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**FINAL**

# Sacramento-Watt Avenue Transit Priority and Mobility Enhancement Demonstration Project Phase II Evaluation Report

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# LIST OF ACRONYMS

| | |
|---|---|
| AVL | Automated Vehicle Location |
| AVO | Average Vehicle Occupancy |
| Caltrans | California Department of Transportation |
| CCTV | Closed Circuit Television |
| CHP | California Highway Patrol |
| CMS | Changeable Message Signs |
| EVP | Emergency Vehicle Preemption |
| FHWA | Federal Highway Administration |
| FTA | Federal Transit Administration |
| GPS | Global Positioning System |
| HAR | Highway Advisory Radio |
| ITS | Intelligent Transportation Systems |
| JPO | Joint Program Office |
| LRT | Light Rail Transit |
| MOE | Measure of Effectiveness |
| RT | Sacramento Regional Transit District |
| SACOG | Sacramento Area Council of Governments |
| SAIC | Science Applications International Corporation |
| TMC | Traffic Management Center |
| TOC | Traffic Operations Center |
| TOS | Traffic Operations System |
| TSP | Transit Signal Priority |
| USDOT | United States Department of Transportation |

# EXECUTIVE SUMMARY

## Introduction

In 2001, the U.S. Congress earmarked funds for selected projects that were assessed as supporting improvements in transportation efficiency, promoting safety, increasing traffic flow, reducing emissions, improving traveler information, enhancing alternative transportation modes, building on existing intelligent transportation systems (ITS), enhancing integration, and promoting tourism. A small number of these projects were selected for national evaluation. The Sacramento – Watt Avenue Transit Signal Priority (TSP) project was among those selected for national evaluation as part of the USDOT ITS Integration Program. This deployment is consistent with the USDOT's objectives to accelerate the integration and interoperability of ITS across system and jurisdictional boundaries.

Under the direction and partial funding of the United States Department of Transportation (USDOT), National ITS evaluations are being conducted to accelerate the integration and interoperability of ITS in metropolitan and rural areas. To investigate the success of ITS across the country and to provide insights into the potential strengths and weaknesses of the overall national integration program, this project was selected for independent national evaluation.

Sacramento County, in partnership with Sacramento's Regional Transit (RT) District, the Sacramento Metropolitan Fire District, the California Highway Patrol (CHP), the Sacramento Area Council of Governments (SACOG), and the California Department of Transportation (Caltrans), have initiated a project to provide additional mobility in a heavily congested corridor (Watt Avenue) through the use of a TSP system intended to increase the reliability of existing bus services in the corridor.

Under direction from the United States Department of Transportation (USDOT) ITS Joint Program Office (JPO), Science Applications International Corporation (SAIC) was selected to develop and implement a "before and after" evaluation of the Sacramento TSP project deployment. The overriding purposes of this evaluation are to determine the degree to which the project goals were met, and to provide valuable cost and benefit data as well as lessons learned to assist other agencies across the nation who may be considering similar deployments.

This Phase II Report presents the results of baseline data collection activities designed to capture the state of system performance and customer satisfaction before the TSP improvements are implemented. Following implementation of the TSP system, a similar data collection effort will be used to describe system performance and customer satisfaction after the system is in use. The Phase III report will present a comparison between the "before" and "after" data.

## Problem Statement and Project Description

Watt Avenue, a major north-south thoroughfare in suburban Sacramento County, is one of only three traffic crossings of the American River in the County. By vote of the residents in the early 1980s, the last segment of right-of-way that could have accommodated another bridge crossing was forfeited and subsequently developed. Today there is an eight-mile gap between river crossings, and as a result, traffic flows on Watt Avenue in the vicinity of the bridge exceed 100,000 vehicles per day. Although the bridge was recently widened (Fall of 2002), traffic volumes on Watt Avenue still exceed capacity and congestion is a significant problem during peak periods. The six-mile stretch of Watt Avenue targeted by the project is bounded by Interstate 80 (I-80) to the north and Highway 50 (US 50) to the south, and serves two bus routes running approximately 30 buses each weekday connecting to light rail stations at either end. The Sacramento Regional Transit District (RT) faces a challenge in providing reliable bus service along Watt Avenue due to this congestion and inconsistent travel times. As shown in Figure ES-1, the impacted bus route segments (Routes 80 and Route 84) extend 9.8 miles north from the Watt/Manlove light rail transit (LRT) station to the Watt/I-80 LRT station.

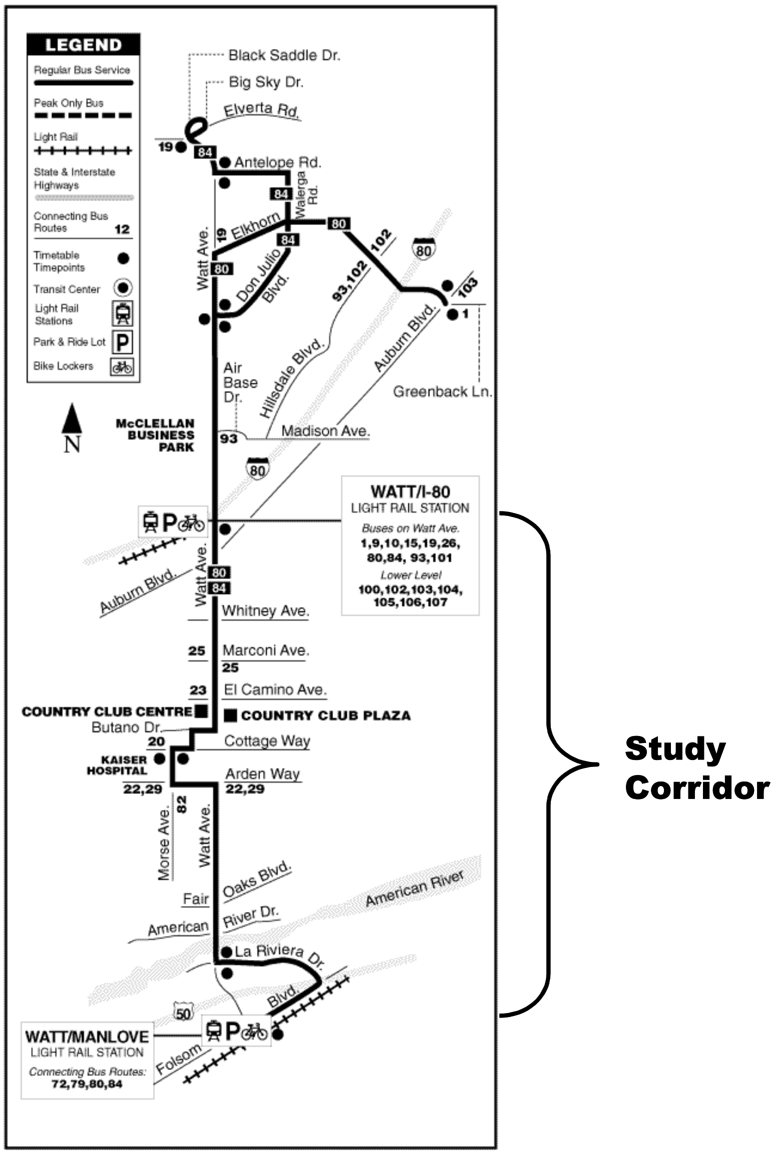


**Figure ES-1. Study Corridor Map Highlighting Routes 80 and 84.**

TSP treatments are being implemented at a total of 15 of the 29 signalized intersections in the corridor. The system will make use of an existing emergency vehicle signal pre-emption system modified to accommodate TSP. Each RT bus operating in the area will have an optical transmitter to alert the signal system of their proximity to the intersection and request priority from the signal system. Signal controllers will be modified to process these requests for priority. Provided the opportunity within the signal cycle, the presence of the bus will trigger an extended green light or an early red depending on the phase of the signal at the time the bus is detected.

The stakeholders expect that TSP will make travel times for buses more reliable by reducing associated signal delay. This is expected to translate into the opportunity for RT to "tighten up" their schedules resulting in more efficient schedules and more reliable transit service.

**Evaluation Approach**

The Evaluation Plan[1] for this project determined that there were three evaluation activities appropriate for measuring the impact of the new system on customer (bus rider) satisfaction, transit system performance, and general traffic conditions, including the following:

- Bus Mobility and Reliability – detailed data collection on board buses operating in revenue service.
- Traffic Mobility and Efficiency – floating car runs with the use of Global Positioning System (GPS) loggers.
- The Transit Customer Service Study – an on-board survey of transit riders in the study corridor.

For data collection and analysis purposes, the study corridor was subdivided into four subsections that have similar traffic and intersection characteristics. These data collection activities took place over a 2-week period in March 2003.

**Findings**

Selected results from the three evaluation activities are described as follows.

<u>Bus Mobility and Reliability</u>

Bus performance data were collected on a total of 117 northbound and 117 southbound trips within the study area, primarily in the morning, mid-day, and afternoon peak periods. Survey workers on board buses used laptop computers with specially designed software to record information and timestamp events. The data collected included:

1. Timestamps at each signalized intersection:

[1] Sacramento-Watt Avenue Transit Priority and Mobility Enhancement Demonstration: Final Evaluation Plan, November 25, 2002.

- The time the bus arrived at the back of the queue at the intersection.
- The time the signal turned green.
- The time the bus began moving (denoting start-up delay).
- The time the bus crossed the intersection stop bar.

2. Timestamps at each bus stop location:
   - The time the bus arrived at the bus stop.
   - The time when all passengers had boarded and paid.
   - The time the bus re-entered the traffic stream.
3. Passenger counts at each bus stop:
   - The number of passengers who alighted the bus.
   - The number of passengers who boarded and paid with a prepaid card.
   - The number of passengers who boarded and paid with cash.

As shown in the Figure ES-2 below, the average bus running time (time the bus is in motion) in the northbound direction is highest during the evening peak period. Signal delay (time stopped due to traffic signals) represents 24 to 32 percent of the running time, while dwell delay (time stopped at bus stops) represents 10 to 12 percent of running time. In the southbound direction, again, evening peak run times are the longest. Signal delay ranges between 24 and 28 percent of the running time; dwell time is 11 to 12 percent of the running time. These baseline data will be compared to data collected after implementation of the system.

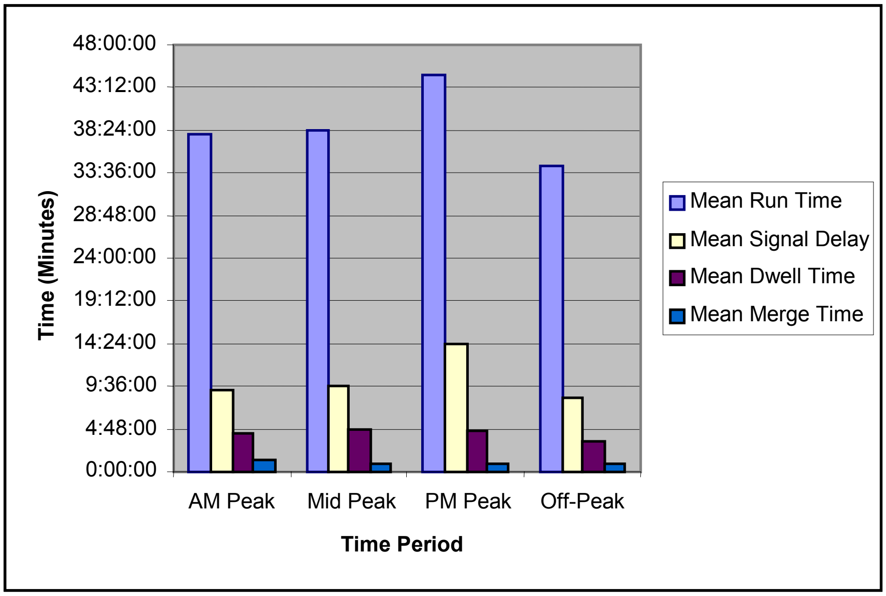


**Figure ES-2. Northbound Travel Time Performance by Time Period – All Study Segments.**

Traffic Mobility and Efficiency

Travel time data were collected for seven days during the morning (7am-9am), mid-day (11am-1pm), and evening (4pm-6pm) peaks using floating cars fitted with GPS-based loggers. Two vehicles were used during the study, with one traveling on Watt Avenue northbound and southbound), and the other traveling on a ”serpentine” route covering five of Watt Avenue’s cross-streets. Data from a total of 167 north/south and 208 east/west trips were collected.

