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Orange County Transit/traffic Management Integration And Traveler Information Project:  
Evaluation Plan

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### Authors

Hall, R.  
Hickman, M.

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CALIFORNIA PATH PROGRAM  
INSTITUTE OF TRANSPORTATION STUDIES  
UNIVERSITY OF CALIFORNIA, BERKELEY

# **Orange County Transit/Traffic Management Integration and Traveler Information Project: Evaluation Plan**

**Randolph Hall  
Mark Hickman**

**California PATH Working Paper  
UCB-ITS-PWP-96-15**

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**Orange County Transit/Traffic Management Integration  
and Traveler Information Project: Evaluation Plan**

Randolph Hall  
Department of Industrial and Systems Engineering  
University of Southern California

Mark Hickman  
California PATH

Submitted to the California Department of Transportation  
Division of New Technology, Materials and Research

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## **ABSTRACT**

The California Department of Transportation (Caltrans) and the Orange County Transportation Authority (OCTA) are conducting a Field Operational Test (FOT) to develop an integrated information system for transit and traffic management and for traveler information that relies on GPS (Global Positioning System) equipped buses as probe vehicles. This document provides the evaluation plan for the FOT. The plan covers three principal elements: (1) Institutional, TMC Operator and Bus Operator, (2) Public Knowledge and Perceptions, and (3) System Performance. The document provides an overall evaluation framework that describes how the evaluation elements will assess project objectives. In addition, for each element, the plan provides goals and objectives, data collection methods, data analysis methods, resources, schedule and deliverables.

## EXECUTIVE SUMMARY

The California Department of Transportation (Caltrans) and the Orange County Transportation Authority (OCTA) are conducting a Field Operational Test (FOT) to develop an integrated information system for transit and traffic management and for traveler information that relies on GPS (Global Positioning System) equipped buses as probe vehicles. As part of this project, California PATH has been asked to conduct an evaluation of both the technical and non-technical aspects of the project.

The cooperative agreement between Caltrans and OCTA has provided the following four objectives for the Transit Probe project.

- Provide traffic managers with information with which they can better manage their network
- Provide transit operations with information with which they can more efficiently operate their vehicles
- Provide the public with both transit and traffic information with which to evaluate trip-making alternatives
- Provide a framework of institutional agreements

There are several elements of this project, and a number of related existing and planned activities, designed to meet these objectives. The particular technical elements of this project include:

1. Implementation of a global positioning system (GPS) for transit vehicle tracking, for approximately **43** transit vehicles;
2. Development of a database for real-time receipt and dissemination of information from OCTA, TMC's at the City of Anaheim and the City of Santa Ana, and Caltrans District 12;
3. Development of an interface to allow the public and the media to access this real-time database; and,
4. Two-way communication links between the database and OCTA, TMC's at the City of Anaheim and the City of Santa Ana, Caltrans District 12, and the public and media interface.

This document provides the evaluation plan for the FOT. The plan covers three principal elements of the evaluation: (1) Institutional, TMC Operator and Bus Operator, (2) Public Knowledge and Perceptions, and (3) System Performance. The document provides an overall evaluation framework that describes how the evaluation elements will assess project objectives. In addition, for each element, the plan provides goals and objectives, data collection methods, data analysis methods, resources, schedule and deliverables.

# 1. INTRODUCTION

## 1.1 Evaluation Background

A cooperative agreement has been established between the California Department of Transportation (Caltrans) and the Orange County Transportation Authority (OCTA) to develop an integrated information system for transit and traffic management and for traveler information. This project, hereafter called the “Transit Probe” project, is intended to improve the cooperative management of the transportation system and to allow travelers to get real-time information on both transit and traffic conditions in Orange County.

As part of this project, California PATH has been asked to conduct an evaluation of both the technical and non-technical aspects of the project. There are several important roles for the evaluation in a project such as this, including:

1. Documentation of the history and development of the project;
2. A story of the system implementation, along with associated successes and failures;
3. Constructive feedback to improve system operations within the project; and,
4. Useful insights on this operational test for others in the transportation community considering similar projects.

This document describes a plan to evaluate the Transit Probe project, including the goals and objectives of the evaluation, data collection and analysis methods, tasks and schedule, resources, and deliverables. These items are outlined in the remainder of this section, and are described in greater detail in subsequent sections of this plan.

## 1.2 Evaluation Framework

### Project Background

The cooperative agreement between Caltrans and OCTA has provided the following four objectives for the Transit Probe project:

- Provide traffic managers with information with which they can better manage their network
- Provide transit operations with information with which they can more efficiently operate their vehicles
- Provide the public with both transit and traffic information with which to evaluate trip-making alternatives
- Provide a framework of institutional agreements

There are several elements of this project, and a number of related existing and planned activities, designed to meet these objectives. The particular technical elements of this project include:



1. Implementation of a global positioning system (GPS) for transit vehicle tracking, for approximately **43** transit vehicles;
2. Development of a database for real-time receipt and dissemination of information from OCTA, TMC's at the City of Anaheim and the City of Santa Ana, and Caltrans District 12;
3. Development of an interface to allow the public and the media to access this real-time database; and,
4. Two-way communication links between the database and OCTA, TMC's at the City of Anaheim and the City of Santa Ana, Caltrans District 12, and the public and media interface.

The bus AVL data will be transmitted to the OCTA dispatch center in Garden Grove, where it will be collected, processed and stored on a local network within the center. From there, it will be disseminated to bus dispatchers at OCTA, who may then use this information to improve service delivery. The availability of the bus AVL data will ensure that the bus dispatchers are better informed of bus locations and current service characteristics (e.g., headways, transfer needs, incidents, etc.). In addition, the bus AVL data will also be shared over a two-way communications link with Caltrans and the Anaheim and Santa Ana TMC's. These data may in turn allow traffic managers at each of these locations to understand the current traffic conditions, incidents, and level of congestion in their network. With this information, they may take appropriate actions to improve traffic flows.

The technical elements of this project will also support dissemination of travel information to the public. Three kiosks will be installed at various locations in the county, allowing for dissemination of both static routes and schedules as well as real-time information on bus arrival times. More specifically, the kiosks will be connected via phone lines to the same data base at the OCTA operations center, allowing periodic updates of data at these kiosks. The public may then use this information to improve their trip planning and/or reduce their uncertainty about the bus.

This project is intended to work cooperatively with the TravelTIP project currently underway between Caltrans and OCTA. In addition to the bus AVL data provided in the Transit Probe project, the TravelTIP project will provide additional real-time traffic data to the kiosks. It will also provide several additional media to disseminate real-time traffic and transit conditions to travelers across Orange County, using means such as cable television, radio, and interactive displays. As much as possible, we will coordinate our evaluation of the Transit Probe traveler information system with that of the TravelTIP project.

Finally, this project will provide a framework for institutional cooperation in Orange County. Such a framework is enhanced through both technical and non-technical elements of this project. On the technical side, the sharing of communications media and time-critical operations data allows each participating agency to take some ownership in the management of the multi-modal transportation system in Orange County. In addition, through the ongoing project development and collaboration, the Transit Probe project will also enhance institutional cooperation and understanding.

## Evaluation Approach

In the evaluation of this project, three “elements” are proposed to cover both the technical and non-technical aspects of this project:

1. Institutional, TMC operator and bus operator effects
2. Public knowledge and perceptions of the project
3. System performance

Each of these three areas is described in greater detail in Sections 2 through 4, respectively. In summary, Table 1 connects these three evaluation elements to the four project objectives described above. The first element in this list is an evaluation of the institutional relationships that grow out of this project. This review should give us a better idea of how the project is meeting the objective of providing a broad framework for institutional cooperation. In addition, we will be evaluating the impact of the transit probe project on the workloads of operators as well as of supervisory and management personnel. With this evaluation, we will assess how the probe data are being used and how it impacts the daily activity for both traffic and transit managers.

