).

Washington Metropolitan Area Transit Authority - Metrorail System

The initial segment of the Washington Metrorail system was opened in 1976. Additional phases have been implemented since that time and construction is still underway to complete the system. The Washington Metropolitan Area Transit Authority (WMATA) is responsible for planning, designing, constructing, and operating Metrorail, as well as the regional bus system. The complete Metrorail system will have 101 miles of track and 81 stations, with 49 miles in subway and 52 surface miles. The system's goals are to relieve traffic congestion by providing an alternative to automobiles and to support a compact pattern of regional centers along corridors which radiate out from downtown Washington, D.C.(19).

In 1976, UMTA requested that the Metropolitan Washington Council of Governments (WASHCOG) initiate a long-term study of the impacts of Metrorail. An evaluation study design was developed by WASHCOG and data collection activities were initiated prior to Metrorail's opening. Ongoing monitoring activities were conducted and information analyzed after the opening of different segments of the system. An advisory panel, comprised of representatives from the Washington, D.C. area and individuals who were involved in the BART study assisted in designing the evaluation program.

The Washington Metrorail Before-and-After Study focused primarily on examining travel impacts of the system, with some consideration of the secondary effects. The series of evaluation reports issued by MWCOG as part of the Metrorail Before-and-After program studies focused only on the first three phases of the system.

The established objectives for the program were to investigate and document the effect of Metrorail in order to increase general knowledge of rail transit impacts, to assist in planning

future rail systems, and to provide information to assist in the future operations of Metrorail. The following three general areas were examined during the study (19,20).

- Travel and transportation impacts
- Land use and activity impacts
- Policy analysis

A variety of data collection and monitoring activities were used to obtain the information needed for the evaluation. These included Metrorail ridership counts and passenger surveys, surveys of central area commuters, cordon counts, bus revenue allocation surveys, and rail marketing surveys. In addition, information from the regional residential building permit files, the U.S. Census, regional employment forecasts, and the U.S. Census of Retail Trade were examined.

Transit Use and Service. The evaluation program examined the growth of Metrorail ridership as different segments of the system opened. It also examined the effects of Metrorail on the total transit system, including regional bus services, and the impact of the rail system on travel to the Washington, D.C. central core. Transit-related impacts measured by the study included (19,20):

- Changes in Metrorail ridership by phase
- Previous travel mode of new riders
- Trip purpose of riders
- Total transit ridership (bus and rail)
- Geographic distribution of rail travel
- Changes in geographic distribution of bus ridership
- Changes in bus service
- Changes in travel to the Central Business District
- Travel time and cost

Total transit ridership remained fairly constant during the first year of the system's operation as previous bus riders shifted onto Metrorail. With the opening of the first extension offering service into a suburban residential area, total transit ridership began to rise along with Metrorail ridership. This indicated that Metrorail was attracting new riders in addition to former bus passengers. Systemwide, 54 percent of riders were found to be former bus passengers and 28 percent were former automobile drivers or passengers. In terms of trip purpose, 69 percent of trips on Metrorail were for commuting with the second most important trip classified as work-related (19).

As the downtown rail network expanded, increases in Metrorail ridership levels were matched by losses in passengers on the bus system. Some of this loss may be attributed to riders choosing the faster mode, while in other cases, bus routes were terminated at rail stations or eliminated altogether. The study established the importance of bus access to Metrorail, finding that one-half of all rail trips in 1979 involved a bus. While Metrorail began to carry riders to

and from the downtown core, the bus system began to shift its focus to serving trips made entirely within suburban area (19).

Data on traffic entering the region's central employment area was also collected and analyzed. The study identified changes in transit ridership and in auto travel to the city core. In 1979, the three Metrorail lines in operation accounted for 44 percent of transit trips entering the core area. For the period from 1977 to 1979, a decline in peak period automobile travel to the core was also recorded. Thus, the Metrorail system allowed substantial increases in travel to the core without increases in highway capacity (19,20).

Analysis of costs and commuting times found that Metrorail users who walked to and from the stations had a shorter trip than did transit riders prior to Metrorail's opening. However, if a bus was required to reach a Metrorail station, the total trip time was longer. Metrorail trips requiring a bus ride were also more expensive than prior bus-only trips, due to the additional fare, while rail-only trips were less expensive (19).

Land Use. The study examined the impact of the system on two aspects of land use and development. First, policy changes in local planning, zoning, and forecasting were monitored and analyzed. Second, a database was established to monitor new developments. Case studies focusing on 18 stations were used to identify changes in planning and zoning in each area. These studies found that several major developers were beginning to concentrate commercial and mixed-use projects in Metrorail station areas and that some localities within the region were developing zoning ordinances to facilitate this type of development and to broaden their tax base (21).

A residential building permit file maintained by WASHCOG was used in the study to analyze the number, type, and location of residential projects in the region. Examination of these records indicated that the total number of dwelling unit permits authorized in the region declined every year from 1977 to 1980. Of the permits issued, almost 60 percent were for townhouse, multiplex or multi-family construction. No direct correlation was found between location of permitted residential projects and Metrorail stations (21).

Overall, the study found that the Metrorail system appeared to have some general effect on various land use decisions in the region. These included areas served by Metrorail lines which had previously been planned for general commercial use, warehouses, industrial use and urban renewal, and were instead being developed as mixed-use projects or were the focus of preservation and revitalization (20,21).

Economic Development. The initial evaluation data documented employment changes and trends in retail sales in station areas and the region as a whole to establish baseline pre-Metrorail conditions. The study planned additional analyses to determine whether shifts in the location of new employment and retail centers were made to take advantage of access to the rail system. This analysis was not completed for the initial impact studies, however.

Calgary Transit - Light Rail Transit System (C-Train)

The first leg of Calgary's light rail transit system, called the C-Train, began operation in May of 1981. The 12.7 km (7.6 mile) South LRT line eventually formed half of a continuous Northwest-South mainline passing through downtown Calgary. The Calgary LRT system presently consists of three legs—South, Northwest and Northeast—encompassing a total of 28.3 km (approximately 17 miles). In the downtown area, the LRT operates on a transit mall. Long-range plans include extensions to the existing lines and new lines to the west, north, and southeast. The system has eleven stations in the downtown transit mall and nineteen suburban stations (22).

An impact study was conducted by the City of Calgary Transportation Department over a two year period to assess the initial effects of the LRT system. The major focus of the study was on ridership, traffic, and development impacts. A number of surveys were conducted as part of the assessment. These included an on-board ridership survey, a home interview, traffic counts, and transit passenger counts.

The summary report for the South LRT impact area provides pre- and post-LRT demographic information for the city and the south corridor. Additionally, the overall improvements in the city's transit system implemented in conjunction with the introduction of light rail service are identified. The introduction of light rail service resulted in a 49 percent increase in total transit hours of operation. The feeder bus network was completely revised and the hours of operation were increased by 89 percent. The hours of operation of the line haul system actually decreased by 14 percent due to the greater efficiency of light rail relative to buses (22).