In general the data collected showed that Watt Avenue is busiest during the PM peak, carrying about 14,500 vehicles in Segment II and 11,500 vehicles in Segment IV. The northbound/southbound volume split on Watt Avenue is roughly equal, indicating that Watt Avenue is a major thruway between the two freeways with no peak direction. Likewise, the cross-streets in Segments II and IV carry between 4,500 and 5,500 vehicles during the PM peak, but in this case, there is evidence of directional peaking, with traffic mostly heading westbound (towards downtown Sacramento) during the AM peak, and eastbound (away from downtown) during the PM peak. This indicates that commuters sometimes use the arterials crossing Watt Avenue as alternate routes to I-80 Business and U.S. 50. Since the general traffic volumes and patterns in Segments II and IV are similar, Watt Avenue’s northbound/southbound volumes in Segment III are expected to be the same. Cross-street volumes in Segment III, which consists of driveways to the shopping centers, however, are expected to behave differently than cross-streets from Segments II and IV, which consists of major arterials such as Arden Way, El Camino Avenue, and Auburn Boulevard.

Traffic patterns on the cross street remained relatively stable throughout the day, except for Auburn Boulevard eastbound during the PM peak, where additional delays were incurred from heavy traffic movements associated with the nearby I-80 Business Loop off-ramp, often doubling the typical travel time (from an average of about four minutes to eight minutes during AM and mid-day peaks). The same was true of Auburn Boulevard westbound during the AM peak, where freeway on-ramp queues often spilled over to Auburn Boulevard and beyond.

Bus Rider Customer Satisfaction Study

The baseline customer satisfaction intercept survey was conducted on Monday, October 7, 2002 through Wednesday, October 9, 2002. Teams of surveyors distributed and collected questionnaires to passengers within the study corridor during morning and afternoon peak periods. A total of 368 completed survey forms were obtained. Over half (56 percent) of the respondents reported having used the bus in this corridor for more than one year, and nearly 60 percent reported using the bus “nearly every day”.

Most of the respondents did not view stops at traffic signals as a problem based on their reported satisfaction with the number of times their bus stops at traffic signals. As shown in Figure ES-3, only 13 percent of the respondents indicated that they were either not satisfied or not at all satisfied with this aspect of their bus service.

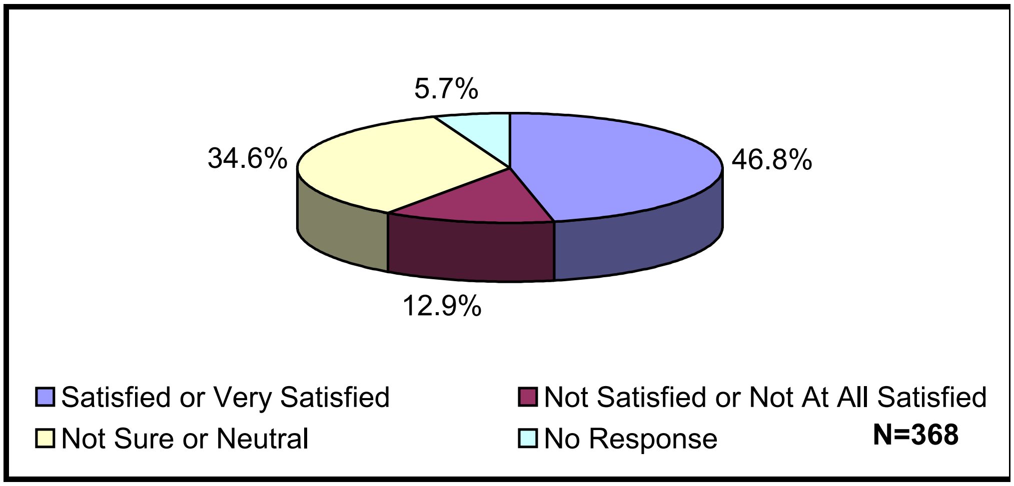


**Figure ES-3. Riders' Level of Satisfaction with Number of Stops for Traffic Lights.**

When asked about how satisfied they were with the on-time performance of buses in the Watt Avenue corridor, less than half respondents (47 percent) indicated that they were satisfied or very satisfied, and just over one quarter (26 percent) reported being not satisfied or not at all satisfied. As shown in Figure ES-4, riders have strategies for accommodating uncertainty about bus arrival times. Nearly one third of the respondents (32 percent) indicated that they could rely on the bus arriving within a few minutes of when they expected it. However, 35 percent of the respondents reported that they either come to the stop early to avoid missing a bus, or take an earlier bus to avoid being late. These riders would potentially save time if the bus service was more reliable.

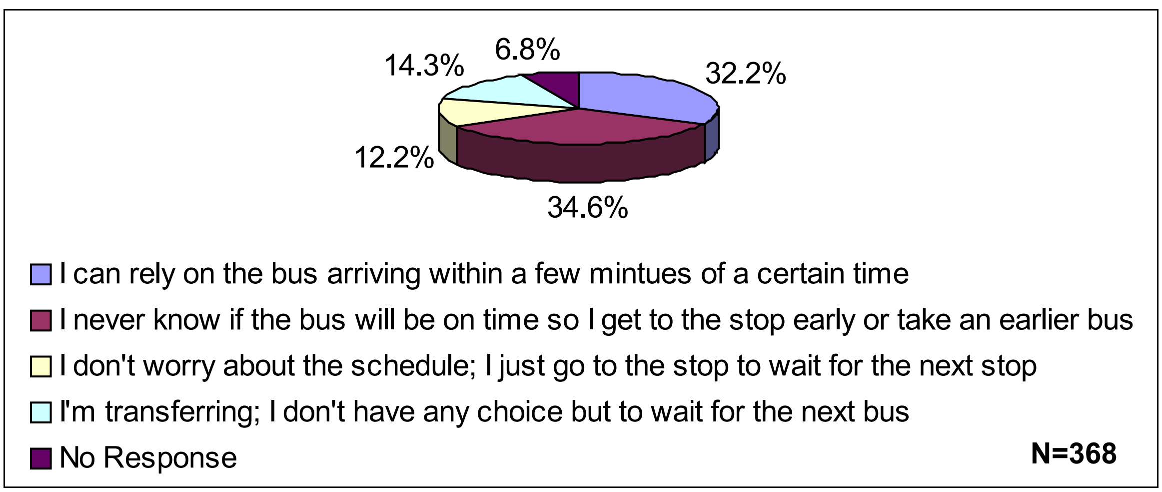


**Figure ES-4. Statements Describing Riders' Bus Waiting Strategies.**

## Evaluation Risk Assessment

The continuation of the evaluation of the Watt Avenue Transit Priority and Mobility Enhancement Demonstration project offers significant opportunities, with little or no risk. By all accounts, the deployment is proceeding on schedule, and the partners remain committed to supporting the evaluation efforts. Based on this and the Evaluation Team's experience in developing the Evaluation Plan, working with the project partners, collecting baseline data, and analyzing baseline conditions, the Evaluation Team recommends that the Federal Highway Administration's (FHWA) ITS Joint Program Office consider continuing on with the Phase III evaluation efforts.

# 1. INTRODUCTION

## 1.1 PROGRAM OVERVIEW

In 2001, the U.S. Congress earmarked funds for selected projects that were assessed as supporting improvements in transportation efficiency, promoting safety, increasing traffic flow, reducing emissions, improving traveler information, enhancing alternative transportation modes, building on existing intelligent transportation systems (ITS), enhancing integration, and promoting tourism. A small number of these projects were selected for national evaluation. The Sacramento – Watt Avenue Transit Signal Priority (TSP) project was among those selected for national evaluation as part of the USDOT ITS Integration Program. This deployment is consistent with the USDOT's objectives to accelerate the integration and interoperability of ITS across system and jurisdictional boundaries.

Under the direction and partial funding of the United States Department of Transportation (USDOT), National ITS evaluations are being conducted to accelerate the integration and interoperability of ITS in metropolitan and rural areas. To investigate the success of ITS across the country and to provide insights into the potential strengths and weaknesses of the overall national integration program, this project was selected for independent national evaluation. Science Applications International Corporation (SAIC) was selected to develop and implement the "before and after" evaluation. The overriding purposes of this evaluation are to determine whether the project goals are met, and to provide valuable costs and benefits and lessons learned to potentially assist other agencies across the nation who may be considering similar deployments.

As part of Phase II of the evaluation, a "before" assessment was conducted to establish a baseline to which future evaluation data will be compared. This report presents the results of the baseline assessment. Following deployment of TSP, and during Phase III of the evaluation, corresponding "after" data will be collected and compared to the "before" data presented in this report.

This evaluation involves a system impact study that addresses transportation system impacts, operational impacts, and changes in customer satisfaction. The evaluation will also document any institutional issues or challenges encountered in deploying the Sacramento TSP project.

## 1.2 REPORT ORGANIZATION

This document outlines the evaluation strategies, data collection plans, and baseline results for the Sacramento – Watt Avenue Transit Signal Priority (TSP) project. This Phase II Report represents the second major deliverable of the evaluation effort. The Evaluation Plan, which presented the detailed objectives, hypotheses, and data needs for each evaluation goal area, was the first deliverable.[2] The next major deliverable will

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[2] Sacramento-Watt Avenue Transit Priority and Mobility Enhancement Demonstration: Final Evaluation Plan, November 25, 2002.

be the Phase III Report, which will include before-and-after analyses of the projects' impacts on system performance and customer satisfaction by comparing the data collected in Phases II and III of the evaluation. This Phase II document is structured in the following format:

- **Section 1 – Introduction:** Provides background information on the project, including project participants, system components, and system objectives.
- **Section 2 – Bus Mobility and Reliability:** Details the data collection plan, data collection process, and baseline results related to measuring transit travel times and signal delays.
- **Section 3 – Traffic Mobility and Efficiency:** Details the data collection plan, data collection process, and baseline results related to measuring non-transit vehicle speeds and travel times, including cross-streets.
- **Section 4 – Customer Satisfaction:** Details the data collection plan, data collection process, and baseline results related to the customer satisfaction surveys.
- **Section 5 – Recommendations:** Provides an assessment and recommendations for the continuation of Phase III of the evaluation in terms of the current deployment plans and schedules and opportunities.

## 1.3 PROJECT DESCRIPTION

### 1.3.1 Problem Statement

Watt Avenue, a major north-south thoroughfare in suburban Sacramento County, is one of only three traffic crossings of the American River in the County. By vote of the residents in the early 1980s, the last segment of right-of-way that could have accommodated another bridge crossing was forfeited and subsequently developed. Today there is an eight-mile gap between river crossings, and as a result, traffic flows on Watt Avenue in the vicinity of the bridge exceed 100,000 vehicles per day. Although the bridge was recently widened (Fall of 2002), traffic volumes on Watt Avenue still exceed capacity and congestion is a significant problem during peak periods as seen in Figure 1-2. The six-mile stretch of Watt Avenue targeted by the project is bounded by Interstate 80 (I-80) to the north and Highway 50 (US 50) to the south, and serves two bus routes running approximately 30 buses each weekday connecting to light rail stations at either end. The Sacramento Regional Transit District (RT) faces a challenge in providing reliable bus service along Watt Avenue due to this congestion and inconsistent travel times. The study corridor is outlined in Figure 1-1.