**TABLE 1: Connection of Project Goals to the Evaluation Elements**

Project Goals	Evaluation Element		
	Institutional, TMC operator and bus operator	Public knowledge and perceptions	System performance
Provide traffic managers with information with which they can better manage their network	<i>J</i>		<i>J</i>
Provide transit operations with information with which they can more efficiently operate their vehicles	✓		<i>J</i>
Provide the public with both transit and traffic information with which to evaluate trip-making alternatives		<i>J</i>	<i>J</i>
Provide a framework of institutional agreements	✓		

A second element in our evaluation is a review of public awareness of the transit probe project and their perceptions of how it is improving transportation services in the region. First, we will assess the extent to which transit passengers are aware of the probe project, and any perceptions they may have about how the bus AVL system is being used to enhance their travel. At another level, the transit probe project includes dissemination of transportation information directly

through kiosks, and later, through media connected with the TravelTIP project. Public perceptions and use of this information will also be evaluated.

Finally, the third element of the evaluation identifies the extent to which the transit bus probe data are used by both transit and traffic managers to improve the operation of the transportation system. With the bus AVL data, we will evaluate how this information may be used at OCTA to enhance transit service. At the same time, the buses will be acting as traffic probes, and can provide useful congestion and incident information to traffic managers. We will evaluate how each organization is using These data, and what impacts this may have on the operation of the transportation system.

### **1.3 Evaluation Responsibilities**

To complete these three elements, we have further subdivided these into specific evaluation tasks. These are described in greater detail in Sections 2,3 and 4, and are summarized as follows:

#### Institutional, TMC and Bus Operator Element

- o **Institutional Study** Examination of institutional relationships through project development and implementation.
- o **TMC Study** Evaluation of the use of transit probe data and associated workloads at transportation management centers.
- o **Bus Operator Study** Evaluation of the use of bus monitoring data and associated workloads at the OCTA operations center.

#### Public Knowledge and Perceptions Element

- o **Transit On-Board Study** Evaluation of changes in perceptions and experiences of regular and infrequent transit riders.
- **Kiosk Study** Assessment of the use and experience with local kiosk information, including electronic information about OCTA transit service.

#### System Performance Element

- **Bus System Performance** Examination of changes in bus schedule adherence, transfer coordination, and sources of schedule delay.
- **Buses as Traffic Probes** Evaluation of the performance of transit buses as traffic probes on both the arterial and freeway system.

The primary evaluation responsibilities for these tasks are summarized in Table 2 and detailed in the later sections of this plan. Table 3 also gives the level of effort expected for each of these tasks. For Element 1, Randolph Hall will be the leader for the Institutional study and Baher Abdulhai (California PATH) will be the leader for the TMC and Bus Operator studies. A graduate research assistant will assist with the data collection for the TMC and Bus Operator studies, primarily for observation and bus ride-alongs.

For Element 2, Baher Abdulhai will be the leader for the bus on-board survey and Randolph Hall will be the leader for the kiosk intercept surveys. For both the transit survey and the kiosk survey, the task leaders will develop the surveys, but these will be fielded by a survey research firm contracted from PATH. Data analysis will be conducted by the respective task leaders with necessary assistance from a graduate research assistant.

Baher Abdulhai will be the task leader for the bus system evaluation, Task 3A. A graduate research assistant, under the supervision of the task leader, will be responsible for the bus ride-alongs and intersection-based observations of bus delays. All data analysis will be performed by the task leader with assistance from graduate researchers, as necessary. Randolph Hall will be the leader for the analysis of buses as traffic probes element (Task 3B). He will be responsible for model creation and verification, and responsible for supervising a graduate research assistant, who will collect and analyze data. A student aide will be utilized in floating car and bus-following data collection.

**TABLE 2: Responsibilities by Task**

Task	Task Leader	Additional Resources
1A Institutional Study	Randolph Hall	Baher Abdulhai
1B TMC Study	Baher Abdulhai	Graduate research assistant
1C Bus Operator Study	Baher Abdulhai	Graduate research assistant
2A Transit On-Board Study	Baher Abdulhai	Survey research firm Graduate research assistant
2B Kiosk Study	Randolph Hall	Survey research firm Graduate research assistant
3A Bus System Performance	Baher Abdulhai	Graduate research assistant
3B Buses as Traffic Probes	Randolph Hall	Graduate research assistant

**TABLE 3: Level of Effort by Task**

Task	Personnel	Expected Effort
1A Institutional Study	Randolph Hall	1.5 months
	Baher Abdulhai	1.5 months
1B TMC Study	Baher Abdulhai	1.0 month
	Graduate Assistant (USC)	1.0 month
1C Bus Operator Study	Baher Abdulhai	1.0 month
	Graduate Assistant (USC)	1.0 month
2A Transit On-Board Study	Baher Abdulhai	1.0 month
	Graduate Assistant (UCB)	1.0 month
	Survey Research Firm	\$15,000
2B Kiosk Study	Randolph Hall	1.0 month
	Graduate Assistant (USC)	0.5 month
	Survey Research Firm	\$20,000
3A Bus System Performance	Baher Abdulhai	3.0 months
	Graduate Assistant (UCB)	6.0 months
3B Buses as Traffic Probes	Randolph Hall	3.0 months
	Graduate Assistant (USC)	6.0 months
	Student Aide (USC)	1.0 month

## 1.4 Master Schedule

Using the list of tasks outlined above, Table 4 gives the schedule of data collection waves, and Table 5 gives expected due dates for project deliverables. For the institutional study, two waves of interviews are planned, beginning in the summer of 1996 and again in the fall of 1997. The TMC and Bus Operator studies are also slated with two waves of interviews and observations, beginning shortly after project implementation in the spring of 1997 and again later in the fall of 1997. All activities under element 1 will be summarized in a final report due at the end of January 1998. All dates provided here and elsewhere should be considered tentative. The final schedule may be adjusted if delays occur in the deployment of probes.

For the Public Knowledge and Perceptions element, separate survey strategies are planned. For bus passengers, a single wave of on-board surveys will be fielded during the early summer of 1997. This will provide the primary source of data on the perceived changes in transit service as part of the Transit Probe project. In addition, two survey waves of kiosk users are planned. The first wave is planned for early spring 1997, to allow analysis and early feedback on kiosk performance. A second wave will be conducted in late summer 1997. A summary report of both studies will be available by the end of October 1997.

Data on system performance will be collected in a series of waves. For the OCTA bus system, a “baseline” wave will be collected in December 1996, allowing a source of data before the bus monitoring system is in place. For both the bus system and buses as probes studies, one-week data collection waves will be conducted in March, June, September, and December of 1997. These waves will combine several data sources, including bus AVL and probe data, field observations, and TMC and OCTA dispatch logs. An initial report covering findings to March 1997 will be completed in the late spring, and the final report will be completed by June 1998.