Ridership and Travel Characteristics. In November 1982, a mail back questionnaire was given to LRT passengers boarding at suburban LRT stations in the morning peak-period and 1:00 and 3:00 P.M. Information was requested on mode of access to the system, travel characteristics, previous modes, and socio-economic characteristics.

Most LRT passengers surveyed on the South Line accessed the system by feeder buses. Approximately 50 percent of all peak-period passengers and 48 percent of the off-peak passengers arrived at LRT stations in this manner. For morning peak-period passengers, personal vehicles were the second most common access mode, accounting for 26 percent. Walking, at 32 percent, represented the second most popular mode of access for off-peak passengers (23). Similar responses were received from surveys of passengers on the Northeast and Northwest Lines (24,25).

The survey also obtained information regarding trip purpose and destinations. Work trips accounted for over 90 percent of peak-period travel, while non-work trip purposes comprised approximately of 70 percent of off-peak travel. Purposes other than work included shopping, school, social or recreational, and personal business (23,24,25). The percentage distribution of work and non-work trip destinations by region was also calculated from the survey. Almost 90 percent of all morning peak work trips were destined for downtown Calgary. Overall, the

downtown was the destination for 83 percent of peak-period travel and 50 percent of off-peak travel (23,24,25).

The on-board survey also examined the modes used by passengers prior to the introduction of light rail service. Former bus passengers accounted for 49 percent of peak and 39 percent of off-peak LRT riders. Former automobile drivers comprised 15 percent of the peak and 19 percent of the off-peak riders. New travel, including those who did not make the trip previously and new residents of the LRT impact area, accounted for about 30 percent of both peak and off-peak passengers (23).

A home interview survey was conducted after the South Line had been in operation for a year. Approximately five percent of the households in the South LRT impact area were surveyed to obtain information on the travel and socio-economic characteristics of residents. The home interview measured post-LRT travel within the impact area by distribution, mode, and purpose. Information on other factors influencing mode choice and the perceived impacts of the LRT system on travel in the South corridor was also obtained through the surveys.

Information from the surveys indicated that morning peak-period automobile travel to the downtown had dropped by 12 percent, while transit's share of the morning peak travel rose from 42 percent to 55 percent. The LRT system accounted for 48 percent of all morning peak-period travel to the downtown. Transit usage also increased from 31 percent to 42 percent for off-peak downtown travel (23).

Information was also obtained from the home interview survey on factors affecting mode choice of the respondent who indicated they had changed from driving alone to using the LRT system. Some 29 percent of the respondents cited convenience and flexibility as their main reason for using the LRT system, while 22 percent switched because rail offered lower out of pocket cost. Other factors cited for changing to LRT were total time, 16 percent, parking at destination, 11 percent, and rush hour driving, 6 percent (23).

The survey also examined the perceived impact of the LRT system on traffic congestion and transit service in the South LRT corridor. Approximately 46 percent of those surveyed felt the system had reduced traffic congestion levels and 47 percent stated that transit service had improved with the opening of the LRT system (23).

Safety. Information on safety was also monitored during the initial phases of system operation. A total of twenty accidents involving light rail vehicles in the Downtown Transit Mall occurred during the first two years of operation. The nature of these accidents was examined, along with the causes. No accidents were reported in the LRT corridors (23,24,25).

Urban Development. The impact of the LRT system on developments and land uses in the corridors and around stations was also monitored. Activities and trends in development from 1979 to 1983 was tracked by the number of residential units, square meters of commercial construction, and number of hotel rooms approved and built during that period. In the South LRT corridor, a number of new developments had been built or were under construction. Thus,

the line was judged to have influenced the consolidation and intensification of land uses in station areas (23).

Traffic/Transit Counts. Traffic counts of all person trips—auto, bus, and LRT—were made at two screenlines before and after the opening of the South Line. One screenline was located at the northern edge of the corridor and one was located within the corridor. The counts were taken for one day in May of 1981 and again in May of 1982. The results indicated a significant increase in transit passenger volumes and increased modal splits for transit for all time periods at both locations after the opening of the LRT system (23).

The greatest increase in transit usage at screenlines occurred during the afternoon peak-period. An 80 percent increase in transit usage was reported at the south downtown screenline, with a 3 percent increase in total vehicle trips. Transit usage increased by 70 percent at the screenline within the South corridor, with a 1 percent decrease in total vehicle trips during that period (23).

Tri-County Metropolitan Transportation District (Tri-Met) - MAX Light Rail System

The Tri-County Metropolitan Transportation District (Tri-Met) Metropolitan Area Express (MAX) light rail system in Portland, Oregon began operation on September 8, 1986. The 15-mile MAX line operates from downtown Portland east to the community of Gresham.

The MAX LRT line was developed through the joint efforts of Tri-Met and the Oregon Department of Transportation (ODOT). ODOT was responsible for 5 miles of freeway relocation and rehabilitation, bridge rebuilding to accommodate light rail, and construction of several light rail structures. Tri-Met was the lead agency for overall project management, scheduling, budget administration, and for designing and constructing the system (25).

A number of studies were initiated to monitor the impact of MAX. The major focus of these efforts were on the impacts of MAX on business attitudes and development trends, assessing the interest of developers in coordinating projects with future light rail stations, and examining changes in ridership and the characteristics of riders.

Transit Ridership. Over the first eight months of operation MAX ridership averaged 19,700 per day on weekdays, with weekend ridership often exceeding 25,000 passengers per day. A patronage profile published in 1990 examined ridership levels, trip purposes, access modes, fare information, demographics and station boarding information compiled since MAX began operation in 1986. This profile indicated that weekday ridership had remained fairly constant, at approximately 20,000 passengers since the 1986 opening. This study also reported that home-based work trips accounted for 53 percent of all weekday MAX trips. This figure is similar to that experienced on the bus system. Two-thirds of all trips on the MAX system began or ended in downtown Portland. Approximately 38 percent of all MAX trips included a walk at both ends, about 30 percent involved park-and-ride use, and about 30 percent included a bus transfer (26).

Economic Development. A consultant was retained by Tri-Met to examine the impacts of the MAX light rail system on businesses along the line and to assess developer interest in possible future joint projects. Interviews were conducted with store owners and managers to measure the impacts of construction activities on businesses, as well as examining the effects of MAX on business operations and growth, sales, business visibility and exposure, and benefits to employees. The study also assessed support in the business community for future expansion of the LRT system. Overall, most of those interviewed had positive responses to MAX, however, some loss in sales were reported during construction (27).

Real estate development professionals were mostly positive about the potential of locating future developments near LRT stations. The availability of the LRT system was noted as just one of many factors influencing location decisions, however. About two-thirds of those interviewed believed that property investments near MAX had benefitted from the system. Perceived advantages related to convenience for work commuters and the potential for increased customer sales through enhanced visibility. A smaller number of developers indicated some willingness to consider a long-term lease arrangement with a public entity for the purpose of developing a project at future MAX stations (28).