**Figure 1-1. Study Corridor Map Highlighting Routes 80 and 84.**

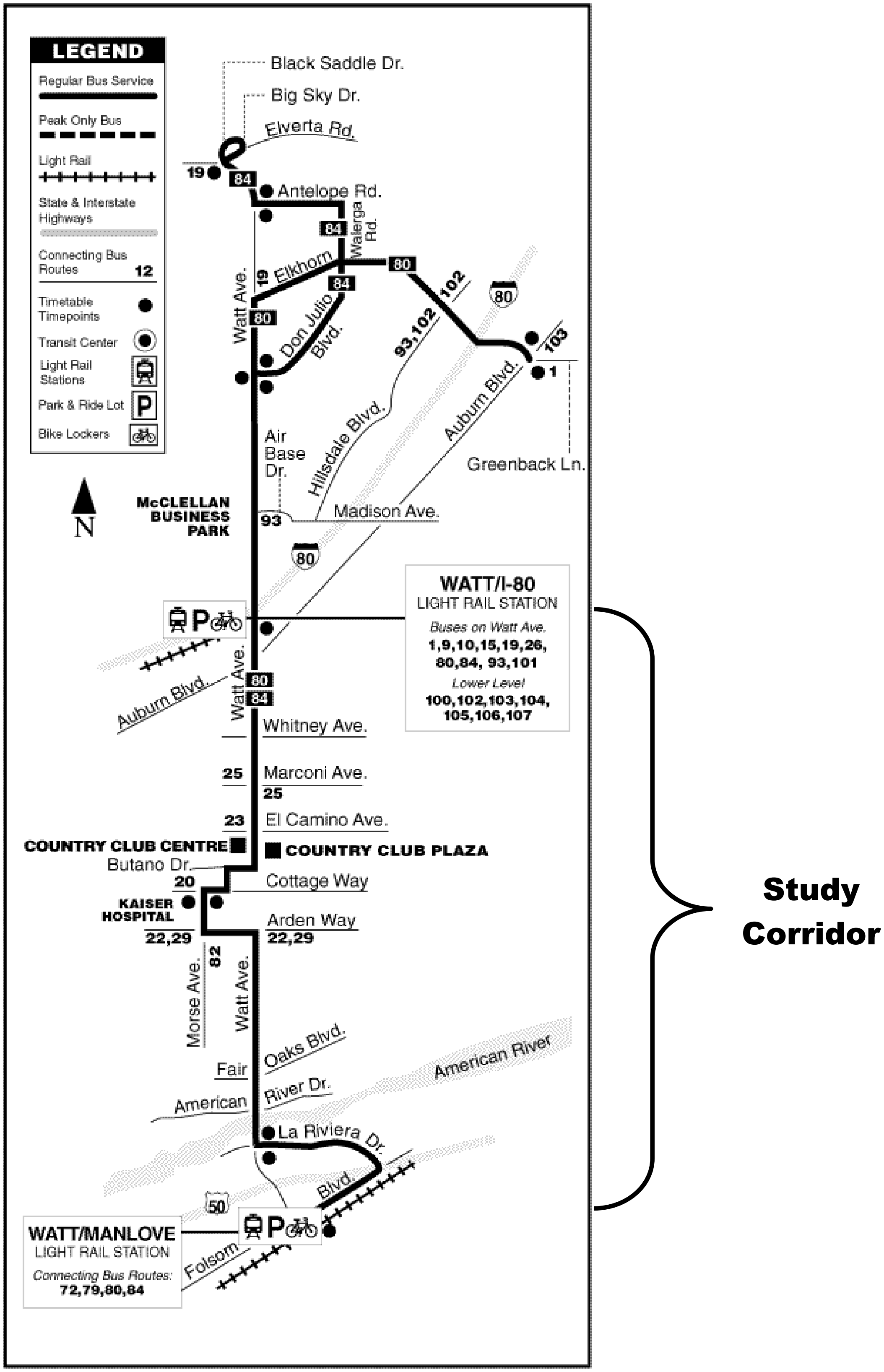



**Figure 1-2. Congestion on Watt Avenue.**

### 1.3.2 Overview

The Watt Avenue corridor runs north/south, providing travelers with arterial service connecting US 50 at the south with I-80 at the north, and serving light rail stations at either end. Current transit routes on Watt Avenue (Routes 80 and 84) have headways of 30 minutes and are coordinated with light-rail and other bus transfers at the transit stations on either end[3]. The LRT service between these stations covers a longer route with an average travel time of 45 minutes.

[3] "Measured Performance for Sacramento Watt Avenue ITS Transit Signal Priority Improvements," ITE Conference, 2002. Presentation given by P.D. Gross and J.M. Wright.

**Figure 1-3. LRT Crossing North of Watt Avenue.**

Sacramento County has recently embarked on a major initiative to upgrade the Watt Avenue corridor. Intersection improvement projects totaling $2.2 million have been completed, and the American River Bridge was widened, opening on September 8, 2002. Sacramento County also recently completed the integration of their Traffic Operations Center, as shown in Figure 1-4, which includes closed circuit television (CCTV) surveillance cameras, changeable message signs (CMS), highway advisory radio (HAR), and a fiber optics communications trunkline.

**Figure 1-4. Sacramento County Traffic Operations Center.**

### 1.3.3 Project Stakeholders

The project stakeholders and partners for the Transit Signal Priority project are listed in Table 1-1 below along with their corresponding roles.

**Table 1-1. Stakeholder Participants**

| Stakeholder | Role |
|---|---|
| U.S. Department of Transportation | Project Sponsor |
| County of Sacramento, Department of Transportation | Project Sponsor, Project Management, Traffic Management |
| Sacramento Regional Transit District | Transit Management |
| Sacramento Metropolitan Fire District | Emergency Response |
| California Highway Patrol | Incident Management |
| Caltrans District 3 | Incident Management, Traffic Management |
| Sacramento Area Council of Governments | Regional ITS Architecture |

### 1.3.4 Project Description

The Sacramento-Watt Avenue Transit Priority and Mobility Enhancement Demonstration project aims to improve travel time reliability for both transit and personal vehicles in the heavily traveled Watt Avenue corridor, through the implementation of:

- A TSP system that is carefully integrated with optimized corridor signal timing plans. This is expected to translate into improved transit scheduling and customer satisfaction, while maintaining overall arterial traffic flow.
- More effective signal timing plans with the aid of fiber connections and CCTVs, which is expected to improve the overall arterial traffic flow.
- Arterial service patrols and CCTVs that are expected to improve incident response performance.
- Improved traveler information that will be provided through HAR, CMS, the Internet, and ultimately, through the provision of arterial travel times.

This evaluation focuses primarily on measuring the impact of the first two components of this project; however the other components will not be excluded when studying overall arterial traffic flow. It would be difficult to isolate the impacts resulting directly from the TSP system or improved signal timing plans versus those resulting from improved incident response times or improved traveler information. Therefore, the impact of all of these components will be measured concurrently.

This project combines a comprehensive array of *advanced technology, conventional, and operational* solutions within a 36-month time frame, hoping to achieve improved corridor traffic conditions that will be a part of a long-range program with more extensive operational improvements. The project categories are detailed as follows:

- In the *conventional* area, geometric improvements will be implemented at significant constraint points along the corridor, intending to benefit both public transit and private vehicles. The improvements include items such as roadway and intersection (i.e., right turn only lanes) widening.
- In the *operational* area, controller upgrades/replacements and traffic signal system upgrades with new signal timing plans will create better traffic flow on the existing arterial. “Queue jump” operation will be provided to allow for more efficient transit vehicle movements.
- In the *advanced technology* area, buses will be outfitted with devices to allow remote positioning, passenger counting (load factors), and signal priority. A signal priority system will give buses priority at signalized intersections, so they are ushered through a series of green lights, rather than incur delay at traffic signals in what otherwise would be a stop-and-go manner.

The TSP system will be deployed over three stages. In the initial phase, the emitters will be on from the moment a vehicle begins its route until the engine is turned off. Then, depending on the system’s initial performance, the project partners intend to implement Phases II and III to make the TSP system more efficient. In the second phase, transit vehicles using the Watt Avenue corridor will be outfitted with automated vehicle location (AVL) capabilities that will allow system managers to determine if the vehicle is behind schedule, and to temporarily disable the Opticom™ TSP emitter (and thus the priority request) if this is not the case. Finally, a “queue jump” operation will be added to the system during the third phase. Queue jumping combines TSP with an additional transit-dedicated travel lane (or a right turn lane) to provide a “transit dedicated early green signal" to transit vehicles, allowing them to pass through the intersection in advance of the general flow of traffic. Specific intersections where queue jumping will be deployed will follow evaluation of the performance of TSP to determine the most effective locations. Section 2.1 discusses the project schedule in more detail.

Moreover, a fiber optic communications system will be deployed along Watt Avenue as a part of the County's long-range Traffic Operations System (TOS) communications plan. This fiber optic backbone will allow for center-to-center communication between the County Traffic Operations Center and the Caltrans District 3 Regional Transportation Management Center and future links to the Transit Dispatch Center and the City of Sacramento Traffic Management Center. Multiple CCTV cameras along the corridor will allow operators to have seamless surveillance of actual traffic conditions, taking manual control as needed to respond to incidents and to manage traffic flow. Access to traffic data through the center-to-center communication will allow for management of traffic condition information available on CMS at the approaches to freeway entrances. Traveler information infrastructure such as CMS, dynamic messaging, and annunciation systems at selected high-volume bus stops and LRT stations will be implemented.

There are several existing infrastructure components that are currently in place. The County has installed a hardwired, twisted copper pair interconnect for the signal system on Watt Avenue. Sacramento County maintains and operates emergency vehicle preemption (EVP) hardware owned by the Sacramento Metropolitan Fire District at the signalized intersections on Watt Avenue. This equipment has the additional capacity for "soft" or transit priority. Currently, there are right turn only lanes at several key intersections that will facilitate the use of transit vehicle 'queue-jumping' with no additional roadway capacity necessary.

Sacramento County and RT are members of the Sacramento ITS Deployment Partnership that was formed in 1998 to explore the potential for coordinated deployment of ITS, and to develop a project proposal for integration of the various transportation operation and management centers (TOCs and TMCs) in the region. The original partnership included the City of Sacramento, the County of Sacramento, Sacramento Regional Transit District, Caltrans District 3, the Caltrans New Technology and Research Program, and the Sacramento Area Council of Governments (SACOG). The California Highway Patrol (CHP) was also represented on the original partnership project team.

The integration project will also benefit from the additional, proposed ITS deployments. The County has completed construction of a TOS that will deploy various ITS transportation management elements that shall be consistent with the National ITS Architecture. RT has programmed funds for on-time performance monitoring, an operations and transportation information system, and automated trip planning software. In the future, both RT and Sacramento County ultimately plan to provide real-time travel time information to the public through their respective management centers.

### 1.3.5 The Study Area

The study area consists of a 9.8-mile section of Routes 80 and 84 from the Watt/I-80 light rail station to the Watt/Manlove light rail station as shown in the route map in Figure 1-5. The route includes a total of 37 bus stops and 30 intersections. Routes 80 and 84 operate on alternating 60-minute headways, so that each stop along the route is serviced by 30-minute headways. For study purposes the route was divided into four segments of varying land uses and characteristics as described below. The TSP intersections are identified in Figure 1-6.