**TABLE 4: Schedule of Data Collection Activities**

<b>1 Institutional, TMC Operator and Bus Operator Element</b>	
<u>Institutional Study</u>	
- Wave 1	July 1996
- Wave 2	October 1997
<u>TMC Operator Study</u>	
- Wave 1	February 1997
- Wave 2	November 1997
<u>Bus Operator Study</u>	
- Wave 1	February 1997
- Wave 2	November 1997
<b>2 Public Knowledge and Perceptions Element</b>	
<u>Transit On-Board Survey</u>	
- Wave 1	June 1997
<u>Kiosk Survey</u>	
- Wave 1	March 1997
- Wave 2	August 1997
<b>3 System Performance Element</b>	
<u>Bus System Performance</u>	
Baseline Wave	December 1996
Wave 2	March 1997
Wave 3	June 1997
Wave 4	September 1997
Wave 5	December 1997
<u>Buses as Traffic Probes</u>	
Wave 1	March 1997
Wave 2	June 1997
Wave 3	September 1997
Wave 4	December 1997

**TABLE 5: Schedule of Deliverables**

Task	Deliverable	Date
1A Institutional Study	Wave 1 Memorandum	11/30/96
	Final Report	1/3 1/98
1B TMC Study	Wave 1 Memorandum	3/3 1/97
	Final Report	1/3 1/98
1C Bus Operator Study	Wave 1 Memorandum	3/3 1/97
	Final Report	1/3 1/98
2A Transit On-Board Study	Final Report	9/30/97
2B Kiosk Study	Wave 1 Memorandum	5/3 1/97
	Final Report	10/3 1/97
3A Bus System Performance	Initial Findings Memorandum	6/30/97
	Final Report	6/30/98
3B Buses as Traffic Probes	Initial Findings Memorandum	6/30/97
	Final Report	6/30/98

### **1.5 Organization of the Plan**

The outline of this report follows the major elements of the evaluation, as described above. In each of these sections, we begin with a discussion of the goals and objectives for evaluating that element, followed by data collection and analysis methods, tasks and a schedule for completing the analysis, available personnel and other resources, and intended deliverables.

Section 2 describes our proposed evaluation of the institutional relationships that are being developed as part of this project. In addition, that section describes our evaluation of the impacts of the transit probe project on operations and operator workloads at Caltrans, the TMC's in Anaheim and Santa Ana, and OCTA.

Continuing, Section 3 describes our proposed evaluation of public perceptions of transit service and transit information resulting from this Transit Probe project. This includes a discussion of three public surveys, which may also be coordinated with similar surveys from the TravelTIP project.

Finally, Section 4 describes the uses of the AVL data by OCTA and by Caltrans and the local TMC's. First, the AVL data may be used by OCTA to improve operations, perhaps in real time but also off line for system planning. An analysis of OCTA uses of the data will be complemented by an analysis of the practical use of bus AVL data for meaningful traffic network information (i.e. for travel times, incident reports, etc.). This last activity provides an assessment of practical benefits of the AVL system for both transit and traffic management.

## 2. INSTITUTIONAL, TMC OPERATOR AND BUS OPERATOR ELEMENT

The project is a cooperative effort among multiple jurisdictions (City of Anaheim, City of Santa Ana, Caltrans and OCTA), with OCTA acting as the lead agency. The project will be built around a "multi-agency, multi-modal, multi-user, multi-node Transportation Operations System (TOS)." In addition to providing real-time data on schedule adherence, the project is intended to "integrate the transit and traffic management systems" of the partner agencies.

A key measure of the project's success will be its ability to develop and implement a system that meets the needs of the partners, and to successfully integrate probe data into TMC and bus operations. The focus of the Institutional, TMC Operator and Bus Operator (ITB) Element will be to develop a project history that tracks system design, system implementation and system operation. A second focus will be on documenting how TMC and bus operators utilize probe data and the probe system, and how the data might be enhanced to improve their effectiveness. The element will rely on interviews and observations as data collection mechanisms.

### 2.1 Goals and Objectives

The ITB Element will concentrate on the fourth project objective:

*Providing a framework of Institutional Agreements:*

- Effectiveness of the project in "sharing of data, hardware, and communications, together with the shared obligation of operations and management."
- Effectiveness of the multi-jurisdictional framework for ATMS and ATIS projects, in design, implementation and operation.

The Institutional and TMC Element will support the evaluation of the first and second project objectives:

*Providing traffic managers with information with which they can better manage their network*

*Providing transit managers with information with which they can more efficiently operate their vehicles.*

With respect to these latter objectives, the focus of the ITB element will be on documenting operator attitudes and perceptions, as well as documenting how the operator interfaces with the system. More technical aspects of these objectives will be covered in the system performance element.



## 2.2 Data Collection

The ITB Element will be largely qualitative and rely on interview methods. Interviews will be conducted with employees of the involved agencies, along with project contractors, at various project stages. The interviews will be utilized to construct the project history, identify key issues and their resolution, and assess attitudes and perceptions toward the project. Three types of interviews (coupled with observations) will be administered, as described in the following studies.

### 2.2.1 Institutional Study

**Scope:** Interviews will focus on institutional issues, including system design, system implementation and system management. Interviews will be coupled with observations from steering committee meetings and reviews of project documents.

**Format:** Interviews will be semi-structured, following an interview guide. The interview guide will contain a common set of open-ended questions, generated from meeting observations and review of project documents. Interviewers will provide additional probe questions (i.e., questions that explore issues in further depth), which will vary from person to person. Interviews will be administered in person.

**Interview Group:** Members (and former members) of project steering committee (approximately 20 people). Managers for consultant teams.

**Interview Length:** 30 minutes to 1 hour.

**Interviewers:** Interviews will be administered by the Principal Investigators (Randolph Hall and Baher Abdulhai).

**Waves:** Two waves, to be administered in Summer of 1996 and Fall of 1997. The first wave will concentrate on design, specification and organizational structure. The second wave will concentrate on implementation and operation.

### 2.2.2 TMC Study

**Scope:** Assessment of how probe data is integrated into TMC operations, including usage in traffic operations (e.g., incident detection and verification) and usage in transit operations (e.g., schedule control and transfer coordination), and assessment of changes that would make probe data more useful in TMC operations.

**Format:** Interviews and observations. Interviews will be semi-structured, following interview guide. Interview questions will be developed in advance, but may be customized by organization. Interviewers will provide additional probe questions, which will vary from person to person. Interviews will be administered in person. Interviews will be supplemented by observations of how TMC operators utilize probe data.

**Interview Group:** TMC operators, including both traffic and transit operations.

**Interview Length:** 1 hour, supplemented by observations (length TBD).

**Interviewers:** Initial interviews will be administered by Baher Abdulhai. Initial interviews will be followed up with additional interviews and observations by Graduate Research Assistants.

**Waves:** A minimum of two waves of interviews, to be administered soon after the system becomes operational (approximately February, 1997) and well after the system has become operational (likely Fall of 1997). The first wave will concentrate on initial experience utilizing probe data, and the second wave will concentrate on usage after the initial break-in period.

### **2.2.3 Bus Operator Study**

**Scope:** Assessment of how the probe system is utilized by bus operators (e.g., for communicating transfer and incident information) and how the probe affects bus operators (e.g., whether monitoring affects driver attitudes).

**Format:** Interviews and observations. Interviews will be semi-structured, following interview guide. Interview questions will be developed in advance of interviews. Interviewers may provide additional probe questions, which will vary from operator to operator. Interviews will be administered in person before and after schedule operations. Interviews will be supplemented by observations of how bus operators utilize the probe system during ride-alongs.

**Interview Group:** OCTA bus operators on affected bus lines along with operators on unaffected lines (for control purposes).

**Interview Length:** 15 minutes per operator supplemented by ride-along observation of 1-2 hours.

**Interviewers:** Interviews and observations will be performed by a Graduate Research Assistant under the direction of the Principal Investigators.

**Waves:** A minimum of two waves of interviews, to be administered soon after the system becomes operational (approximately February, 1997) and well after the system has become operational (likely Fall of 1997). The first wave will concentrate on initial experience utilizing the probe system, and the second wave will concentrate on usage after the initial break-in period.

## **2.3 Data Analysis**

Due to the qualitative nature of the data, analysis will be limited to summarizing and comparing responses. Specific products will include:

- Project chronology, including key milestones, issues and their resolution.
- Cross-sectional comparison of attitudes and perceptions among city traffic departments, state traffic department and transit agency.
- Comparison of attitudes and perceptions among project participants between initial and final waves.