Metropolitan Transit Development Board (MTDB) - San Diego Trolley

The San Diego light rail system, referred to as the San Diego Trolley, was planned, designed, and constructed by the San Diego Metropolitan Transit Development Board (MTDB). The trolley began operation in the summer of 1981 on the initial line from downtown San Diego to the Mexican Border. The line is approximately 16 miles in length and operates on existing streets in the central city and on rehabilitated main-line railway facilities for approximately 14 miles. The line has 11 suburban stations and seven stops within the central city. Although the Trolley began service as a single-track operation, a double track system has been in operation since February 1983. Additional extensions to the system have been made and more are in the planning stage.

To evaluate the impact of the initial Trolley line on travel characteristics, land use, and socio-economic conditions in the area, MTDB, San Diego Trolley, Inc. (SDTI), and the San Diego Association of Governments (SANDAG) initiated in a Guideway Monitoring Study. This study was partially funded by the FTA.

A variety of data collection activities were conducted as part of the evaluation program. These included trolley ridership counts, on-board surveys, monitoring station activity, traffic volume counts, recording accident information, and monitoring development and land use changes (30).

Transit and Traffic Impacts. The Trolley experienced substantial increases in patronage during the first three years of operation, although initially, its overall ridership gains were minor. This increase in ridership was considered especially significant in relationship to the nearly 20 percent decrease in transit ridership in areas outside of the Trolley service area (30).

A survey of 1,500 passengers conducted two months after service began indicated that more than half of the Trolley riders had previously riden the bus to make the same trip. Almost 30 percent of all riders had previously used an automobile for the trip and 10 percent did not make the trip prior to the LRT service (30).

The study compared passenger surveys taken before and after the initiation of Trolley service. This analysis indicated that overall origins and destinations were similar for riders before and after the system opened. The Trolley carried a slightly higher percentage of school, shopping, and other trips, however, and a lower percentage of work and personal business trips than other routes in the area (30). The 1983 passenger survey also indicated that modes of access for Trolley riders were 60 percent walking, 19 percent by automobile, and about 20 percent transferring from local bus routes (30).

Traffic counts in the area were also examined as part of the study. This analysis indicated that changes in traffic volumes were not related to Trolley operation. Because the Trolley system is not totally grade separated, surveys were conducted on cross traffic delays at specific intersections. Based on the locations surveyed, the Trolley did increase traffic delays on some cross streets. The delays were well within the range found acceptable by traffic engineering standards, however. At most intersections, the Trolley accounted for only one part of the cause for delay, with crossing auto traffic having an equal or greater impact (30).

Accident incidents involving or related to the Trolley system in the central city were monitored by the City of San Diego. Overall, accidents declined after the Trolley began operating, but the study found that street modifications and decreased vehicular traffic volumes should be factored into this and did not make a straight before and after evaluation possible (30).

Land Use Policy and Development. The study evaluated data on planning and zoning changes and building activity collected from 1980 to 1984 by the planning departments in San Diego, National City, Chula Vista, and the County of San Diego. The land use impact study area was limited to lots adjacent to the Trolley right-of-way and approximately one-third mile around station sites. These boundaries were used to help ensure that land use changes considered could be directly influenced by the Trolley (30).

The study found that two changes to the General Plan in San Diego involved two of the Trolley station sites. One amendment was made for the purpose of compatibility with the LRT. This changed a parcel designation to take advantage of the access provided by the Trolley. The second amendment was made in conjunction with the annexation of property in the vicinity of a Trolley station to make the area consistent with the General Plan. None of the zoning changes made in the impact area during the four years were primarily related to their location near stations (30).

Building permits were used as a indicator of new construction activity in the land use impact study area. Over 1,100 residential units and 50 commercial, industrial, and institutional projects were processed in the area during the study period; no permits were issued along the Trolley right-of-way between station areas (30,31).

In addition to the information provided by area planning departments, a survey of the developers and leasing agents for ten of the projects constructed in the land use impact study area during the 1980-1984 period helped to assess the role of the Trolley in development location decisions and in the marketing and leasing success of the properties. In general, respondents representing projects in suburban areas indicated that the Trolley station was an important factor in their decision to develop the property and that it played a role in their leasing strategy. In contrast, at the time of the 1984 report, most respondents representing projects in the central city said that locating near a Trolley station was not a key factor in their development decisions. All central city respondents did indicate it was important to their marketing and leasing efforts, however (30). Increased interest on the part of developers in coordinating new projects with the Trolley system was reported in a 1989 study (31).

Houston HOV Lanes

The first HOV facility in Houston was the I-45 North Freeway Contraflow Lane (CFL) demonstration project, implemented in 1979. The success of this project led to the development of additional HOV facilities in other freeway corridors. Currently, 64 miles of a planned 110-mile HOV lane network are in operation in the Houston area. HOV facilities are in operation in 5 freeway corridors. Most of these are one-lane reversible, barrier separated facilities located in the freeway median. A short segment of a two-lane, two-direction HOV facility is in operation in one corridor.

The evaluation procedures, measures of effectiveness, and data collection activities associated with assessing the effectiveness of the Houston HOV lanes have evolved over the last 15 years. A brief review of the process used with the initial evaluation of the I-45 North Freeway CFL demonstration project and the development of the current procedures is provided here.

The I-45 North Freeway Contraflow lane was implemented as a UMTA-funded demonstration project. As such, a fairly extensive before-and-after evaluation was conducted of the facility. The evaluation was conducted by Cambridge Systematics, Inc., with assistance from TTI on many of the data collection activities. The project objectives and evaluation measures as outlined in the final report, are summarized next (32).

Project Objectives:

- Decrease (or slow the growth of) corridor vehicle-miles of travel (VMT) and associated fuel consumption and vehicle emissions
- Increase vehicle occupancy in the corridor
- Reduce congestion and, thus, decrease travel time
- Encourage acceptance and usage of public transportation

Evaluation Measures:

- Person and vehicle utilization
- Characteristics of both contraflow lane users and non-priority travelers
- Impact on non-priority users of the freeway

- Influence in promoting bus and vanpool use relative to other corridor improvements
- Associated safety and enforcement issues
- Public acceptance
- Impacts on corridor VMT, fuel consumption and vehicle emissions
- Associated costs

A variety of data collection activities were conducted to support the evaluation. This included the collection and analysis of traffic and CFL vehicle volume data and a number of surveys of commuters in the corridor. Surveys were conducted of bus passengers, van drivers, van passengers, peak-direction auto drivers and passengers, and off-peak direction drivers. This appears to have been the most extensive use to date of surveys to measure the attitudes and reactions of both users and non-users of HOV lanes.