Segment I: Manlove LRT Station to La Riviera & Watt on-ramp (2.79 miles)

- 7 signalized intersections *(no TSP)*
- 11 bus stops
- Suburban residential arterial; parallel to light rail track

Segment II: Watt & Fair Oaks to Watt & Arden (2.35 miles)

- 4 signalized intersections *(all TSP)*
- 6 bus stops
- High-speed suburban arterial

Segment III: Arden & Professional to Butano & Watt (1.74 miles)

- 6 signalized intersections *(1 TSP)*
- 10 bus stops
- Urban arterial (closely spaced intersections); commercial land use

Segment IV: Watt & Country Club to Watt & I-80 LRT Station (2.69 miles)

- 12 signalized intersections *(10 TSP)*
- 10 bus stops
- Low speed suburban arterial; commercial and high-density residential development

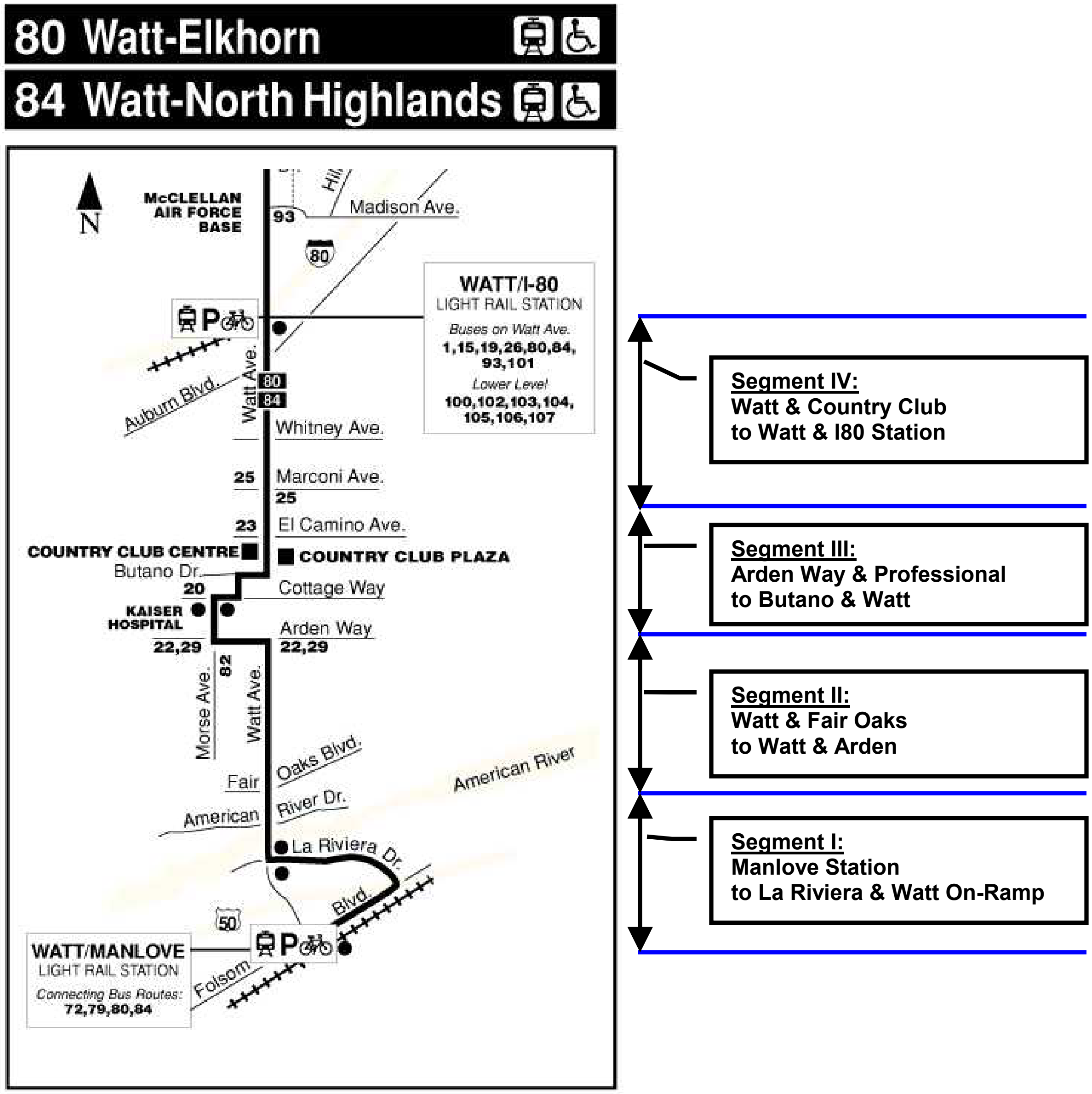



**Figure 1-5. Map of Study Corridor Showing Segments and Intersections.**

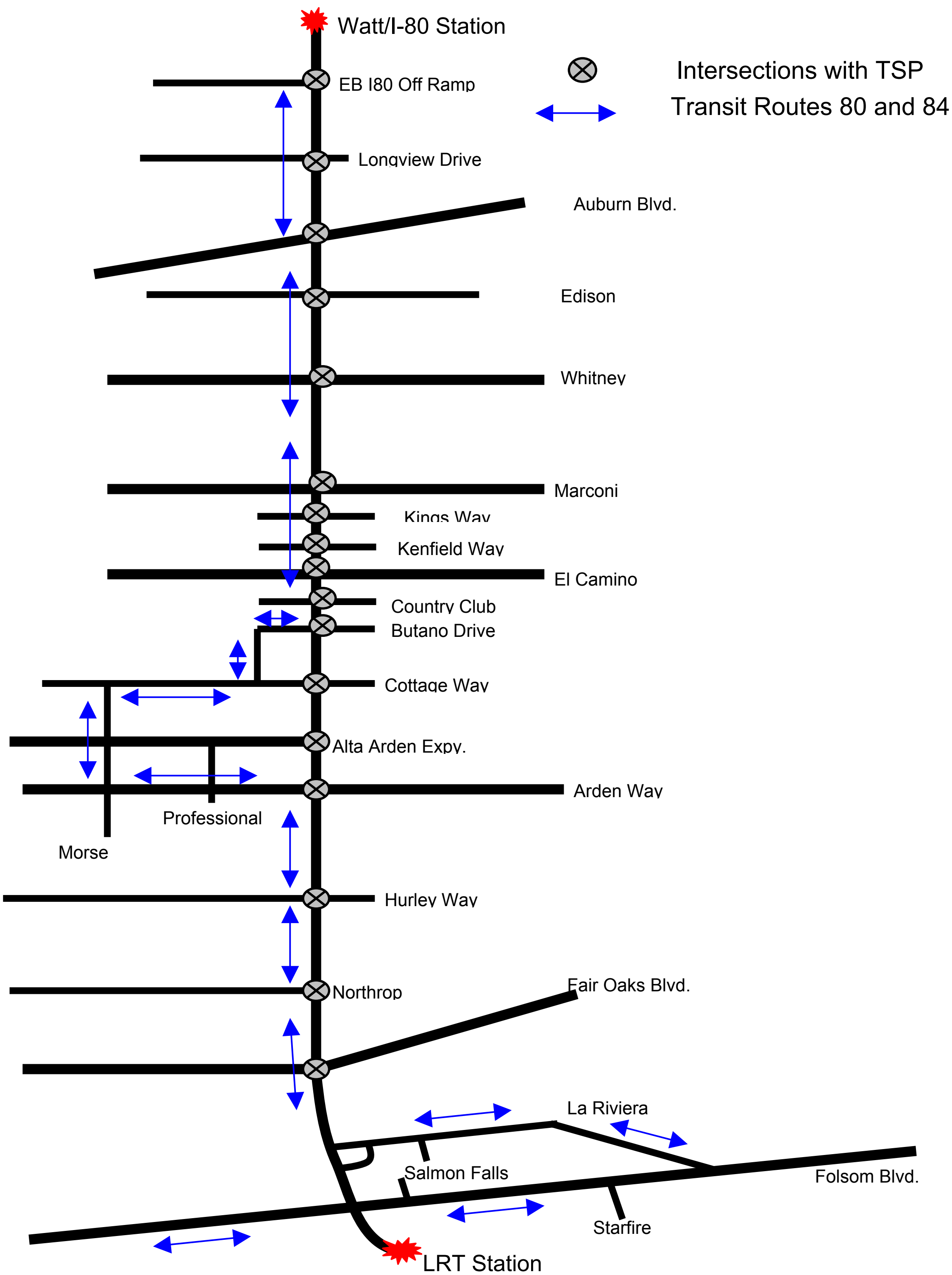



**Figure 1-6. TSP and Non-TSP Intersections on Watt Avenue.**

## 1.4 EVALUATION OVERVIEW

The evaluation of the Sacramento – Watt Avenue TSP project involves three components, each with their own evaluation activities:

- Bus Mobility and Reliability (evaluated with the use of on-board performance data collection).
- Traffic Mobility and Efficiency (evaluated with the use of floating car runs on Watt Avenue and cross-streets).
- Transit Customer Satisfaction (evaluated through on-board passenger surveys).

The Evaluation Plan identified a set of measures of effectiveness (MOEs), to measure each of these components. The project goals, along with corresponding hypotheses and MOEs, are provided in Table 1-2. The key hypotheses are:

- TSP will improve transit system mobility and performance by reducing transit travel times, minimizing signal delay, improving transit reliability (reducing variability in travel times), and reducing the number of buses required to operate the service.
- TSP will increase transit customer satisfaction by improving transit schedule reliability and reducing transit travel times.

Throughout the course of the evaluation the MOEs have been modified based on additional knowledge and information that the Evaluation Team has gained through working with the local project stakeholders. These changes are described below.

It will be important to determine whether or not the TSP system has affected safety in the study corridor. After subsequent consideration of this goal area, however, the Evaluation Team discovered that only one intersection within the study area (Watt Avenue and Fair Oaks Drive) currently has a red light running camera in place. Therefore, it is not likely that there will be sufficient red light running data to provide meaningful results in terms of a surrogate for measuring safety impacts of the TSP system. As it has been hypothesized that *speed variability* may serve as an appropriate surrogate measure of crash risk, the Evaluation Team has added *speed variability* as an additional surrogate measure of safety. Baseline data collected on vehicle speeds throughout the corridor will be used to calculate speed variability, and these data will be compared before and after system deployment.

It should be noted that *red light running data for buses* will also be considered as another MOE that may be used to measure the safety throughout the corridor. It is possible that the amount of red light running could even decrease as a result of buses along this corridor receiving priority.

It should also be noted that the Evaluation Team will no longer be evaluating the perceptions of non-transit travelers. After subsequent consideration of this metric, the Evaluation Team determined that it would be difficult to capture this type of data cost-effectively, and that these data would not be likely to produce meaningful results. However, the evaluation goals were recently modified to include the perceptions of bus drivers and traffic operations personnel. As a result, Phase III of the evaluation will include interviews (or focus groups, depending on the number of drivers RT identifies as being appropriate for this) with bus drivers who are assigned to Routes 80 and 84. The goal of this will be to measure the impact of the system qualitatively, by speaking with the drivers who have first-hand experience with the Watt Avenue corridor. This portion of the evaluation is contingent on when the TSP system becomes completely functional since drivers' routes are reassigned each quarter (the next scheduled driver rotation is December 2003), and it will be important to obtain the perceptions of drivers who drove the route in the timeframes both before and after the TSP deployment. The Evaluation Team will also be conducting interviews with traffic operations personnel to obtain their insight into their thoughts about the system and its impact on traffic mobility.