## 2.4 Resources

Randolph Hall will be the leader for the Institutional study and Baher Abdulhai will be the leader for the TMC and Bus Operator studies. The Principal Investigators will be responsible for conducting most interviews. A graduate research assistant will support the TMC and Bus Operator Study, primarily through TMC observation and bus ride-alongs.

### Institutional Study

Randolph W. Hall	1.5 months
Baher Abdulhai	1.5 months

### TMC Study

Baher Abdulhai	1.0 month
Graduate Research Assistant (USC)	1.0 month

### Bus Operator Study

Baher Abdulhai	1.0 month
Graduate Research Assistant (USC)	1.0 month

## 2.5 Tasks and Schedule

### Institutional Study

1) Design Interview Guide, Wave 1	6/1/96 - 6/15/96
2) Review Revisions for Guide	6/16/96 - 6/30/96
3) Execute Initial Interview Wave	7/1/96 - 7/31/96
4) Summarize Findings of Initial Wave in Memorandum	8/1/96 - 8/30/96
6) Design Interview Guide, Wave 2	9/1/97 - 9/15/97
7) Review Revisions for Guide	9/16/97 - 9/30/97
8) Execute Second Interview Wave	10/1/97 - 10/31/97
9) Document Findings of Institutional Study in Report	11/1/97 - 1/31/98

## TMC Operator Study

1) Design Interview Guide, Wave 1	1/1/97 - 1/15/97
2) Review/Revisions for Guide	1/16/97 - 1/30/97
3) Execute Initial Interview/Observation Wave	2/1/97 - 2/28/97
4) Summarize Findings of Initial Wave in Memorandum	3/1/96 - 3/31/97
6) Design Interview Guide, Wave 2	10/1/97 - 10/15/97
7) Review/Revisions for Guide	10/16/97 - 10/30/97
8) Execute Second Interview/Observation Wave	11/1/97 - 11/30/97
9) Document Findings of TMC Operator Study in Report	12/1/97 - 1/31/98

## Bus Operator Study

1) Design Interview Guide, Wave 1	1/1/97 - 1/15/97
2) Review/Revisions for Guide	1/16/97 - 1/30/97
3) Execute Initial Interview/Observation Wave	2/1/97 - 2/28/97
4) Summarize Findings of Initial Wave in Memorandum	3/1/96 - 3/31/97
6) Design Interview Guide, Wave 2	10/1/97 - 10/15/97
7) Review/Revisions for Guide	10/16/97 - 10/30/97
8) Execute Second Interview/Observation Wave	11/1/97 - 11/30/97
9) Document Findings of Bus Operator Study in Report	12/1/97 - 1/31/98

## **2.6 Deliverables**

**Institutional Study: Wave 1 Memorandum** Deliverable will include a project chronology, current to 8/1/96, and descriptions of key project issues that arose prior to 8/1/96. Memorandum will also identify questions for second interview wave.

**Institutional Study: Final Report** Deliverable will include a complete project chronology, and descriptions of key project issues and their resolution. Report will compare attitudes and perceptions toward the project between first and second wave, and among participating agencies. Report will include an assessment of project successes and lessons learned, and provide recommendations for implementation of similar projects elsewhere.

**TMC Study: Wave 1 Memorandum** Deliverable will document initial experience of TMC operators with probe data. It will describe problems encountered in system implementation and integration, how these problems were resolved, and how probe data are initially utilized.

**TMC Study: Final Report** Deliverable will document experience utilizing probe data over a full one year period, including comparison between first and second waves of interviews. Operator adaptation and learning will be explored. Operator generated suggestions for improving the system will be documented.

**Bus Operator Study: Wave 1 Memorandum** Deliverable will document initial experience of bus operators with probe system. It will describe problems encountered in system

implementation and integration, how these problems were resolved, and how the probe system is initially utilized.

**Bus Operator Study: Final Report** Deliverable will document experience utilizing TMC data over a full one year period, including comparison between first and second waves of interviews. Operator adaptation and learning will be explored. Operator generated suggestions for improving the system will be documented.

### 3. PUBLIC KNOWLEDGE AND PERCEPTIONS ELEMENT

The Transit Probe project may affect the public knowledge and perceptions of OCTA service in a number of ways. First, as OCTA makes use of the AVL data to monitor and control bus service, the characteristics of the bus service itself may change. These changes may or may not be perceived by the passengers, and may be perceived positively or negatively. In addition, the public information aspects of the project allow passengers to learn about OCTA service through new media. A set of strategically placed kiosks will provide the primary source of information for both transit passengers and the traveling public. These kiosks will present both static and real-time information on transit services, allowing travelers to access information for better trip planning.

#### 3.1 Goals and Objectives

The goal of this element of the evaluation is to examine public perceptions and reactions to the OCTA service, with the AVL system, and to new sources of transit information. Most broadly defined, this element supports the project goal of:

*Providing the public with both transit and traffic information with which to evaluate trip-making alternatives*

To this end, specific objectives for the evaluation include:

1. Assess public awareness of the Transit Probe project and its objectives;
2. Evaluate public perceptions of OCTA service on the selected routes with AVL;
3. Evaluate the extent to which regular transit passengers and visitors/tourists of Orange County and Anaheim make use of the kiosk information;
4. Evaluate changes in these regular passengers' and tourists' perceptions of transit service resulting from this information; and,
5. Evaluate any changes in trip-making behavior due to the availability of the transit information, including changes in the drive-alone category.

To measure these changes in perceptions and in trip-making, a survey of transit riders and of kiosk users will be conducted. From these surveys, changes in public perceptions and behavior will be noted through a number of different measures. Changes in public perceptions are perhaps best captured through subjective questions, describing the public's level of comfort and the convenience of the information system, as well as resulting perceptions of transit service. Such data will be collected using quantitative responses (e.g., on a 1-5 scale). Other more objective quantitative measures, including the usage of kiosks as well as observable changes in trip behavior from the information, will also be collected and analyzed.

### **3.2 Data Collection**

Two survey efforts will be conducted for this evaluation. To measure awareness and perceived impacts of the bus monitoring system by transit passengers, we will conduct an on-board survey of transit passengers on each of the routes selected for the project: routes 29, 42, 47, 49, 69 and 205. A separate survey, conducted in two waves, will target kiosk users at the three primary kiosk locations in Anaheim, Santa Ana, and Fullerton. This survey will investigate whether and how travelers are using the kiosk information, for what purposes, and whether this information influences their perceptions and/or behavior in traveling. Both surveys are described separately below.

#### Transit On-board Survey

**Scope:** Evaluate (1) the awareness of transit passengers of the transit AVL / probe system; (2) awareness and use of the kiosk information service; and (3) any perceived effects of the vehicle monitoring system for improved schedule adherence and transfer coordination.

**Format:** On-board, structured, written surveys of transit passengers. The survey will be designed to take 5-10 minutes to complete. Types of questions will include: (1) awareness of the AVL / probe system on board the buses, and awareness of the probe project; (2) awareness and use of kiosks at key transit terminals; (3) perceptions of any changes in vehicle schedule adherence on the affected routes; and, (4) experiences and perceptions of improvements in transfer coordination.

**Method:** Questionnaires will be distributed to passengers as they board and will be collected as passengers depart, or using a mail-back form. Surveys will be distributed by a survey research firm approved by OCTA and under the direction of the Principal Investigators and OCTA staff. For a reasonable statistically valid sample, approximately 100 completed questionnaires per route (on each of the six AVL-equipped routes) will be needed. Assuming a response rate of 50% (for on-board collection and/or mail-back), about 1200 questionnaires will be distributed, for a total of 600 (completed) surveys. If necessary, a small incentive (e.g., a pass good for a free ride) may be included with the survey to ensure a reasonable response rate. Each route will be sampled for different times of day (morning, mid-day, and evening peak periods) and in both directions.