As other HOV lanes were planned and implemented in Houston, a standardized evaluation program and corresponding monitoring and data collection program began to emerge. The Texas Department of Transportation (TxDOT) and the Metropolitan Transit Authority of Harris County (METRO) have sponsored this effort, which has been conducted by the Texas Transportation Institute. The major elements of this process focus on data collection efforts needed to evaluate the following objectives (33):

- Increase the effective person-movement capacity of the freeway
- HOV lane implementation should not unduly impact freeway mainlane operation
- The HOV lane project should be cost effective
- Development of the HOV lanes desirably will have public support
- HOV lanes should have favorable impacts on air quality and energy consumption

Specific levels of improvement have been identified for many of these objectives. To evaluate HOV lanes based on these general objectives, a variety of information is collected on a regular basis by TTI. The following list provides a summary of the major elements of the ongoing monitoring process.

Vehicle and Occupancy Counts. Vehicle and occupancy counts are taken on the HOV lanes and the general-purpose freeway lanes; the same counts are taken on two freeways that do not currently have HOV lanes. These facilities act as a control group. In addition, vehicle and occupancy counts are taken on eight arterial streets that serve as alternative routes to the HOV lane and freeway facilities and on freeway frontage roads. These counts are taken on a quarterly basis for the freeways, parallel alternative routes, and the HOV lanes.

Park-and-ride Counts. Parked vehicle counts are conducted at the park-and-ride lots associated with the HOV lanes and the two control freeway corridors. These counts are taken on a monthly basis.

Travel Time Runs. Travel time runs are conducted on the four HOV lanes and adjacent freeway mainlanes and the two control freeways on a quarterly basis.

User and Non-user Surveys. Surveys of bus users, carpoolers, and vanpoolers using the HOV lanes and single occupant vehicles in the general-purpose lanes are conducted on approximately an annual basis. These surveys are designed to obtain information on users' and non-users' perceptions of HOV lane utilization, reasons for mode choice selection, and general attitudes toward the impact of the HOV lanes.

Accident Data. Accident data are collected by the Houston Department of Public Safety for the freeway mainlanes and alternative parallel routes, and by METRO for the HOV lanes.

Violation Rates. METRO Transit Police monitor the violation rates on the HOV lanes. The vehicle and occupancy counts conducted by TTI also provide a check on violation rates.

Land Use Impacts. Periodic studies have been conducted to measure the impacts of the HOV lanes on land uses and developments, especially in areas around major park-and-ride lots. The studies conducted to date have not been able to identify any significant impacts on development patterns from the HOV lanes or park-and-ride facilities (34).

The Houston HOV lane evaluation program represents the most extensive and comprehensive ongoing monitoring and evaluation program being conducted of HOV facilities. As such, it represents one of the better models for consideration by other areas.

I-394—Minneapolis

The I-394 HOV facility includes a number of components. I-394 is located on the western side of Minneapolis; extending 11 miles from downtown Minneapolis to the City of Wayzata. The facility includes HOV lanes, general-purpose freeway lanes, and supporting transit improvements. For an eight mile segment, I-394 consists of 3 travel lanes in each direction. The inside lanes are HOV lanes, reserved for buses, carpools, and vanpools in the morning and afternoon peak-periods. The two-mile segment approaching the downtown area consists of two mixed traffic lanes in each direction and a barrier separated, reversible 2-lane HOV facility in the median. Other components of the system include 2 major transit stations, 7 park-and-ride lots, ramp metering, HOV bypass lanes of selected ramp meters, and 3 new parking garages in downtown Minneapolis. The garages, which contain approximately 6,000 spaces are directly accessible from the I-394 HOV lane and provide discounted parking rates for carpools and vanpools.

To help manage traffic during the construction of I-394, which was built on the alignment of existing TH12, and to introduce the HOV concept in the area, an interim HOV lane was implemented. The interim lane, called the *Sane Lane*, was opened in November 1985. The interim lane continued in use until the opening of the full facility in 1993.

An extensive before-and-after study of the interim and final HOV lanes was initiated prior to the opening of the initial lane. The evaluation effort is being funded by the Federal Highway Administration (FHWA) and the Minnesota Department of Transportation (Mn/DOT) and is being conducted by the consulting firm, SRF, Inc. A set of project goals and objectives was

identified by the I-394 Project Management Team, which is comprised of representatives of the different agencies involved with the project, for both the interim and completed facilities. These formed the basis for the development of the evaluation program.

The development of the evaluation program was completed prior to the opening of the interim facility in 1985. Three different time periods were identified for the project evaluation. These were the construction period, when the interim facility would be in operation, the start-up period for the completed facility, and the stable operating period. The following objectives were identified for the HOV facility. Although the objectives were to apply in general to all the evaluation periods, the evaluation program noted that the degree to which they are achieved will vary for each period (35).

- Increase the peak-hour carpool/vanpool modal split for the I-394 corridor
- Increase the peak-hour transit modal split for the I-394 corridor
- Improve the level-of-service for mixed traffic on I-394
- Maintain or improve the existing level-of-service for mixed traffic on I-394
- Maintain or improve the accident rate along I-394
- Achieve and maintain a low violation rate of the HOV lanes on I-394
- Construct a cost-effective HOV facility on I-394

For each of these objectives, specific performance measures were identified and a corresponding performance threshold was established for each time period. The thresholds were established based on an analysis of the existing conditions and the forecasted use for the different time periods.

The I-394 evaluation program is supported by an ongoing data collection effort. This program includes many of the same elements as those described previously with other studies. These include regular vehicle and occupancy counts on the HOV lane, mainlanes, and parallel facilities, travel time runs, accident data, violation rates, surveys of users and non-users, and evaluation of the different marketing and public information programs. Regular evaluations have been conducted and reports issued summarizing the results of the ongoing effort (36,37). Like the Houston program, the I-394 evaluation program represents one of the more extensive and comprehensive evaluation programs currently being conducted.

Municipality of Metropolitan Seattle (Metro) - Downtown Bus Tunnel

The Downtown Seattle Transit Project (DSTP) was developed to address the transportation needs of those travelling to, from, and within the Seattle Central Business District (CBD). The DSTP included a 1.3 mile electrified transit tunnel, dual-power diesel/electric buses for operation through the tunnel, and additional bus service on surface streets to enhance circulation in the CBD. Construction on the project started in 1986 and the downtown tunnel was opened in 1990. The goals of the project were (38):

- To provide adequate transit capacity for projected rush-hour ridership
- To improve the reliability and speed of transit service through downtown Seattle

- To provide adequate downtown transit circulation
- To provide the opportunity for conversion to a light rail system

The transit tunnel is the key element of the DSTP. Initially planned to serve dual-powered buses, switching from diesel to electric power as they approach downtown, the tunnel was designed to permit eventual conversion to rail transit. The tunnel has five passenger stations, including one at each end, which can be accessed from various points in Seattle's CBD.

An evaluation of the downtown bus tunnel was initiated by the local agencies. The Puget Sound Council of Governments (PSCOG), the MPO for the area, took the lead in this effort. Funding for the before data collection activities was provided by FTA. To prevent possible bias which might arise from having a local agency analyze data and evaluate the bus tunnel, FTA specified that the study would be limited to data collection of before conditions. As originally planned, PSCOG would compile data on the DSTP and a consultant would be retained to analyze the information. However, lack of funding prevented further action on the evaluation of the DSTP. The study does represent a relatively thorough assemblage of baseline data and for that reason is included in this report (38,39).