It should also be noted that "bus maintenance frequency" was a measure identified in the evaluation plan for this effort. However, it was found that the frequency of brake-related maintenance is actually set by inspection schedules (which are based on mileage), so this data is irrelevant. Therefore, this measure would not provide insight into impacts of TSP in terms of any reductions in wear and tear on the buses as a result of less braking at signalized intersections. In addition, because various vehicles are assigned to Routes 80 and 84, any impact would be shared by all vehicles in the fleet and would therefore be difficult to discern.

**Table 1-2. Project Goals, Hypotheses, and MOEs**

| Bus Mobility and Reliability | | |
|---|---|---|
| **Goal** | **Hypothesis** | **MOE** |
| Improve transit system mobility and performance. | TSP will improve transit system mobility and performance by reducing transit travel times, minimizing signal delay, improving transit reliability (reducing variability in travel times), and reducing the number of buses required to operate the service. | Transit travel times |
| | | Transit signal delay |
| | | Number of transit stops at red lights |
| | | Ridership data |
| | | Number of buses required to operate the service |
| | | Number of TSP calls |
| Improve schedule reliability. | TSP and traffic data will allow for the transit agency to develop improved schedules. | Changes in schedule and/or operations by transit agency based on system information |
| | | Bus travel time variability |
| | | Bus schedule delay |
| **Safety** | | |
| **Goal** | **Hypothesis** | **MOE** |
| Maintain current levels of safety. | TSP will maintain the current level of transit safety throughout the corridor. | Number of transit crashes |
| | | Red light running data for buses |
| Maintain current levels of safety. | TSP will maintain the current level of traffic safety throughout the corridor. | Red light running data |
| | | Vehicle average operating speeds |
| | | Speed variability |
| **Traffic Mobility and Efficiency** | | |
| **Goal** | **Hypothesis** | **MOE** |
| Improve corridor efficiency. | Corridor efficiency will be improved by increasing transit ridership, leading to a reduction in passenger car usage, and maintaining minimal negative impacts on arterial traffic flow. | Corridor volume |
| | | Transit ridership |
| | | Non-transit average vehicle occupancy |
| Improve traveler mobility in the corridor. | TSP will improve traveler mobility in the corridor by reducing vehicle delay and travel times. | Corridor and signal delay |
| | | Cross street delay |
| | | Vehicle average operating speeds |
| | | Overall corridor travel time |
| **Customer Satisfaction** | | |
| **Goal** | **Hypothesis** | **MOE** |
| Improve transit customer satisfaction. | TSP will increase transit customer satisfaction by improving transit schedule reliability and reducing transit travel times. | Perceptions of transit travelers |

# 2. BUS MOBILITY AND RELIABILITY

The primary goal of the Watt Avenue TSP deployment is to improve transit mobility and efficiency throughout the study corridor. In particular, the project seeks to improve the reliability of transit travel times. Project partners expect that reductions in transit travel times and signal delay will improve transit mobility and travel time reliability, and will allow the transit agency to develop improved transit schedules resulting in improved on-time performance. This section focuses on the performance evaluation of transit service in the study area (Routes 80 and 84 on Watt Avenue).

This section is organized as follows:

- 2.1 Data Collection Approach
- 2.2 Findings from Baseline Data Collection

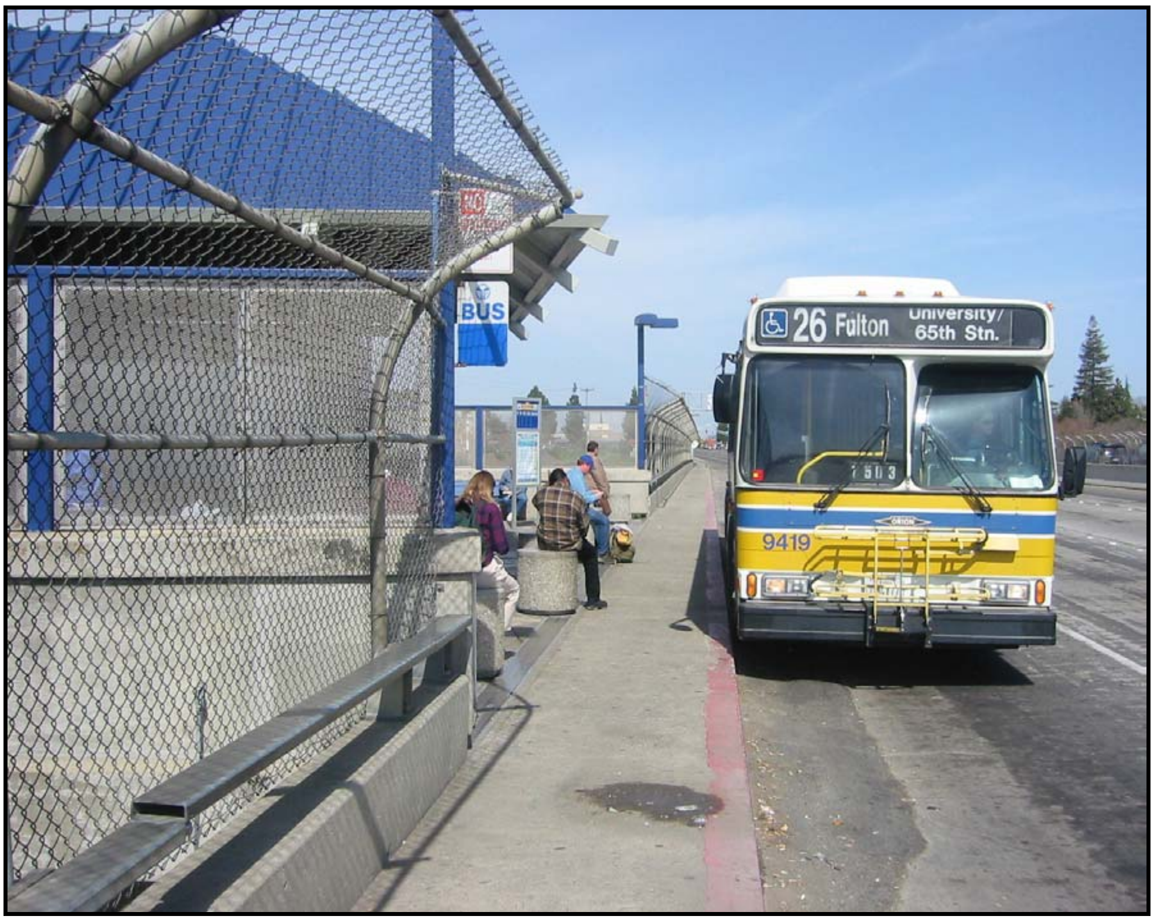



**Figure 2-1. Bus Station at I-80 and Watt Avenue.**

## 2.1 DATA COLLECTION APPROACH

The purpose of the transit data collection is to investigate the impact of the TSP system on transit vehicles traveling along the Watt Avenue corridor. The data that were collected serve as "baseline" data (collected prior to deployment), and will later be compared with data collected after the TSP system is deployed. The following section provides details on the format, assumptions, and collection methods used in gathering transit-related data to evaluate the performance of transit service along Watt Avenue.

The transit-related data focused on the following measures of effectiveness (MOEs):

- Bus travel time along the corridor;
- Bus travel time variability;
- Signal delay (the time it takes a bus to traverse from the back of a queue at an intersection to the point it crosses the intersection);
- Average number of bus stops at red lights per run (i.e., on average and for every run, how many times do we expect the bus to stop at red lights?);
- Percentage of buses stopping at red lights (i.e., what is the percentage of buses that stopped at red lights at a specific intersection?);
- Number of signal failure occurrences at each intersection (signal failure was defined as occurring when the queue at an intersection was long enough that the bus was not able to clear the intersection during the first available green phase).

### 2.1.1 Data Collection Periods

Baseline data were collected for a two-week period from March 10th to March 21st of 2003. Data were primarily collected Monday through Friday during the three periods of peak traffic flow: AM peak; mid-day; and PM peak. In order to investigate the impact of the system on buses during off-peak hours, a few runs were also collected outside of these time periods. A period of two weeks was selected by the Evaluation Team based on the results of a statistical power analysis that was conducted to determine the sample size needed to show significant and/or meaningful results. The power analysis is provided in Appendix A for reference. The power analysis was performed using a two-sided test (since the direction of expected change could not be specified with certainty) assuming that $\alpha = 0.05$ (i.e., a change in transit travel times as small as a 5 percent would be able to be detected), and $\beta = 0.8$ (i.e., there would be an 80 percent probability of detecting a difference between the two sample means).

As shown in Table 2-1 below, a total of 117 runs were conducted in the northbound and southbound directions. Please note that the sample size for the off-peak is significantly lower than the other peaks.

**Table 2-1. Number of Transit Runs Collected**

| Number of Transit Runs | AM Peak (6:30-8:30) | | MD Peak (11:00-1:00) | | PM Peak (3:30-6:00) | | Off-Peak | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | NB | SB | NB | SB | NB | SB | NB | SB | NB | SB |
| | 38 | 38 | 36 | 35 | 33 | 34 | 10 | 10 | 117 | 117 |

### 2.1.2 Data Elements Collected

The following data were collected for each run. Intersection-related data were collected at all intersections in the study corridor regardless of whether or not TSP was planned for that intersection. For the after case, those intersections with and without may be identified and compared.

1. Standard information for each trip:
   - Trip direction (northbound or southbound),
   - Day of week.
   - Data collection period.
   - Weather conditions.
2. Timestamps at each signalized intersection:
   - The time the bus arrived at the back of the queue at the intersection.
   - The time the signal turned green.
   - The time the bus began moving (denoting start-up delay).
   - The time the bus crossed the intersection stop bar.
3. Timestamp at each bus stop location:
   - The time the bus arrived at the bus stop.
   - The time when all passengers had boarded and paid.
   - The time the bus re-entered the traffic stream.
4. Passenger counts at each stop:
   - The number of passengers who got off the bus.
   - The number of passengers who got on the bus and used a prepaid card.
   - The number of passengers who got on the bus and paid with cash.

5. Other relevant information:

- The number of times the wheelchair lift was used.
- The number of times the bike rack was used.
- The number of red light running occurrences (not actual crashes or citations, but rather observations of the research team that the bus ran a red light).
- The number of signal failure occurrences that occurred.

### 2.1.3 Data Collection Methodology

The Evaluation Team collected data using laptop computers running a Microsoft Excel/Visual Basic application developed by Sacramento County. A screenshot of the data collection interface is shown in Figure 2-2 below, and a detailed description of the software is provided in Appendix B. The software was created to provide a sequential event list for each bus stop and intersection (this was possible since both Routes 80 and 84 are fixed, and the sequence of bus stops and intersections along these routes is known), which allowed the Evaluation Team to capture timestamps as each event occurred. For example, rows 11 through 14 in Figure 2-2 represent four distinct events (back of queue, green, start-up, and intersection) to be time-stamped at the intersection of Watt and Longview (if the signal head is red when the bus approaches the intersection). The main prompt screen requires the user to input a “0” to skip this intersection routine if the signal head is green when the vehicle is approaching the intersection.