**Schedule:** A single survey wave will be conducted approximately 6 months after the system becomes operational (most likely in summer 1997).

## Kiosk Survey

**Scope:** Evaluate the awareness and use of the three information kiosks located at major transit terminals, and how the information is used by visitors from the **LA** region, tourists from outside the region, and transit passengers.

**Format:** Structured interviews with kiosk users and others at associated terminals, **as** well as observations and other kiosk usage records. Interviews will be structured, based on questions developed in advance, and will be 5-10 minutes in length. Questions will investigate: (1) how frequently the kiosk is accessed; (2) perceptions on the ease of use of the kiosk; and, (3) uses of the kiosk information.

**Method:** A survey research firm will be contracted to conduct these intercept interviews and to observe kiosk use. A sampling strategy will be generated to ensure coverage of morning, mid-day, and evening peak periods, and of each of the three kiosk locations (Fullerton, Anaheim, and Santa Ana). Two survey waves are anticipated, with a total of 250-300 completed interviews per wave. The analysis will also make use of additional information on specific details of kiosk use (e.g. duration of session, use of specific menu options, etc.), as it is recorded by the kiosk directly. Two weeks of kiosk usage data will be needed for this analysis.

**Schedule:** The first survey wave will be conducted approximately 2-3 months after kiosks are installed (spring 1997) to establish initial experience with the kiosk system. A second wave will be scheduled approximately **3-4** months later (likely in late summer 1997) to examine changes in kiosk usage patterns over time.

### **3.3 Data Analysis**

Data from each of the two surveys will be analyzed **as** described below. In general, the summary and analysis of survey data will be limited to basic statistical summaries and cross-tabulation. This somewhat limited scope of analysis is anticipated because: (1) the TravelTIP project and evaluation are likely to investigate public awareness and perceptions at a much more detailed level, drawing from similar groups of transit users; and, (2) the natural limitation of resources for this element of the Transit Probe evaluation.

## Transit On-Board Survey

Analysis of the transit on-board survey data will involve typical statistical summaries of the survey responses. For the qualitative data on awareness and perceptions of changes in transit service, we will simply summarize passenger responses and provide tabular results where appropriate. Critical issues for improving public perceptions of the system will be identified from these responses, where such perceptions differ from the measured project performance.

For most of the survey responses, the data analysis will be conducted with traditional quantitative analysis techniques: traditional statistical analysis and cross-tabulation. Specific measures on

user awareness of the project, perceived changes in service, and the use of kiosks will be tabulated, noting important findings and differences as they appear in the data. As much as possible, measures will be compared and contrasted as differences appear across the six AVL-equipped bus routes, by time of day, or by passengers' frequency of transit use.

### Kiosk Survey and Related Kiosk Data

The kiosk survey, and any kiosk usage recorded directly in the kiosk, will likewise provide quantitative measures of public perceptions. Quantitative measures of people's awareness of the kiosks and on the ease of use of the kiosks will be tabulated, and specific comments from the interviews will also be summarized. In our analysis of the initial phase of kiosk data, we will identify both the major positive aspects and possible problems with the kiosk information and user interfaces. The analysis of qualitative measures in the second wave will allow us to observe any changes in these perceptions or traveler behavior (e.g., mode selection) over time, and/or as kiosk features are updated. Qualitative measures will be compared across the three kiosk sites and across different sets of users (regular transit passengers, visitors, tourists).

The quantitative data on kiosk usage from the survey will also be combined with any additional data directly recorded by each kiosk. Statistical summaries and cross-tabulations will be generated for various measures of kiosk usage, including: frequency of use, time spent on each screen, duration of kiosk session, menu options selected, etc. Important findings and differences in the data will be identified, particularly looking at differences across the three kiosk sites and/or across different sets of users (regular transit passengers, visitors, tourists). Changes in usage patterns between the first and second survey waves will also be noted.

### **3.4 Resources**

Baher Abdulhai will be the leader for the bus on-board survey and Randolph Hall will be the leader for the kiosk intercept surveys. For the transit survey, distribution and collection of surveys will be conducted by OCTA interns, as they are available, and/or by a survey research firm, with close supervision by the task leader (Hickman). For planning project resources, we assume that no OCTA interns will be available, thus yielding a "worst case" estimate of time from the survey research firm. The kiosk survey will be developed by Randolph Hall; the survey will be fielded and data collected by a survey research firm contracted to PATH. Data analysis will be conducted by the respective task leaders with necessary assistance from a graduate research assistant.

#### Transit On-Board Survey

Baher Abdulhai	1.0 month
Graduate Research Assistant (UCB)	1.0 month
Survey research firm	\$15,000



## Kiosk Survey

Randolph Hall	1.0 month
Graduate Research Assistant (USC)	.5 month
Survey research firm	\$20,000

### 3.5 Tasks and Schedule

#### Transit On-Board Survey

1) Develop Sampling Strategy	4/15/97 - 4/30/97
2) Design Survey Instrument	5/1/97 - 5/15/97
3) Review and Revisions to Survey Instrument	5/16/97 - 5/31/97
4) Administer Survey	6/1/97 - 6/30/97
5) Code and Analyze Survey Data	7/1/97 - 8/31/97
6) Document Survey Findings in Report	9/1/97 - 9/30/97

#### Kiosk Survey

1) Develop Sampling Strategy	12/1/96 - 1/31/97
2) Design Survey Instrument	2/1/97 - 2/14/97
3) Review and Revisions to Survey Instrument	2/15/97 - 2/28/97
4) Execute Intercept Surveys, Wave 1	3/1/97 - 3/31/97
5) Collect Kiosk Usage Data, Wave 1	3/1/97 - 3/15/97
6) Code and Analyze Survey Data	4/1/97 - 4/30/97
7) Summarize Findings in Memorandum	5/1/97 - 5/31/97
8) Review and Revise Sampling Strategy and Survey Instrument	6/1/97 - 7/31/97
9) Execute Intercept Surveys, Wave 2	8/1/97 - 8/31/97
10) Collect Kiosk Usage Data, Wave 2	8/1/97 - 8/15/97
11) Code and Analyze Survey Data	9/1/97 - 9/30/97
12) Summarize Findings in Report	10/1/97 - 10/31/97

### 3.6 Deliverables

**Transit On-Board Survey: Final Report** Deliverable will describe perceptions of the transit probe project among OCTA transit passengers. It will review ridership patterns on each of the six routes in the project, awareness and understanding of the project, and perceived changes in service characteristics. Perceived changes will be compared with observations of improved system performance. In addition, critical areas for improved project marketing and passenger information will be identified.

**Kiosk Survey: Wave 1 Memorandum** Deliverable will describe use of the kiosk system in the early stages of project implementation. The memo will include a description of what elements of the kiosks are being used, what information appears to be the most useful, and perceptions on the

ease of use of the kiosk interface. Recommendations on possible short-term improvements in the kiosk information and interfaces will be provided based on these results.

**Kiosk Survey: Final Report** Deliverable will include a *summary* of the second wave of intercept surveys, documenting similar measures as in the Wave 1 Memorandum. Report will also compare and contrast the findings from the two waves, and make specific recommendations for similar public information systems such as TravelTIP.

## 4. SYSTEM PERFORMANCE ELEMENT

The AVL data from the various OCTA bus routes employed for this test can be used within OCTA to improve transit service. The AVL data generated as part of this project allow better real-time monitoring of transit conditions, and allows transit operators to make dynamic adjustments in service to improve schedule adherence. Also, the bus AVL data may also be used as probe data to give travel time and incident information to traffic managers at Caltrans District 12 and the cities of Anaheim and Santa Ana. In separate sections below, these two performance aspects of the transit probe project are identified, and evaluation methods are discussed.