Information was collected and examined for five general elements. These included the following (38,39):

- Traffic composition - transit, carpool, single-occupancy vehicles, etc.
- Vehicle and pedestrian traffic conditions - volumes, geographic distribution, travel times, average vehicle occupancy, etc.
- Incentives offered by employers and building owners to discourage single-occupancy vehicle commuting
- Parking - availability, cost
- Transit operations - financial data, ridership and performance indicators

Further, the study was divided into the following twelve tasks:

- Project Management
- Revised Study Design
- Workplace Employee Survey
- Business Firm Survey
- CBD Circulation Survey
- Traffic Conditions
- Transit Passenger Profile
- Transit Operations Profile
- Land Use Profile
- Economic Profile
- Environmental Profile
- Final Report, Before Phase

Workplace Employee Survey and Circulation Survey. The downtown Seattle employee survey was conducted during April and May of 1987. The survey was designed to obtain basic descriptive characteristics of travel to and from the downtown, and travel throughout the day, from people who worked in the CBD. The first part of the employee survey obtained information on the demographics of downtown employees, including age and sex; occupation; residence location (broken down by sex, income, and occupation); household size and auto availability; and income (38).

The survey results also established baseline data on employee travel to and from work. Information was gathered on commuter's typical mode to work, the mode used the day before, residence location, employer characteristics, scheduled work times, and scheduled work days. CBD employees were also surveyed for mode changes and the reasons for any changes.

The study further examined the responses of those indicating that they typically took the bus to work. Information was obtained on fare payment methods. Respondents who reported driving alone or carpooling to work provided information on parking costs and subsidies. The survey form also included a trip diary for respondents to record time, location, trip purpose and trip mode for trips made during one day. The results provided information on mode and purpose of trips made within the CBD.

Business Firms Survey. The downtown employer survey was designed to obtain basic descriptive information on the characteristics of employers and to identify transportation-related benefits provided to workers. This survey, which was conducted by telephone, was paired with the previously discussed workplace employee survey. The sample of employers was based on the three criteria of number of employees, type of industry, and proximity to the bus tunnel alignment. Businesses were grouped into the four categories of services and government, financial, retail, and other. Businesses were further divided into categories according to number of employees. In addition, the survey sample was divided equally between those businesses located within one block of the bus tunnel and those located beyond one block.

The survey provided information on work schedules for downtown employees. Data were also obtained on the provision of parking by employers, and the location, cost, and ownership of parking facilities. Employers were surveyed to ascertain the percentage of businesses providing transit and commuting services or programs. Information was obtained regarding provision of transit schedules, discount transit passes, ticket books, or stickers, general transportation subsidies, company vehicles for carpools and vanpools, carpool and vanpool matching services, and the use of company cars for personal emergencies. This information was broken down by type of business, by size, and by location.

Employers were asked how long they had been in the same downtown location and if they had any immediate plans to relocate. The survey also examined possible transit influences on business relocation decisions. More than a quarter of the businesses with plans to move in the near future indicated that transit services had been considered in the location decision making process (38).

Transportation and Traffic Conditions. The database on transportation and traffic conditions included information on traffic counts and intersection levels of service, parking costs, utilization of park-and-ride facilities, average travel speeds, auto and vehicle occupancy levels, and traffic composition. Since the study was not funded until after construction had begun on the tunnel, data collected prior to construction were used in the database when possible. Sources for existing data included the Seattle Engineering Department for traffic and intersection counts, average travel times, and parking costs, and Seattle Metro for data on park-and-ride lot use.

The traffic counts and intersection level-of-service databases were created with information compiled from several sources. The traffic data were obtained from the Seattle Engineering Department, along with ramp volumes from the Washington State Department of Transportation (WSDOT). Data on the number of vehicles trips to and from the west obtained from the Washington State Ferry Department. Information on intersection level of service was collected by a consulting firm to assist in detour planning during construction of the bus tunnel.

The PSCOG conducted an inventory of off-street parking in the Seattle CBD during 1987 and developed a report which included summaries of parking costs and parking lot utilization rates. Information was gathered on the total number of parking spaces in the CBD, parking capacity and occupancy, losses and gains due to construction, and all-day and monthly parking fees. Data on utilization of park-and-ride facilities were obtained from Metro, which conducts weekly field checks and compiles monthly and quarterly reports.

Average travel speeds during the peak and mid-day time periods were obtained from the Seattle Engineering Department. Travel speeds for transit operations were estimated to be 10 to 50 percent lower than auto speeds because of frequent stops. Vehicle and auto occupancy data were collected by the PSCOG at selected cordon points around the CBD during the morning and afternoon peak periods. Peak-period occupancy at cordon locations and at four general locations around the CBD were tabulated, as well as vehicle and person distributions. A traffic composition database was also developed for the DSTP. Information on traffic composition was collected during the mid-morning and mid-afternoon periods, with ten categories of vehicles monitored.

Parking. PSCOG conducted an off-street parking survey of the Seattle CBD, divided into 13 zones. Each zone was surveyed during one morning and one evening period in the spring of 1987. All off-street public and private parking, and the number of parking stalls, was noted. In addition, information was gathered on the location of parking lots, ownership, cost of parking, and occupancy. The inventory included public and private lots, free and pay stalls, and parking spaces at hotels, motels, and condominiums. The data were entered into a Statistical Analysis System (SAS) dataset. Results of a 1984 SED parking survey were matched with the 1987 PSCOG survey and added to the computer file.

Transit Passenger Profile. A 1985 on-board transit survey of all in-bound riders conducted by Metro was used as the source of before data for the PSCOG study. The survey provided information on origins and destinations, trip purpose, fare payment, car availability, disabilities

and the use of wheelchair lifts, as well as standard demographic information on age, sex, ethnicity, household size, and income.

The basic information collected in the 1985 survey was broken out to identify characteristics of riders whose routes were planned to be routed through the bus tunnel. Characteristics of the potential tunnel bus riders were compiled by age, sex, income, and ethnicity. In addition, PSCOG looked at the trip characteristics of the tunnel bus riders, such as trip purpose, car availability, access to the bus, time of boarding, number of days the bus was ridden, and trip origin.

Transit Operations Profile. In order to develop evaluation measures for system performance, transit system totals over time were compiled for comparison with data collected after completion of the tunnel. Data used for this analysis included Metro's FTA Section 15 reports, Metro budget documents, and WSDOT's *Annual Public Transportation Statistics* reports. Route specific trip files from Metro's database were also used.

The performance measures were developed using simple ratios. Information on annual passenger trips (linked trips), annual passenger trips per capita, passengers per vehicle hour, vehicle miles per vehicle hour, total annual revenues and expenses, and operating costs per total vehicle mile were examined. In order to derive information on average weekday transit operations, not adequately addressed in the WSDOT annual statistics, data from Metro's Section 15 reports and budget documents were analyzed. Since the bus tunnel's impact was estimated to be greatest during the weekday, performance indicators that reflect the morning and afternoon peak periods were examined.