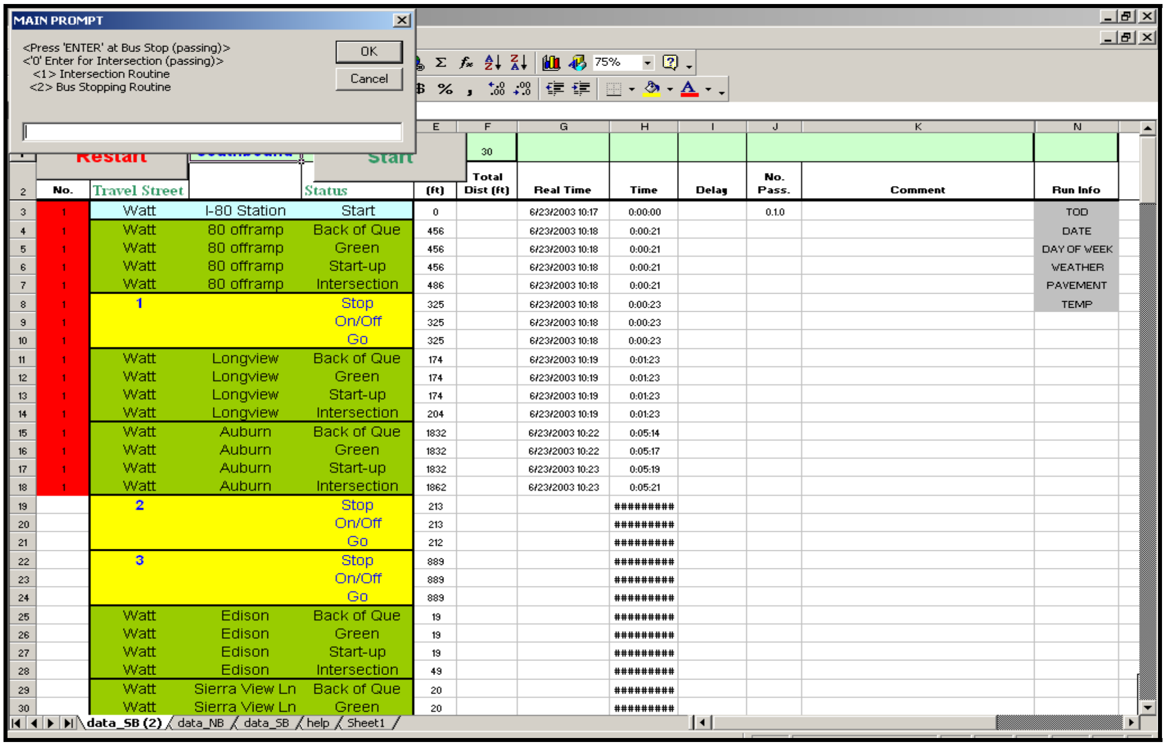



**Figure 2-2. Data Collection Interface.**

## 2.2 FINDINGS FROM BASELINE DATA COLLECTION

The Evaluation Team initially expected that transit travel times might vary by day of week (Monday/Friday versus Tuesday/Wednesday/Thursday). However, no statistically significant differences were found after comparing travel times and signal delay. Therefore, for the purposes of this study, all data were grouped together regardless of day of week. Figure 2-3 and Figure 2-4 illustrate the result of the day of the week comparison on Watt Avenue for both travel times and signal delays, respectively.

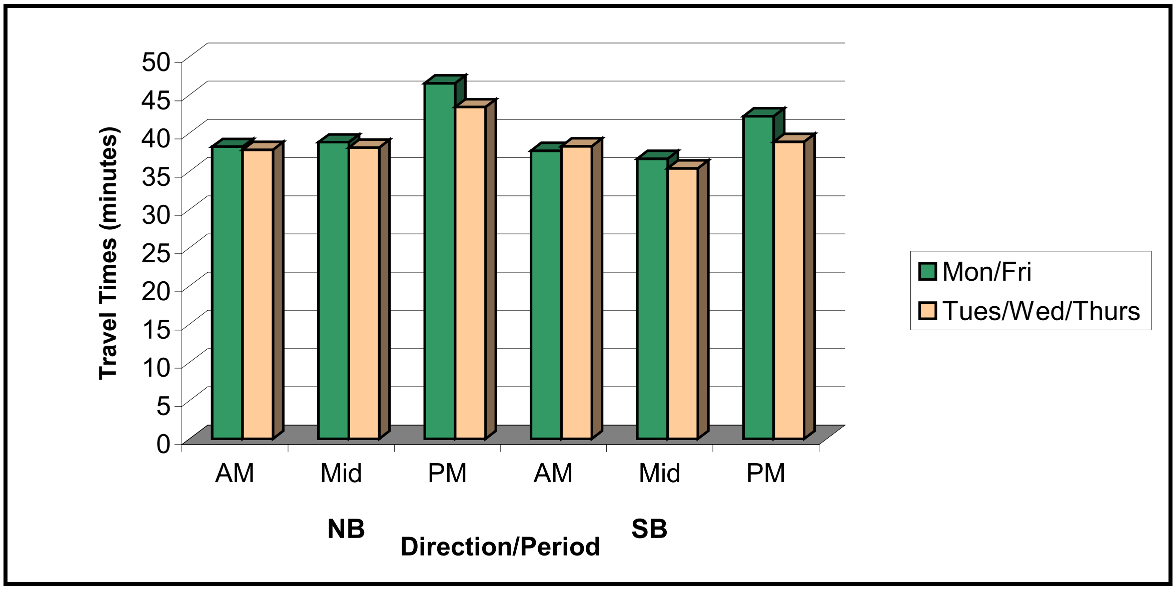



**Figure 2-3. Comparison of Average Transit Travel Time on Mondays and Fridays versus Mid-Week.**

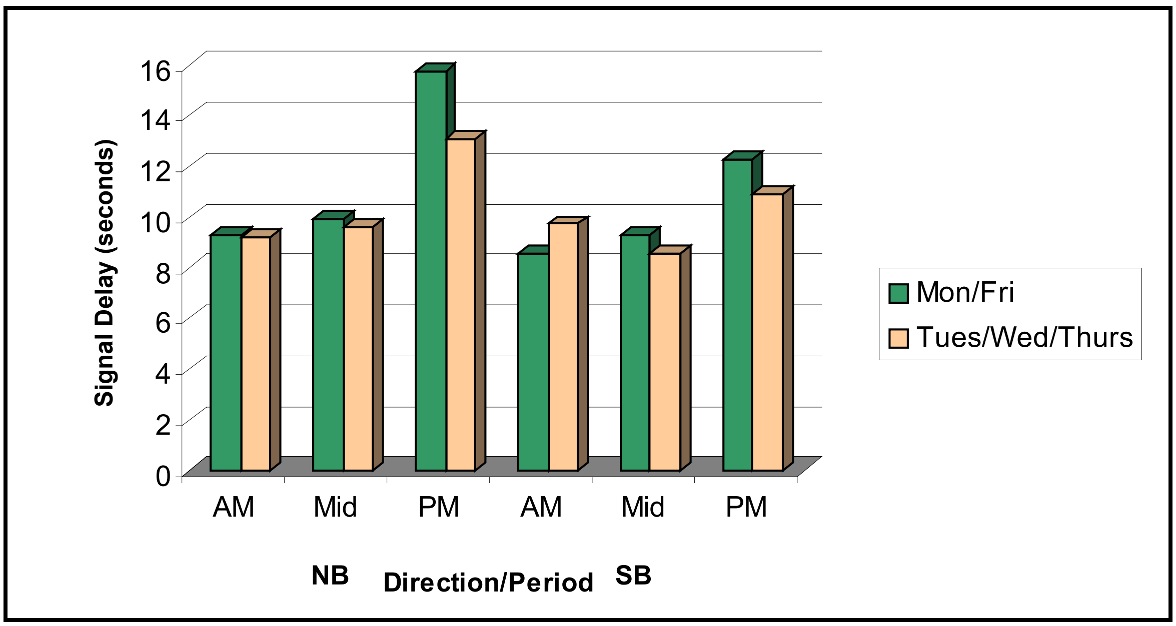



**Figure 2-4. Comparison of Average Transit Signal Delay on Mondays and Fridays versus Mid-Week.**

A summary of the transit performance on Watt Avenue is presented in this section. The section is divided into three parts:

- **Section 2.2.1 – Part 1** presents a data summary organized by study area segment (segment descriptions were provided in Section 1.3.5, and a map of the segments was shown in Figure 1-5). The data summary tables for this part include average travel time, running time, signal delay, dwell time, and merge time by time of day.
- **Section 2.2.2 – Part 2** presents a data summary organized by intersection. The data summary tables for this part include the average signal delay and the percent of buses stopping at red lights by time of day. In addition, the number of red-light-running occurrences and signal failure occurrences are provided for each intersection.
- **Section 2.2.3 – Part 3** presents a data summary organized by bus stop. The data summary tables for this part include transit ridership, payment method, and number of wheelchair and bike racks used at each bus stop.

It is important to note that data were also collected for segments/intersections where TSP will not be deployed so that a comparison between before and after scenarios for both TSP and non-TSP segments/intersections can be investigated.

### 2.2.1 Part 1 – Summary Data by Segments

Table 2-2 summarizes the mean and standard deviation for the travel time, running time, signal delay, dwell time, and merge time by time of day in the northbound (NB) direction for all the segments combined. Tables 2-3 through 2-6 summarize the data for segments I through IV, respectively. Similarly, Tables 2-7 through 2-11 summarize the data in the southbound (SB) direction. Please note that the sample size for the off-peak runs was lower than the sample sizes for the other peaks. The Evaluation Team had originally planned to conduct data collection only during the peak periods, but later decided to collect additional data during the off-peak to determine the impact of TSP during off-peak periods.

*Travel time* refers to the total bus travel time including the signal delay, dwell time, and merge time. *Running time* excludes signal delay, dwell time, and merge time. *Signal delay* refers to the amount of time it takes a bus to traverse from the back of a queue at an intersection (when the signal phasing is red) to the point it crosses the intersection. delay (specifically the time the bus crosses the intersection stop bar). *Dwell time* refers to the time the bus spends loading and/or unloading passengers at a bus stop. *Merge time* refers to the time the bus spends attempting to merge back into through traffic after stopping at a bus stop.

One essential indicator of schedule reliability is the standard deviation of bus travel times. It is vital to investigate whether TSP has the potential to reduce the variation in bus travel time and to improve schedule reliability. Less travel time variation can reduce the need for schedule recovery time. Even if no significant decrease in average travel time is detected from implementing TSP, schedule reliability can benefit if travel time variation decreases. Standard deviations were calculated and are provided in the summary tables.

This baseline information was analyzed to provide a basis for comparison with data that will be collected during the post-deployment period. Overall, travel time and signal delay during the PM Peaks were much higher than the AM Peaks or Mid-day. This is likely due to the fact that the shopping centers located on Watt Avenue between Arden Way and El Camino Avenue generate heavy traffic during the PM peak. Furthermore, travel time and signal delay in the northbound (NB) direction was slightly higher than the southbound (SB) direction, which could indicate that the signal coordination on Watt Avenue might be optimized for the southbound direction.