### 4.1 Bus Performance

Within OCTA, the installation of AVL on up to **43** vehicles allows operators at the dispatch center to know the locations and schedule adherence of vehicles along several routes in Orange County. Using these data, bus drivers and dispatchers may improve bus service by taking appropriate actions when potential problems, such as incidents or schedule delays, are identified.

#### 4.1.1 Goals and Objectives

The evaluation of the bus system performance with the transit vehicle monitoring capability addresses the second main goal of the project:

***Provide transit operations with information with which they can more efficiently operate their vehicles***

To assess the achievement of this goal, this element of the evaluation has the following objectives:

1. Evaluate the effectiveness of bus AVL data to improve transit operations monitoring and management, as determined through improved performance
2. Assess causes of delay for buses on the AVL-equipped routes

This evaluation element is intended to track not only what improvements in transit service are achieved through use of the bus AVL system, but also to identify what the current problems are in achieving timely and reliable service on these selected bus routes. The means of evaluating

these two objectives will largely be through quantitative data available both through the OCTA vehicle monitoring system as well as through direct observation by the evaluation team. Dispatcher logs and bus AVL data will be used directly to identify a baseline and subsequent changes in bus timeliness. Separately, we will conduct observations in the field of possible problems with bus schedule reliability, including bus ride-alongs and time checks at intersections and other route time points.

#### **4.1.2 Data Collection**

The evaluation of bus system performance will be based virtually entirely on quantitative measures. Specific measures that will be collected include:

- Bus deviations from schedule at key time points
- Incidents on buses or along the selected bus routes
- Any directions or other control actions made by OCTA dispatchers
- Time spent by buses at major intersections on each route
- Time spent by buses boarding and alighting passengers on each route

In order to develop these measures, a preliminary list of data needs are shown in Table 6. These data are organized by relative frequency of data updating: static, once per run, and once per AVL polling cycle. Within these major areas are specific data for schedule adherence and traffic probe purposes. To obtain these data, the following three major data collection activities are planned. These focus on data needs for the bus system performance; section 4.2 outlines data collection related to the use of transit vehicles as traffic probes.

##### Pre-AVL and AVL-based schedule adherence data

Data on bus schedule adherence and on transfers will be collected on all six bus routes slated for this project: routes 29, 42, 47, 49, 69, and 205. Data on scheduled and actual bus arrival times at waypoints will be collected over a one-week period in a total of five waves, beginning in December 1996 and again in March, June, September and December 1997.

Because the AVL system will not be operational, data for the first wave will be collected manually. In this wave, data collection will be shared between checkers from OCTA, as they are available, and a graduate research assistant from UC - Berkeley. The data sample will include runs in the morning, mid-day, and afternoon peak periods on each of the six bus routes. Schedule adherence data and observations of passengers requesting transfers will be collected, and the evaluation team will handle data coding and analysis. For subsequent waves, we anticipate that the AVL system will be operational in January, 1997, and will automatically record all necessary schedule adherence data (according to Table 6).

Once the AVL system is operational, there is an open question about how transfer information will be recorded. As much as possible, transfer information will be recorded by OCTA dispatchers as part of the daily dispatch logs. If this is not possible, these data will be sampled

**TABLE 6: Data Needs for the System Performance Evaluation**

**Static Data**

*A VL and Schedule Adherence Data:*

- List of bus stops, routes serving these stops, and corresponding latitude and longitude
- Route maps by road segment / link
- Major waypoints on relevant routes, including all transfer points, terminals, primary bus stops and other waypoints
- Expected bus arrival times at each major waypoint

*Traffic Probe and Congestion Data:*

- Posted speed limits on street segments
- List of all intersections on bus routes
- Signal timing plans at all possible signalized intersections on the selected bus routes
- Stop signs or other control for any unsignalized intersections on the selected bus routes

**Data Needed for Each Run**

*A VL and Schedule Adherence Data:*

- Run number
- All waypoints for each bus run, up to and including route terminus
- Actual time of arrival at all waypoints
- A textual record and description of any control actions taken (e.g. holding a vehicle at a time point, inserting an additional vehicle on a route, etc.)

*Traffic Probe and Congestion Data:*

- Congestion level indicator for all street segments in run

**Data Needed Each Polling Cycle**

*A VL and Schedule Adherence Data:*

- Vehicle latitude and longitude
- Vehicle heading
- Vehicle speed / velocity
- Current time (WWV standard)
- Vehicle ID number
- Estimated time to all waypoints for the current run (when updated)
- Estimated current deviation from schedule (if calculated)
- Estimated headway between vehicles (if calculated)
- Connecting route number of any transfer passenger
- Forecast vehicle ID and run number for intercept at transfer point (when needed)
- Actual vehicle ID and run number for intercept at transfer point (when needed)

*Traffic Probe and Congestion Data:*

- Minimum, maximum and average speed in polling cycle

using point checks and ride checks conducted by a graduate research assistant for the evaluation team.

**Data transfer procedures:** Evaluation-related data produced by the bus monitoring and traffic probe system at OCTA will be stored on the network at OCTA's operations center in Garden Grove. These data will be stored for one-week periods during each of the four waves in 1997. After each of these one-week periods, the evaluation team will download these data from OCTA using the following means. Data will be downloaded directly from OCTA to PATH. PATH will be given an account to access the OCTA local area network (i.e. the Transit Probe project server), and files will be downloaded using ftp or other suitable method. Alternately, depending on security and access control requirements, OCTA will be responsible for the timely downloading the data directly to a PATH server (i.e., within 2 weeks of the data collection wave).

### Dispatcher logs

The OCTA dispatcher logs can contain other useful information on (1) incidents, (2) transfers between routes, and (3) any supervisory actions taken to improve transit service. Such information (edited by OCTA as necessary) will be collected, either electronically or on hard copy, by OCTA during each of the five one-week waves. These waves will coincide with other data collection efforts; namely, in December 1996, March, June, September and December 1997. OCTA will be responsible for either putting an electronic version on the project server, or for providing the evaluation team directly with the hard copy.

### Field observations

The data above will be supplemented by field observations consisting of (1) route ride-alongs on the selected routes, (2) bus-following records, and (3) observations of bus delays at key intersections. Route ride-alongs will be conducted to examine causes of delay on each of the bus routes. These ride-alongs will be scheduled for a sample of runs on each of the six bus routes in the project, and will be timed to coincide with other data collection during the last four waves in March, June, September and December 1997. Data on the number of bus stops, passenger boarding and alighting times, intersection delays, travel times and schedule adherence will be collected.

The bus-following experiments are described in the following section (4.2) and will primarily be used to evaluate buses as traffic probes. However, this information may also be used to enhance the ride-along data as a record of bus speeds, travel times, and delays at boarding stops and at intersections. A third set of field observations will record bus delays at key intersections, primarily in Santa Ana. This activity is intended to enhance the ride-along data set by providing additional data on bus delays at intersections. Moreover, these data will be used to evaluate the use of buses as probes (section 4.2).

### 4.1.3 Data Analysis

The data collected by the three means identified above will be analyzed primarily using quantitative analysis tools. Three different areas will be analyzed, as described below.

**Schedule Adherence Analysis:** Five waves of bus schedule adherence data will be collected. The data will be analyzed to determine (1) changes in schedule adherence before and after the AVL system is installed, and (2) changes in schedule adherence over time as OCTA uses the AVL system. For each route and each time point, scheduled and actual bus arrival times will be compared, using the AVL data (when available) and other observations collected by both OCTA and the evaluation team.