Land Use Profile. Information from a land use inventory conducted for the City of Seattle in 1979, and updated in 1982 was examined in the study. The PSCOG updated this information to 1986. In addition to this land use inventory of the downtown area, Seattle's land use policies and zoning designations were reviewed, including the City of Seattle's new zoning ordinance for the downtown, which was adopted in 1985.

Economic Profile. Baseline information on office space and absorption rates, retail businesses, and the hotel market in the Seattle CBD and Puget Sound region was established as part of the study. One problem noted in comparing information from various sources was the lack of a standard definition for the Seattle CBD's geographic boundaries. Information on office space was obtained from the region's Coldwell Banker database. Historical data on prime office space and the office space absorption rate for the region and for downtown Seattle for the period from 1982 through 1987 were examined from this source. Data on new prime office space and vacancy rates for the region and the downtown were also included.

The report's retail data were compiled from the U.S. Census of Retail Trade and the Washington State Department of Revenue *Quarterly Business Review*. The report provides information on gross retail sales for 1977 to 1987 for the Puget Sound region and for Seattle. Retail sales by category data is given for 1977 and 1982 for the region and the Seattle CBD. Also included in this section is a 1986 distribution of retail stores by zip code in the downtown

Seattle area. Information on the hotel market from 1982 through 1987 examined included available room nights, occupied room nights, market occupancy rates, and average room rates for downtown Seattle and for King and Snohomish counties, combined.

Environmental Profile. The environmental profile for the study addressed air quality, noise, and transit fuel consumption. The air quality measures examined were carbon monoxide, total suspended particulates, and ozone. Existing environment noise levels for twelve sites along the proposed tunnel route were established by a consultant in 1982, as part of the Environmental Impact Statement process. In addition, the consultant's study determined the individual noise levels for cars, trucks, diesel buses, and electric trolleys, and established the typical diesel bus noise levels in an enclosed space for use in the station noise analysis.

CHAPTER FOUR—DART LRT STARTER LINE ASSESSMENT STUDY DESIGN

The information presented in the previous chapters was utilized in the development of the study design for assessing the impacts of the DART LRT Starter Line. The DART goals, principles, and key criteria guided the overall focus of the study design. These were used to help identify critical elements to be examined in the assessment. The review of existing data collection activities provided an indication of historical information that could be used in the assessment as well as the potential for coordinating future data collection and monitoring efforts. Finally, the results from the examination of recent fixed-guideway evaluation studies helped identify those factors that a new LRT system could realistically be expected to influence. In addition, the problems and issues encountered in those studies, and the lessons learned, were used to develop a practical study design for the DART LRT Starter Line Assessment.

This chapter presents the proposed study design for assessing the impacts of the DART LRT Starter Line. To accomplish this objective, the chapter is divided into six sections. The purpose of the DART LRT Starter Line assessment is presented first. This is followed by a discussion of the approach and phasing for the study. To ensure that a comprehensive assessment is conducted, a five phased study is outlined. The five focus areas for the assessment are described next. The major data collection activities for each of the five areas—mobility, development and land use, environment, costs, and community attitudes—are also outlined. A tentative schedule for the assessment is presented next, followed by a preliminary budget and suggested project management approach. The chapter concludes with the identification of the next steps in the process.

Purpose of Assessment

The purpose of the DART LRT Starter Line assessment is to enhance the understanding of the principal effects of an LRT system in Dallas. Thus, the primary goal of the assessment is to provide information to local transportation professionals and decision makers on the impacts of the LRT Starter Line. In the short-term, this information can be used to expand and enhance the positive impacts of the system, and address and mitigate any negative aspects. Over the longer term, the study results can be used in planning future LRT extensions and other related projects in the Dallas area.

On a secondary level, the results of the DART LRT Starter Line assessment will be of interest and of benefit at the state and national levels. Information from the DART study could be utilized by other cities in Texas considering LRT systems. Given the unique characteristics of Texas and other Southwestern cities, the results from the DART assessment will be of special value to other transit systems in these areas.

Finally, the DART assessment study can assist in establishing an ongoing national database on LRT systems. Building a common body of knowledge on the use and effects of LRT systems is needed to continue to keep pace with the issues facing transportation

professionals and decision makers in urban areas. A common database on LRT systems can assist in ensuring that all groups are kept informed on the latest developments in the field.

Approach and Phasing

A comprehensive approach, covering all time periods, is proposed for the DART LRT Starter Line Assessment. A five phased study design is proposed to accomplish this objective. The five phases—before, initial operation, full operation, after, and ongoing monitoring—are identified in Table 4. The general time period for each phase is highlighted along with the major elements to be addressed. The major components of each phase are described in more detail next. The specific data collection activities anticipated in each phase are discussed in the following section.

Table 4. DART LRT Starter Line Assessment Phasing

Phase	Time Period	Major Focus
Before	At least 1 year before Starter Line opens	Establish base line information for all elements.
Initial Operation	Six months after Starter Line opens	Interim picture of system impacts shortly after service starts; limited data collection.
Full Operation	One year after Starter Line opens	Effects of full system; more extensive data collection and analysis focusing on mobility impacts and attitudinal changes.
After	Three to five years after Starter Line opens	Comprehensive data collection and evaluation effort focusing on assessing impacts of mature system.
Ongoing Monitoring	Ongoing	Ongoing monitoring of changes in key characteristics, features, and factors.

- **Before.** The before phase will document existing conditions for a wide range of factors. The before data will establish the base line against which future conditions will be measured. The before data collection should be initiated as soon as possible to assure that an accurate base line is established. Construction

activities, especially those along the North Central Expressway, may have already influenced changes in travel patterns and traffic volumes. A good base line can still be developed, however, with special consideration given to the possible impacts of construction activities. The before assessment should be comprehensive to ensure that the base conditions are adequately documented. It may be better to err on the side of too much, rather than too little, before data.

- **Initial Operation**. The second phase of the assessment should occur after the system has been in operation for six months. The intent of this phase is to provide an interim picture of the system shortly after opening. Data collection activities in this phase would be limited and would focus on operational factors.

- **Full Operation**. The third phase of the assessment should cover the full operation of the DART LRT Starter Line. The third phase would occur after at least a full year of operation and would involve more extensive data collection and analysis. In addition to operational measures, this phase would also examine mobility impacts and attitudinal changes.

- **After**. The fourth phase represents the major focus of the assessment. This phase would be conducted after the LRT Starter Line has been in operation for 3 to 5 years. Thus, the intent of this phase is to measure the impacts of a mature system. A comprehensive data collection and analysis program would be conducted in this phase, closely replicating the effort undertaken in the before phase. It is important that this phase be conducted before other LRT lines are opened.

- **Ongoing Monitoring**. An ongoing monitoring and evaluation program should be continued to measure the long-term impacts of the LRT line. This phase would focus on elements such as land use and development changes, as well as ongoing monitoring of transit ridership levels, travel patterns, and traffic conditions.