**Table 2-2. Northbound - All Segments Combined (in Minutes)**

| Time Measure | AM Peak N=38 | | Mid Peak N=36 | | PM Peak N=33 | | Off-Peak N=10 | | Total N=117 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| Travel Time | 37:59 | 3:08 | 38:22 | 3:35 | 44:44 | 6:22 | 34:25 | 1:51 | 39:42 | 5:33 |
| Running Time | 23:13 | 1:26 | 23:30 | 2:20 | 24:57 | 2:59 | 21:56 | 1:01 | 23:33 | 2:18 |
| Signal Delay | 9:14 | 2:24 | 9:44 | 2:35 | 14:15 | 6:54 | 8:18 | 1:41 | 10:43 | 4:43 |
| Dwell Time | 4:17 | 1:42 | 4:37 | 1:19 | 4:33 | 1:49 | 3:22 | 1:12 | 4:24 | 1:44 |
| Merge Time | 1:15 | 0:54 | 0:57 | 0:28 | 0:58 | 0:24 | 0:49 | 0:24 | 0:62 | 0:38 |

**Table 2-3. Northbound - Segment I (in Minutes)**

| Time Measure | AM Peak N=38 | | Mid Peak N=36 | | PM Peak N=33 | | Off-Peak N=10 | | Total N=117 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| Travel Time | 10:46 | 1:46 | 9:26 | 1:19 | 11:43 | 5:40 | 9:38 | 1:02 | 10:32 | 3:22 |
| Running Time | 7:15 | 1:11 | 6:41 | 0:36 | 6:59 | 1:03 | 6:37 | 0:26 | 6:57 | 0:58 |
| Signal Delay | 2:28 | 1:09 | 1:59 | 1:04 | 3:32 | 6:15 | 2:18 | 0:42 | 2:36 | 3:27 |
| Dwell Time | 0:46 | 0:35 | 0:40 | 0:35 | 0:57 | 0:28 | 0:35 | 0:29 | 0:46 | 0:33 |
| Merge Time | 0:16 | 0:17 | 0:07 | 0:06 | 0:14 | 0:09 | 0:09 | 0:07 | 0:12 | 0:12 |

**Table 2-4. Northbound - Segment II (in Minutes)**

| Time Measure | AM Peak N=38 | | Mid Peak N=36 | | PM Peak N=33 | | Off-Peak N=10 | | Total N=117 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| Travel Time | 7:11 | 1:11 | 6:31 | 1:17 | 10:00 | 1:55 | 6:26 | 0:57 | 7:43 | 2:03 |
| Running Time | 4:41 | 0:48 | 4:29 | 0:37 | 6:09 | 1:51 | 4:13 | 0:28 | 5:00 | 1:21 |
| Signal Delay | 1:56 | 0:50 | 1:42 | 0:51 | 3:25 | 1:39 | 1:53 | 1:02 | 2:17 | 1:20 |
| Dwell Time | 0:22 | 0:14 | 0:12 | 0:13 | 0:19 | 0:14 | 0:10 | 0:09 | 0:17 | 0:14 |
| Merge Time | 0:11 | 0:12 | 0:09 | 0:13 | 0:37 | 0:09 | 0:09 | 0:16 | 0:91 | 0:12 |

**Table 2-5. Northbound - Segment III (in Minutes)**

| Time Measure | AM Peak N=38 | | Mid Peak N=36 | | PM Peak N=33 | | Off-Peak N=10 | | Total N=117 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| Travel Time | 8:42 | 1:24 | 9:16 | 1:44 | 8:49 | 1:19 | 7:59 | 1:13 | 8:51 | 1:30 |
| Running Time | 5:02 | 0:31 | 4:56 | 0:36 | 4:51 | 0:25 | 4:48 | 0:20 | 4:57 | 0:30 |
| Signal Delay | 1:54 | 0:55 | 2:23 | 0:55 | 2:29 | 1:02 | 1:43 | 0:43 | 2:12 | 0:58 |
| Dwell Time | 0:81 | 0:52 | 1:37 | 1:10 | 1:17 | 0:47 | 1:17 | 0:49 | 0:84 | 0:56 |
| Merge Time | 0:25 | 0:36 | 0:20 | 0:21 | 0:13 | 0:08 | 0:11 | 0:05 | 0:19 | 0:25 |

**Table 2-6. Northbound - Segment IV (in Minutes)**

| Time Measure | AM Peak N=38 | | Mid Peak N=36 | | PM Peak N=33 | | Off-Peak N=10 | | Total N=117 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| Travel Time | 11:20 | 2:01 | 13:08 | 2:12 | 14:12 | 2:07 | 10:22 | 0:57 | 12:37 | 2:25 |
| Running Time | 6:15 | 0:43 | 6:57 | 1:18 | 6:59 | 1:12 | 6:19 | 0:23 | 6:41 | 1:60 |
| Signal Delay | 2:56 | 1:26 | 3:41 | 1:13 | 4:48 | 1:35 | 2:24 | 0:54 | 3:39 | 1:36 |
| Dwell Time | 1:47 | 1:16 | 2:08 | 1:08 | 2:01 | 1:07 | 1:20 | 0:24 | 0:12 | 0:68 |
| Merge Time | 0:22 | 0:13 | 0:22 | 0:15 | 0:24 | 0:15 | 0:20 | 0:13 | 0:22 | 0:15 |

**Table 2-7. Southbound - All Segments Combined (in Minutes)**

| Time Measure | AM Peak N=38 | | Mid Peak N=35 | | PM Peak N=34 | | Off-Peak N=10 | | Total N=117 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| Travel Time | 38:03 | 4:05 | 35:52 | 3:13 | 40:04 | 4:41 | 35:07 | 3:23 | 37:44 | 4:20 |
| Running Time | 23:20 | 1:32 | 22:11 | 1:50 | 23:33 | 1:57 | 22:19 | 1:22 | 22:58 | 1:49 |
| Signal Delay | 9:16 | 3:20 | 8:50 | 2:16 | 11:23 | 1:60 | 7:58 | 2:12 | 9:38 | 2:49 |
| Dwell Time | 4:31 | 2:00 | 4:01 | 1:22 | 4:17 | 1:53 | 4:01 | 1:12 | 4:16 | 1:44 |
| Merge Time | 0:56 | 0:23 | 0:50 | 0:28 | 0:51 | 0:35 | 0:50 | 0:32 | 0:52 | 0:29 |

**Table 2-8. Southbound - Segment I (in Minutes)**

| Time Measure | AM Peak N=38 | | Mid Peak N=35 | | PM Peak N=34 | | Off-Peak N=10 | | Total N=117 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| Travel Time | 14:27 | 2:45 | 11:57 | 2:01 | 14:11 | 2:44 | 12:07 | 2:08 | 13:25 | 2:43 |
| Running Time | 8:52 | 0:43 | 8:35 | 1:01 | 9:07 | 1:04 | 8:40 | 0:32 | 8:50 | 0:56 |
| Signal Delay | 3:51 | 2:12 | 2:35 | 1:18 | 3:58 | 1:52 | 2:28 | 1:52 | 3:23 | 1:56 |
| Dwell Time | 1:30 | 1:01 | 0:40 | 0:29 | 0:53 | 0:25 | 0:52 | 0:42 | 0:61 | 0:47 |
| Merge Time | 0:14 | 0:08 | 0:07 | 0:06 | 0:14 | 0:09 | 0:08 | 0:08 | 0:11 | 0:08 |

**Table 2-9. Southbound - Segment II (in Minutes)**

| Time Measure | AM Peak N=38 | | Mid Peak N=35 | | PM Peak N=34 | | Off-Peak N=10 | | Total N=117 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| Travel Time | 6:38 | 1:31 | 5:32 | 1:08 | 6:40 | 1:19 | 5:12 | 1:11 | 6:12 | 1:26 |
| Running Time | 4:11 | 0:50 | 3:35 | 0:35 | 4:10 | 0:41 | 3:35 | 0:30 | 3:57 | 0:45 |
| Signal Delay | 1:24 | 1:07 | 1:26 | 0:51 | 1:41 | 1:00 | 1:11 | 0:42 | 1:29 | 0:59 |
| Dwell Time | 0:49 | 0:53 | 0:23 | 0:19 | 0:38 | 0:31 | 0:19 | 0:16 | 0:36 | 0:38 |
| Merge Time | 0:14 | 0:13 | 0:08 | 0:13 | 0:11 | 0:10 | 0:07 | 0:11 | 0:11 | 0:12 |

**Table 2-10. Southbound - Segment III (in Minutes)**

| Time Measure | AM Peak N=38 | | Mid Peak N=35 | | PM Peak N=34 | | Off-Peak N=10 | | Total N=117 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| Travel Time | 7:29 | 0:59 | 8:06 | 1:03 | 9:14 | 1:27 | 8:13 | 1:10 | 8:14 | 1:21 |
| Running Time | 4:52 | 0:24 | 4:48 | 0:28 | 5:02 | 0:29 | 4:54 | 0:31 | 4:54 | 0:28 |
| Signal Delay | 1:34 | 0:47 | 2:07 | 0:48 | 2:57 | 0:48 | 1:42 | 0:24 | 2:80 | 0:57 |
| Dwell Time | 0:51 | 0:31 | 0:55 | 0:24 | 1:02 | 0:49 | 1:21 | 0:51 | 0:58 | 0:38 |
| Merge Time | 0:12 | 0:09 | 0:16 | 0:14 | 0:13 | 0:21 | 0:17 | 0:22 | 0:14 | 0:16 |

**Table 2-11. Southbound - Segment IV (in Minutes)**

| Time Measure | AM Peak N=38 | | Mid Peak N=35 | | PM Peak N=34 | | Off-Peak N=10 | | Total N=117 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| Travel Time | 9:29 | 1:41 | 10:17 | 1:43 | 9:59 | 1:34 | 9:35 | 1:02 | 9:53 | 1:38 |
| Running Time | 5:24 | 0:31 | 5:12 | 0:29 | 5:14 | 0:28 | 5:10 | 0:27 | 5:17 | 0:29 |
| Signal Delay | 2:28 | 1:18 | 2:42 | 1:08 | 2:47 | 0:56 | 2:37 | 0:47 | 2:38 | 1:60 |
| Dwell Time | 1:20 | 0:35 | 2:03 | 1:05 | 1:25 | 0:57 | 1:30 | 0:28 | 1:41 | 0:54 |
| Merge Time | 0:17 | 0:11 | 0:19 | 0:12 | 0:13 | 0:09 | 0:18 | 0:12 | 0:16 | 0:11 |

### 2.2.2 Part 2 – Summary Data by Intersections

The average signal delay and number of stops are used as valuable MOEs. The average signal delay measures the amount of time a bus spends in the queue at signalized intersections (from the time the bus comes to a complete stop to the time it clears the intersection). The number of times a bus is required to stop at intersections demonstrates the frequency of bus delay due to stopping at signalized intersections. It is hypothesized that reducing bus delay and number of stops at intersections will be a direct benefit of implementing TSP.

Tables 2-12 and 2-13 summarize the mean and standard deviation for buses' signal delays by time-of-day in the NB direction, while Tables 2-14 and 2-15 summarize signal delays by time-of-day in the SB direction. TSP-intersections were separated from non-TSP intersections to facilitate a before/after comparison between these intersections. Again, the project partners expect that TSP will reduce the signal delay means and standard deviations for the intersections where TSP is deployed.

Overall, it was found that most of the signal delay experienced by buses occurred at the intersections along Watt Avenue where TSP is planned for deployment (while only three-quarters of the Watt Avenue intersections are planned for TSP deployment, on average, 82% of the signal delay experienced at Watt Avenue intersections was attributed to these intersections). In addition, the intersections where the bus was required to make a left turn had a larger delay (e.g., northbound Watt Avenue/Arden Way and northbound Watt Avenue/Butano Drive), which was expected. Finally, with the exception of the intersection of Watt Avenue and Folsom Blvd (where the bus often missed several signal cycles while waiting for the light rail train to pass), intersection signal delays encountered in the northbound direction were slightly higher than those encountered in the southbound direction, which could indicate that the signal coordination on Watt Avenue might be optimized for the southbound direction.

It was also found that the standard deviation of the signal delay was large for many of the intersections (even larger than the average in many cases), which indicates that there is a lot of variance in the signal delay, and much room for improvement. The implication of this is that reductions in variance could potentially lead to improvements in schedule reliability as RT could adjust the schedule based on more reliable expected signal delay throughout the corridor.

Table 2-17 presents the average number of times that buses were stopped at red lights during each run. For example, during the AM peak, buses traveling in the SB direction encountered red lights 12 times on average. Looking at this from a different perspective, Table 2-16 shows the percentage of buses stopping at red lights for each intersection by time-of-day. For instance, 91 percent of the buses during the PM peak encountered a red light in the NB direction when making a left turn at Watt Avenue and Arden Way.