In addition, the schedule adherence data will be matched with the dispatch logs to establish any correlation of the schedule adherence with incidents, transfers, or other recorded supervisory actions. Statistical correlations and simple regression models will be used to identify important events that affect bus schedule adherence. The analysis will also examine how deviations from the schedule propagate (over time and space) on each bus route. Bus movements will be plotted using time-space diagrams to ascertain any propagation of delay both within a single run (as the bus continues on the route) and across runs (as other buses follow along the same route).

**Bus Delay Analysis:** The route ride-along data, intersection delay observation data, and bus following data will be pooled to form a single data base on bus delays. These data can be used to investigate the source of bus delays and to identify both internal and exogenous sources of delay. Bus travel time and delay data will be decomposed into time spent traveling, time spent in queue at intersections, and time spent boarding and alighting passengers. A statistical analysis of these measures for each of the six bus routes will be generated. In addition, possible areas of correlation will also be noted, using statistical correlations and regression analysis as appropriate. Areas for this analysis will include: (1) delays at bus stops with the number of boarding and alighting passengers (and with any special needs passengers); (2) delays at intersections with elements of the signal timing plans; and, (3) travel times with ambient traffic congestion levels.

**Transfer Coordination Analysis:** In this analysis, we will examine the effectiveness of transfer coordination, making use of the AVL system. First, we will correlate the dispatcher logs on transfers with the schedule adherence data. We will identify when transfers were requested, anticipated time of the transfer, and actual schedule adherence to the transfer point. From these records, we may infer how closely the anticipated transfers match the actual time when the bus arrives at the transfer point. This level of schedule adherence for transfers will be analyzed as it varies by route, across different points on each route, and for route segments serving a major transfer terminal. For any (likely rare) occurrences when a transfer is made from one AVL-equipped route to another, we will analyze both the scheduled and actual arrival times of both vehicles to the transfer point. Specific control actions taken to enhance these transfers will be noted, and statistical correlations between these actions and resulting improvements in transfer timing will be noted.

#### 4.1.4 Resources

Baher Abdulhai will be the task leader for the bus system evaluation element. For the schedule adherence data collection, OCTA will be responsible to provide a one-week sample, in December 1996, of actual vehicle arrival times at major time points on each of the six routes. The AVL data and driver logs will be collected automatically by OCTA and made available to the evaluation time as described above. A graduate research assistant, under the supervision of the task leader, will be responsible for the bus ride-alongs and intersection-based observations of bus delays. All data analysis will be performed by the **task** leader with assistance from graduate researchers, as necessary. Required resources are described below.

Baher Abdulhai	3.0 months
Graduate Research Assistant, UCB	6.0 months

#### 4.1.5 Tasks and Schedule

##### Schedule Adherence and Dispatcher Data

1) Develop specifications for data formatting	10/1/96 - 10/31/96
2) Refine data formats	11/1/96 - 11/15/96
3) Develop data collection procedures for "Baseline" wave	11/1/96 - 11/30/96
4) Execute initial data collection wave (OCTA responsible)	12/1/96 - 12/31/96
5) Develop (further) specifications for data transfer and formatting	12/1/96 - 1/31/97
6) Execute second data collection wave	3/1/97 - 3/31/97
7) Develop and test analysis procedures	2/1/97 - 5/30/97
8) Prepare memorandum with initial findings	5/1/97 - 6/30/97
9) Execute waves 3-5	6/1/97 - 12/31/97
10) Analyze complete data set	1/1/98 - 3/31/98
11) Prepare final report	4/1/98 - 6/30/98

##### Field Data Analysis

1) Develop data collection procedures for "Baseline" wave	11/1/96 - 11/30/96
2) Execute initial data collection wave (Evaluation Team)	12/1/96 - 12/31/96
3) Refine data collection procedures as necessary	1/1/97 - 2/28/97
4) Execute second data collection wave	3/1/97 - 3/31/97
5) Develop and test analysis procedures	2/1/97 - 5/30/97
6) Prepare memorandum with initial findings	5/1/97 - 6/30/97
7) Execute waves 3-5	6/1/97 - 12/31/97
8) Analyze complete data set	1/1/98 - 3/31/98
9) Prepare final report	4/1/98 - 6/30/98

## 4.1.6 Deliverables

**Initial Findings Memorandum** This deliverable will cover results following the pre-AVL and first AVL wave of data collection. Any issues associated with data collection and analysis will be documented. In addition, specific methods of data analysis will be described. Changes in schedule adherence, bus delays, and possible dispatch control actions will be documented.

**Final Report** This report will provide an expanded set of results based on the pre-AVL wave and the four AVL waves of data collection. Changes in schedule adherence, bus delays, and possible dispatch control actions will be documented. This report will isolate those sources of schedule reliability that are within OCTA's control, and identify the effectiveness of dispatch control measures to improve this reliability. Based on this analysis, the report will offer recommendations to improve real-time monitoring of bus service to enhance system operation.

## 4.2 Buses as Traffic Probes

A unique aspect of the project is that buses will be utilized as a means for collecting data on traffic conditions on arterials in Anaheim and Santa Ana and on the Santa Ana (1-5) freeway. This will be accomplished in two ways: (1) by providing the bus operator with a means for communicating observations on incidents to affected agencies, and (2) by computing roadway congestion measures based on bus location, speed and other probe generated data. As of this writing, the algorithm for creating the roadway congestion measure has not yet been determined.

The purpose of the Buses as Traffic Probes (BTP) Study is to assess the effectiveness of bus probes as a means for determining roadway traffic conditions. The study will be technical and rely on multiple data sources.

### 4.2.1 Goals and Objectives

The BTP Study will concentrate on the first project objective:

*Providing traffic managers with information with which they can better manage their network*

- Effectiveness of the project in "monitoring the progression of transit vehicles through the network" so that "traffic managers can probe the ambient traffic congestion conditions."
- Effectiveness of the project in confirming incidents "more quickly, thus diminishing the response time for corrective or emergency actions."

The study will aim to measure the project's effectiveness as implemented, as well as how it could potentially be implemented. The effectiveness of buses as probes will depend on a variety of factors, including the nature of the road, the bus headway, the route structure and the algorithm developed to interpret probe data. Through the evaluation, opportunities for improving the



algorithm will be explored. In addition, the effect of line headway, roadway congestion, and route structure on the accuracy of congestion measures will be explored. In addition, the study will examine the quality and completeness of incident information provided by bus operators to identify possible improvements in reporting procedures.

#### **4.2.2 Data Collection**

The ITB Element will rely on multiple data sources and be highly quantitative. In addition to source data generated by the probe system, comparison data will be obtained from the City of Santa Ana and Caltrans District 12. The City of Anaheim will not be included due to relative difficulty in extracting data from its signal control system. A limited amount of floating car and bus-following data will also be collected for verification purposes.

#### **Traffic System Data**

##### Data Sampling

Due to the large quantity of data generated by the probe system, the study will rely on data samples. Data will be collected over 1-week intervals in four waves, spaced three months apart. These waves are planned to occur in March, June, September and December 1997 (assumes system will be operational in January, 1997). Data will cover probe bus lines 47, 49, 69 and 205. All probe and comparison data will be recorded for these lines over the sampled week.

##### Probe Data

Requirements for bus generated probe data will be satisfied by data collected for the Bus Performance Study. In addition, all system generated traffic congestion measures will be obtained.

##### Comparison Data

Santa Ana's TMC will be a source of comparison data on arterial congestion. Santa Ana's signal system is 100% interconnected and is capable of generating the following data:

- 60-second traffic volume and percentage occupancy, by lane, immediately upstream from each traffic signal.
- Start and end time of each signal phase.
- 60-second traffic volume and percentage occupancy summed across all lanes at "system detectors", 300 feet upstream from selected traffic signals.

Data will be collected for all signals utilized by OCTA routes 47, 49, 69 and 205. A complete list of covered streets is provided in Table 7.