Focus Areas

Five focus areas, or principal areas of study, are proposed for the DART LRT Starter Line assessment. These are mobility, development and land use, environment, costs, and community attitudes. Each of these contain a number of elements and will require a variety of data collection activities. In combination, they provide a comprehensive assessment of the possible impacts of the DART LRT Starter Line, however. The five focus areas are briefly described next, along with the major data collection and monitoring activities associated with each.

- **Mobility Impacts**. Elements to be examined in this focus area include transit ridership levels, traffic conditions, travel trends, and accessibility changes. The analysis will focus on the travel sheds served by the LRT lines and the control

corridor. The specific elements to be addressed and the data collection activities are highlighted in Table 5.

- **Development and Land Use**. This focus area will monitor and document changes in development and land use patterns around DART LRT stations and in the LRT corridors. The major elements to be examined in this area and the necessary data collection activities are outlined in Table 6. A comprehensive before survey of land uses and developments should be conducted in the LRT station areas and corridors should be initiated to develop the base line. Given the experience in other cities, the land use and development impacts of the DART LRT system can be expected to happen slowly over a period of years. Thus, an ongoing monitoring program is critical for this focus area.

- **Environment**. Three potential environmental impacts are proposed to be examined in this focus area. These are air pollution and air quality levels in station areas, noise levels in station areas and in LRT corridors, and crime in station areas. The data collection activities associated with each of these elements are highlighted in Table 7.

- **Costs**. The capital and operating costs of the LRT Starter Line will be examined as part of the overall assessment. The focus of this effort will be on comparing the actual capital and operating costs with those estimated during the planning process. Any differences will be examined along with the factors influencing the changes. Although it is not anticipated that these elements will be examined in as much detail as other impacts, they can provide useful information for planning future extensions and for other cities considering LRT systems. Table 8 provides an indication of the information needed in this analysis.

- **Community Attitudes**. The attitudes of riders, the community as a whole, developers and businesses, and decision makers will be examined in this step. The attitudes and perceptions of these groups toward the LRT system, and its impact, will be examined through a series of special surveys, interviews, and focus groups. It is realized that many of these perceptions may not be quantifiable, but they are important nonetheless. The types of surveys and other activities that could be conducted to obtain this information are presented in Table 9.

Table 5. Mobility Impacts

Elements	Data Collection
Transit Ridership Levels	▸Route by route ridership counts ▸Park-and-ride lot counts ▸Maximum load counts ▸Transit operations inventory ▸On-board ridership survey
Transit Travel Time	▸Before travel time by route ▸After travel time by route
Traffic Conditions	▸Roadway link and screenline traffic counts Machine counts Peak and daily On and between freeways and arterials Links throughout corridors Screenlines across corridors Around station locations CBD cordon Control locations ▸CBD manual cordon count Peak and off-peak Transit and private vehicles Occupancy ▸Intersection manual counts Level of service (V/C) Turning movements Accidents near grade crossings All arterial intersections around stations
Travel Trends	▸Cordon counts ▸Transit ridership and non-user surveys ▸Transit operations inventory
Accessibility Change	▸Cordon counts ▸Transit ridership and non-user surveys ▸Transit operations inventory

Table 6. Development and Land Use Impacts

Elements	Data Collection
Population	▸Census and other special studies
Employment	▸Census and other special studies
Economic Activity	▸Retail sales ▸Rents and leases by type of business ▸Business impact and relocation analysis
Development	▸Occupancy rates by types of business ▸Changes in development/demolitions
Land Use	▸Current uses by type ▸Building permits ▸Actual construction ▸Plan and zoning changes
Housing	▸Housing inventory by type ▸Prices, rents, occupancy levels
Activity Center Case Study	▸Special study
Station Area Development Studies	▸Special study
Neighborhood Impact Studies	▸Special study

Table 7. Environmental Impacts

Elements	Data Collection
Air Pollution and Air Quality Levels	▸ Base line air quality measurement stations, park-and-ride lots, and in adjacent neighborhoods. ▸ Ongoing monitoring or air quality levels at stations, park-and-ride lots, and in adjacent neighborhoods.
Noise Levels	▸ Base line noise measurements at stations and along LRT corridors. ▸ Ongoing monitoring of noise levels at stations and along LRT corridors.
Crime	▸ Base line information on reported crimes in station areas. ▸ Ongoing monitoring of reported crimes in station areas.

Table 8. Cost Impacts

Element	Data Collection
Capital Costs	▸ Estimated capital costs ▸ Actual costs for each system element
Operating Costs	▸ Estimated operating costs ▸ Actual operating costs by LRT lines, bus route, and other system elements ▸ Before and after fare box recovery, cost by route, and other criteria

Table 9. Community Attitudes

Elements	Data Collection
Community Attitudes	▸Telephone survey ▸Workplace survey ▸Shopper survey ▸Rider and non-user surveys ▸Focus groups
LRT Riders	▸On-board ridership surveys ▸Focus groups
Developers	▸Interviews ▸Surveys ▸Focus groups
Business	▸Interviews ▸Surveys ▸Focus groups
Decision Makers	▸Interviews ▸Surveys ▸Focus groups

Preliminary Schedule

A multi-year schedule is proposed for the DART LRT Starter Line assessment. As discussed previously, this is necessary since many of the impacts of the LRT system will emerge over time. Table 9 provides a preliminary schedule for the assessments focusing on the time needed for each of the five phases. The before or base year inventory should be initiated as soon as possible to provide the best information on conditions before the final construction activities and opening of the system in 1996. It is realized that the schedule may change depending on the timing of the actual opening and different elements of the LRT system.

Estimated Budget

The estimated cost for the first three phases—before, initial operation, and full operation—is approximately $2 million.

Table 10. Preliminary Schedule

Phase	Schedule								
	1995	1996	1997	1998	1999	2000	2001	2002	2003
Before	———	———							
Initial operation			——						
Full operation				———	———				
After							———	———	
Ongoing									——

Suggested Management Approach

Most of the evaluation studies examined in Chapter Four were managed by the metropolitan planning organization (MPO) or other regional organization. Although the transit agency and other agencies responsible for the fixed-guideway system were actively involved in the evaluation process, they were not responsible for the overall conduct of the studies. This approach helps ensure objectivity in the evaluations.

To help maintain objectivity with the DART Starter Line Assessment, it is suggested that TTI continue to take the lead role in the actual evaluation. This would be very similar to the role TTI plays in the ongoing assessment of the East R. L. Thornton HOV lane in Dallas and the HOV lane system in Houston. An interagency Advisory Committee and an expert Advisory Committee would be used to help guide the assessment and ensure coordination among the different agencies.

Next Steps

The next steps needed to initiate the assessment include securing the necessary funding, developing any interagency agreements that may be needed, organizing the interagency and expert Advisory Committees, and finalizing a more detailed work plan. DART, working with NCTCOG, FTA, and others can identify appropriate funding sources for the assessment. Grant applications and other agreements can then be developed. Once funding is secured, any needed interagency agreements can be developed, the various advisory committees can be established, a detailed work plan can be finalized, and the assessment can be initiated.