**TABLE 7: Santa Ana Data Requirements**

<b>Street</b>	<b>Section</b>	<b>Lines</b>
<u>Bristol Street</u>	<u>Memory Lane to Santa Ana</u>	<u>47.49</u>
Turns:	Memory Lane East to Bristol South Bristol North to Memory Lane West Bristol South to Santa Ana East Santa Ana West to Bristol North	
<u>Civic Center Drive</u>	<u>Main to Flower</u>	<u>205</u>
Turns:	Main South to Civic Center West Civic Center East to Main North Civic Center West to Flower South Flower North to Civic Center East	
<u>Flower Street</u>	<u>Civic Center to Santa Ana</u>	<u>205</u>
<u>Grand Street</u>	<u>Santa Ana to Garden Grove Frwy</u>	<u>69</u>
Turns	Grand South to Santa Ana West Santa Ana East to Grand North	
<u>Main Street</u>	<u>Garden Grove Frwy to Civic Center</u>	<u>205</u>
<u>Santa Ana</u>	<u>Bristol to Grand</u>	<u>47.49.69.205</u>
Turns	Broadway North to Santa Ana West	
<u>5th Street</u>	<u>Ross to Mortimer</u>	<u>47.49.69.205</u>
Turns	5th Street East to Broadway North	

Caltrans District 12's TMC will be a source of comparison data on highway traffic congestion. Caltrans' loop detectors are spaced at approximately 1/2 mile intervals along the Santa Ana Freeway. Multiple loop detectors are placed on each on-ramp to measure queue spill-back. Loop detectors provide the following information:

- 30-second traffic volume and occupancy by lane and estimated speed for each detector.
- Estimated queue duration for each on-ramp

Data will be collected for all mainline traffic detectors covered by OCTA route 205 (e.g., between Katella and Route 22, and between Grand and El Toro Road on the Santa Ana Freeway). Data will also be collected for four on-ramps (Table 8)

The District 12 TMC will also be a source of comparison data on highway traffic incidents. A complete incident log will be obtained for the portion of the Santa Ana Freeway covered by route 205.

#### Data Transfer

Probe data transfer will follow procedures outlined under the Bus Performance Study. Caltrans data will be downloaded at PATH through the high-speed data link that was created for the Orange County testbed.

Santa Ana will use their Softgraph2 software to download selected data onto a magnetic tape. USC will retrieve the tape at the end of each sample period. Alternatively, USC might acquire the Softgraph2 software, and obtain data through dial-in modem access. USC would then be responsible for storing the data on magnetic tape for later analysis.

#### **Floating Car/Bus-Following Data**

A limited amount of supplemental data will be collected via "bus-following" and floating car methods. In bus following, a car (driver and passenger) will be instructed to follow selected buses at identical speed. The passenger will record speed and location at 15 second time intervals (synchronized with WWV time). In addition, the delay will be recorded at each signalized intersection, and delay will be estimated for automobiles passing through the intersection. In floating car experiments, the driver will be instructed to travel with the flow of traffic over bus route segments. Speeds, positions and intersection delay will be recorded.

#### **4.2.3 Data Analysis**

Data will be analyzed within several inter-related analyses, as described below:

## TABLE 8: Caltrans Data Requirements

### 1-5 (Santa Ana Freeway)

Katella (MP **36.306**) to 22 (Garden Grove Freeway, MP **34**)

Grand Ave (MP **31.775**) to El Toro Road (MP ???)

Katella EB to I-5 SB On-ramp

Santa Ana EB to 1-5 SB On-ramp

El Toro EB to 1-5 NB On-ramp

### 22 (Garden Grove)

Main to 1-5 (Santa Ana Freeway), WB only

Batavia on-ramp

**Incident Reporting Analysis:** The number of incidents reported by bus operators will be logged continuously for a one year period, from 1/1/97 to 12/31/97. Reported incidents will be plotted at one week intervals and evaluated for trends and seasonalities.

For the one-week sample periods, the reported incidents on Route 205 will be compared to Caltrans' incident logs. Data will be assessed to determine the percentage of total incidents reported by bus drivers, and to determine the percentage of encountered incidents reported by bus drivers. Incidents encountered will be estimated by comparing bus positions to the locations and durations of known incidents.

Bus generated incident data will also be evaluated with respect to completeness and quality. For completeness, individual messages will be examined to determine whether information is sufficient to identify the location and nature of the incident (e.g., the type of equipment required for response). Information quality will be assessed through comparison of incident messages to Caltrans incident logs.

**Signalized Intersection Analysis:** The accuracy of probe data will be assessed for buses as they proceed through signalized intersections. The study will have two purposes:

- 1) To assess the accuracy of probe data through comparison to green/red phases for traffic signal, and comparison to loop-detector data.
- 2) To assess whether congestion measures are consistent with actual delays at intersections.

For the first objective, data will be evaluated to determine whether it is feasible to estimate queueing delays at intersections by tracking the bus' progression through the intersection. Probe data and signal data will be supplemented by a limited amount of floating car and car following data. A model will be developed to isolate the effect of delay at bus stops from signal delay. A statistical inference model will be created to dynamically estimate queueing delay from multiple bus measurements.

For the second objective, delay estimates will be compared to the system generated congestion measures. A regression model will be created to correlate congestion measures with queue time estimates, and determine whether congestion measures accurately represent intersection delay.

**Highway Congestion Analysis:** Congestion measures and bus speed estimates generated for the Santa Ana Freeway will be compared against speed estimates produced by loop detectors. A linear regression model will be developed to correlate bus speeds with loop-detector speed estimates. These data will be supplemented by bus following and car following data, to gauge the accuracy of loop detector data and probe data.

#### **4.2.4 Resources**

Randolph Hall will be the leader for the BTP Element. He will be responsible for model creation and verification, and responsible for supervising a graduate research assistant, who will collect

and analyze data. A student aide will be utilized in floating car/bus- following data collection. Required resources are identified below.

Randolph W. Hall	3.0 months
Graduate Research Assistant (USC)	6.0 months
Student Aide (USC)	1.0 month

#### 4.2.5 Tasks and Schedule

##### Arterial Analysis

1) Develop specification for data transfer and formatting	12/1/96 - 1/31/97
2) Test/refine data transfer procedure and formatting	1/16/97 - 2/28/97
3) Execute initial data collection wave	3/1/97 - 3/31/97
4) Develop/test analysis procedures	2/1/97 - 5/30/97
5) Prepare memorandum with initial findings	5/1/97 - 6/30/97
6) Execute waves 2-4	6/1/97 - 12/31/97
7) Analyze complete data set	1/1/98 - 3/31/98
8) Prepare final report	4/1/98 - 6/30/98

##### Freeway Analysis

1) Test/refine data transfer procedure and formatting	1/16/97 - 2/28/97
2) Execute initial data collection wave	3/1/97 - 3/31/97
3) Develop/test analysis procedures	2/1/97 - 5/30/97
4) Prepare memorandum with initial findings	5/1/97 - 6/30/97
5) Execute waves 2-4	6/1/97 - 12/31/97
6) Analyze complete data set	1/1/98 - 3/31/98
7) Prepare final report	4/1/98 - 6/30/98

#### 4.2.6 Deliverables

**Initial Findings Memorandum** Deliverable will cover first data collection wave. Problems encountered and their resolution will be documented. Data analysis procedures will be described in detail, and initial findings will be provided. The memorandum will cover both highways and arterials.

**Final Report** The final report will provide a comprehensive set of results for the BTP study, including data collection, data analysis and findings. Recommendations will be provided for improving the traffic congestion algorithm. Conclusions will be provided as to the usefulness of buses as probes as a function of line headway, roadway congestion and network configuration.