REFERENCES

1 Dallas Area Rapid Transit. *Profile and Update*. Dallas: Dallas Area Rapid Transit, January 1990.

2 Dallas Area Rapid Transit. *Project Development Progress Report*. Dallas: Dallas Area Rapid Transit, September 1994.

3 Turnbull, Katherine F., Russell Henk, and Dennis Christiansen. *Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities*. College Station, Texas: Texas Transportation Institute, 1991.

4 City of Atlanta. *Transit Station Area Development Plans: Study Design*. Atlanta: City of Atlanta, Bureau of Planning, 1975.

5 Atlanta Regional Commission. *Transit Impact Monitoring Program: 1982 Annual Report*. Atlanta: Atlanta Regional Commission, 1983.

6 Atlanta Regional Commission. *Transit Impact Monitoring Program: Results of Travel time Studies in the East-West Corridor, Interim Report*. Atlanta: Atlanta Regional Commission, 1982.

7 Atlanta Regional Commission. *Transit Impact Monitoring Program: Results of 1980 On-Board Survey of MARTA Transit Patrons*. Atlanta: Atlanta Regional Commission, 1984.

8 Atlanta Regional Commission. *Transit Impact Monitoring Program: Traffic Changes in Rail Corridors and Station Areas, East-West Line 1979-1980, Northeast-South Line, 1984-1985*. Atlanta: Atlanta Regional Commission, 1987.

9 Atlanta Regional Commission. *Transit Impact Monitoring Program: Transit Station Area Development Studies, Implementation Status Report*. Atlanta: Atlanta Regional Development Commission, 1984.

10 City of Atlanta. *Transit Station Area Update*. Atlanta: City of Atlanta, Bureau of Planning, 1986.

11 Atlanta Regional Commission. *Transit Impact Monitoring Program: Analysis of MARTA Operations Data in the East-West Line Corridor FY 1979-FY 1981, Interim Report*. Atlanta: Atlanta Regional Commission, 1984.

12 Bandy, Gene. *Transportation Technical Memorandum 51 - Baltimore Metro Impact Study: Documentation of Baseline Conditions Prior to Operation*. Baltimore: Regional Council, 1985.

13 Harrold, Cliff. *Staff Paper 54-Section A Baltimore Metro Impact Study: A Before and After Comparison.* Baltimore: Regional Planning Council, 1987.

14 Quackenbush, Karl H., Erik Holst-Roness, Thomas J. Humphrey, and Geoff Slater. *Red Line Extension to Alewife: Before/After Study.* Boston: Central Transportation Planning Staff for the Massachusetts Bay Transportation Authority, 1987.

15 Quackenbush, Karl H., Erik Holst-Roness, Thomas J. Humphrey, and Geoff Slater. *Red Line Extension to Alewife: Before/After Study—Appendices.* Boston: Central Transportation Planning Staff for the Massachusetts Bay Transportation Authority, 1987.

16 Chicago Area Transportation Study. *The O'Hare Road Transit Extension Before-After Analysis.* Chicago: Chicago Area Transportation Study, 1986.

17 Metropolitan Transportation Commission. *BART Impact Program: BART in the San Francisco Bay Area - A Summary of the Final Report of the BART Impact Program.* Washington, D.C.: U.S. Department of Transportation, 1979.

18 Metropolitan Transportation Commission. *BART Impact Program.* San Francisco: Metropolitan Transportation Commission, 1985.

19 Dunphy, Robert T. and Robert E. Griffiths. *The First Four Years of Metrorail: Travel Changes.* Washington, D.C.: Metropolitan Washington Council of Governments, 1981.

20 Donnelly, Paget. *Rail Transit Impact Studies: Atlanta, Washington, San Diego.* Washington, D.C.: Price, Williams and Associates, 1982.

21 Dunphy, Robert T. and the Department of Community and Economic Resources. *Trends Before Metrorail.* Washington, D.C.: Metropolitan Washington Council of Governments, 1982.

22 Calgary Transit. *Calgary's LRT Program Status Report.* Calgary: Calgary Transit, 1988.

23 City of Calgary. *South LRT Impact Study: Part IV - Summary Report.* Calgary: City of Calgary Transportation Department, 1985.

24 City of Calgary. *Northwest LRT Impact Study On-Board Survey.* Calgary: City of Calgary Transportation Department, 1988.

25 City of Calgary. *Northeast Impact Study: Part I - On-Board Survey.* Calgary: City of Calgary Transportation Department, 1988.

26 Higbee, Ronald W. and Scott R. Farnsworth. *Portland's Light Rail Project: Construction Completion of MAX.* Presented to the American Public Transportation Association of Light Rail Conference, June 1987.

27 Tri-County Metropolitan Transit District. *MAX Light Rail Line Patronage Profile.* Portland: Tri-County Metropolitan Transportation District, 1990.

28 Region West Research Consultants. *Portland Business Experience: The Benefits and Impacts of Being Located Near MAX Light Rail. Executive Summary.* Portland: Region West Research Consultants, 1988.

29 Region West Research Consultants. *Developer Interest, Attitudes about PublicPrivate Ventures, and Assessment of the Development Potential for Future Light Rail Station Projects. Executive Summary.* Portland: Region West Research Consultants, 1988.

30 San Diego Association of Governments. *San Diego Trolley: The First Three Years.* Washington, D.C.: U.S. Department of Transportation, 1984.

31 Thorpe, Richard D. *LRT Progress in San Diego.* Presented at the 1989 American Public Transportation Rapid Transit Conference, June 1989.

32 Atherton, Terry J. and Ellyn S. Eder. *Houston North Freeway Contraflow Lane Demonstration.* Washington, D.C.: U.S. Department of Transportation, 1982.

33 Wade, Montie, Dennis L. Christiansen, and Daniel E. Morris. *An Evaluation of Houston High-Occupancy Vehicle Lane System.* College Station: Texas Transportation Institute, 1990.

34 Washington, Earl J. and Robert W. Stokes. *Land Use Impacts of the Houston Transitway System: Summary Report.* College Station: Texas Transportation Institute, 1989.

35 Strgar-Roscoe, Inc. *I-394 Transportation System Management Plan Objectives.* Minneapolis: Strgar-Roscoe, Inc., 1984.

36 SRF, Inc. *I-394 Interim HOV Lane: A Case Study.* Minneapolis: SRF, Inc., 1987.

37 Minnesota Department of Transportation. *I-394 HOV Lane Phase II Evaluation.* St. Paul: Minnesota Department of Transportation, 1994.

38 Puget Sound Council of Governments. *Downtown Seattle Transit project Before and After Study: Final Report.* Seattle: Puget Sound Council of Governments, 1989.

39 Puget Sound Council of Governments. *Appendices to Downtown Seattle Transit Project Before and After Study: Final Report*. Seattle: Puget Sound Council of Governments, 1989.