Table 2-18 summarizes the number of red-light running occurrences and the number of signal failure occurrences encountered by buses at each intersection as observed by the Evaluation Team while collecting data on-board the buses.

As mentioned earlier, this baseline information was analyzed to provide a basis for comparison with similar data that will be collected during the post-deployment period. Please note that the sample size for the off-peak runs was lower than the sample sizes for the other peaks. The Evaluation Team had originally planned to conduct data collection only during the peak periods, but later decided to collect additional data during the off-peak to determine the impact of TSP during off-peak periods.

**Table 2-12. Average and Standard Deviation for Signal Delay – TSP Intersections (Northbound)**

| Intersection Name | Average Signal Delay Northbound (in Seconds) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | TSP Intersections | | | | | | | | | |
| | AM Peak | | Mid Peak | | PM Peak | | Off-Peak | | Total | |
| | Avg | Std Dev | Avg | Std Dev | Avg | Std Dev | Avg | Std Dev | Avg | Std Dev |
| Watt Avenue & Fair Oaks Blvd. | 39 | 40 | 23 | 27 | 106 | 81 | 27 | 36 | 52 | 62 |
| Watt Avenue & Northrop Avenue | 1 | 5 | 1 | 3 | 8 | 15 | 6 | 10 | 4 | 10 |
| Watt Avenue & Hurley Way | 16 | 21 | 9 | 16 | 23 | 23 | 12 | 14 | 15 | 20 |
| Watt Avenue & Arden Way | 60 | 33 | 69 | 38 | 68 | 46 | 68 | 39 | 66 | 39 |
| Butano Drive & Watt Avenue | 64 | 42 | 68 | 44 | 57 | 39 | 59 | 38 | 63 | 41 |
| Watt Avenue & Country Club | 2 | 7 | 13 | 21 | 25 | 19 | 0 | 0 | 12 | 18 |
| Watt Avenue & El Camino Avenue | 13 | 32 | 13 | 22 | 23 | 25 | 9 | 25 | 16 | 27 |
| Watt Avenue & Kentfield Way | 3 | 8 | 10 | 16 | 6 | 13 | 8 | 14 | 6 | 13 |
| Watt Ave & Chenu/Kings Way | 16 | 21 | 13 | 21 | 25 | 24 | 17 | 12 | 18 | 22 |
| Watt Avenue & Marconi Avenue | 30 | 33 | 38 | 38 | 51 | 40 | 24 | 19 | 38 | 36 |
| Watt Avenue & Whitney Avenue | 6 | 12 | 15 | 22 | 18 | 24 | 5 | 16 | 12 | 20 |
| Watt Avenue & Edison Street | 27 | 25 | 26 | 22 | 42 | 36 | 19 | 15 | 30 | 28 |
| Watt Avenue & Auburn Blvd. | 52 | 34 | 52 | 36 | 58 | 41 | 43 | 31 | 53 | 36 |
| Watt Avenue & Longview Drive | 9 | 32 | 14 | 27 | 12 | 21 | 5 | 13 | 11 | 26 |
| Watt Avenue & I-80 Off-Ramp | 13 | 23 | 24 | 36 | 23 | 31 | 15 | 32 | 19 | 31 |

**Table 2-13. Average and Standard Deviation for Signal Delay – Non-TSP Intersections (Northbound)**

| Intersection Name | Average Signal Delay Northbound (in Seconds) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Non-TSP Intersections | | | | | | | | | |
| | AM Peak | | Mid Peak | | PM Peak | | Off-Peak | | Total | |
| | Avg | Std Dev | Avg | Std Dev | Avg | Std Dev | Avg | Std Dev | Avg | Std Dev |
| Station Road & Watt Avenue | 25 | 26 | 13 | 16 | 11 | 13 | 23 | 22 | 17 | 20 |
| Watt Avenue & Folsom Blvd. | 54 | 45 | 46 | 38 | 53 | 44 | 73 | 30 | 53 | 42 |
| Folsom Blvd. & Manlove Road | 5 | 11 | 5 | 11 | 7 | 12 | 0 | 0 | 5 | 11 |
| Folsom Blvd. & Starfire Street | 8 | 11 | 7 | 13 | 6 | 11 | 7 | 9 | 7 | 11 |
| Folsom Blvd. & La Riviera Drive | 34 | 27 | 29 | 24 | 107 | 369 | 16 | 12 | 52 | 198 |
| La Riviera Drive & Salmon Falls | 4 | 9 | 2 | 6 | 3 | 7 | 1 | 3 | 3 | 7 |
| La Riviera Drive & Watt Ave | 18 | 21 | 15 | 13 | 25 | 25 | 17 | 17 | 19 | 20 |
| Arden Way & Professional Street | 5 | 10 | 15 | 21 | 8 | 13 | 9 | 17 | 9 | 16 |
| Arden Way & Morse Avenue | 11 | 15 | 23 | 23 | 24 | 20 | 12 | 15 | 19 | 20 |
| Morse Avenue & Alta Arden | 21 | 22 | 24 | 21 | 51 | 27 | 16 | 17 | 30 | 26 |
| Morse Avenue & Ped. Crossing | 4 | 7 | 5 | 8 | 2 | 5 | 4 | 8 | 4 | 7 |
| Morse Avenue & Cottage Way | 8 | 7 | 7 | 7 | 8 | 10 | 3 | 3 | 7 | 8 |
| Watt Avenue & Ped. Crossing | 0 | 1 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 2 |
| Watt Avenue & Sierra View Lane | 4 | 11 | 0 | 2 | 5 | 23 | 0 | 0 | 3 | 14 |

**Table 2-14. Average and Standard Deviation for Signal Delay – TSP Intersections (Southbound)**

| Intersection Name | Average Signal Delay Southbound (in Seconds) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | TSP Intersections | | | | | | | | | |
| | AM Peak | | Mid Peak | | PM Peak | | Off-Peak | | Total | |
| | Avg | Std Dev | Avg | Std Dev | Avg | Std Dev | Avg | Std Dev | Avg | Std Dev |
| Watt Avenue & Fair Oaks Blvd. | 33 | 39 | 25 | 33 | 41 | 39 | 33 | 33 | 33 | 37 |
| Watt Avenue & Northrop Avenue | 5 | 11 | 11 | 15 | 16 | 19 | 15 | 15 | 11 | 15 |
| Watt Avenue & Hurley Way | 20 | 24 | 20 | 18 | 25 | 23 | 12 | 16 | 21 | 21 |
| Watt Avenue & Arden Way | 26 | 27 | 29 | 25 | 19 | 23 | 12 | 22 | 24 | 26 |
| Butano Drive & Watt Avenue | 15 | 18 | 12 | 19 | 12 | 21 | 17 | 18 | 13 | 19 |
| Watt Avenue & Country Club | 3 | 6 | 14 | 17 | 16 | 18 | 7 | 12 | 11 | 15 |
| Watt Avenue & El Camino Avenue | 19 | 30 | 30 | 35 | 15 | 30 | 19 | 23 | 21 | 31 |
| Watt Avenue & Kentfield Way | 1 | 4 | 3 | 10 | 2 | 6 | 2 | 5 | 2 | 7 |
| Watt Avenue & Chenu/Kings Way | 7 | 12 | 9 | 14 | 19 | 18 | 8 | 16 | 11 | 15 |
| Watt Avenue & Marconi Avenue | 34 | 31 | 26 | 31 | 23 | 25 | 43 | 45 | 29 | 31 |
| Watt Avenue & Whitney Avenue | 12 | 20 | 16 | 20 | 22 | 19 | 12 | 17 | 16 | 20 |
| Watt Avenue & Edison Street | 11 | 19 | 6 | 15 | 8 | 19 | 6 | 11 | 8 | 17 |
| Watt Avenue & Auburn Blvd. | 38 | 30 | 34 | 28 | 48 | 23 | 32 | 34 | 39 | 28 |
| Watt Avenue & Longview Drive | 7 | 18 | 7 | 15 | 5 | 16 | 11 | 16 | 7 | 16 |
| Watt Avenue & I-80 Off-Ramp | 14 | 24 | 15 | 17 | 7 | 15 | 15 | 24 | 12 | 20 |

**Table 2-15. Average and Standard Deviation for Signal Delay – Non-TSP Intersections (Southbound)**

| Intersection Name | Average Signal Delay Southbound (in Seconds) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Non-TSP Intersections | | | | | | | | | |
| | AM Peak | | Mid Peak | | PM Peak | | Off-Peak | | Total | |
| | Avg | Std Dev | Avg | Std Dev | Avg | Std Dev | Avg | Std Dev | Avg | Std Dev |
| Station Road & Watt Avenue | 48 | 39 | 30 | 20 | 43 | 32 | 18 | 20 | 39 | 32 |
| Watt Avenue & Folsom Blvd. | 139 | 113 | 92 | 64 | 136 | 89 | 93 | 90 | 120 | 93 |
| Folsom Blvd. & Manlove Road | 13 | 17 | 13 | 17 | 13 | 19 | 15 | 15 | 13 | 17 |
| Folsom Blvd. & Starfire Street | 9 | 13 | 4 | 7 | 7 | 12 | 6 | 7 | 7 | 11 |
| Folsom Blvd. & La Riviera Drive | 9 | 12 | 8 | 13 | 17 | 17 | 8 | 6 | 11 | 14 |
| La Riviera Drive & Salmon Falls | 4 | 9 | 3 | 7 | 3 | 7 | 1 | 3 | 3 | 7 |
| La Riviera Drive & Watt Avenue | 8 | 12 | 5 | 8 | 18 | 16 | 7 | 11 | 10 | 13 |
| Arden Way & Professional Street | 1 | 6 | 9 | 12 | 15 | 13 | 3 | 6 | 8 | 12 |
| Arden Way & Morse Avenue | 40 | 35 | 62 | 34 | 82 | 35 | 55 | 25 | 60 | 38 |
| Morse Avenue & Alta Arden | 21 | 17 | 16 | 15 | 44 | 30 | 18 | 18 | 26 | 24 |
| Morse Avenue & Ped. Crossing | 1 | 3 | 1 | 4 | 2 | 5 | 0 | 0 | 1 | 4 |
| Morse Avenue & Cottage Way | 16 | 14 | 27 | 21 | 21 | 21 | 10 | 11 | 20 | 19 |
| Watt Avenue & Ped. Crossing | 0 | 0 | 0 | 0 | 1 | 5 | 3 | 9 | 1 | 4 |
| Watt Avenue & Sierra View Lane | 0 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 3 |

**Table 2-16. Percentage of Buses Stopping at Red Lights**

| Intersection Name | Percentage of Stopping at Red Lights Northbound | | | | Percentage of Stopping at Red Lights Southbound | | | |
|---|---|---|---|---|---|---|---|---|
| | TSP Intersections | | | | | | | |
| | AM | Mid | PM | Off | AM | Mid | PM | Off |
| Watt Avenue & Fair Oaks Blvd. | 55 | 42 | 58 | 30 | 47 | 49 | 59 | 60 |
| Watt Avenue & Northrop Avenue | 8 | 3 | 18 | 10 | 11 | 34 | 35 | 30 |
| Watt Avenue & Hurley Way | 37 | 25 | 45 | 20 | 50 | 60 | 59 | 40 |
| Watt Avenue & Arden Way | 89 | 86 | 91 | 100 | 71 | 77 | 56 | 40 |
| Butano Drive & Watt Avenue | 87 | 89 | 85 | 80 | 58 | 34 | 29 | 60 |
| Watt Avenue & Country Club | 8 | 33 | 73 | 0 | 16 | 49 | 53 | 30 |
| Watt Avenue & El Camino Avenue | 21 | 28 | 58 | 10 | 32 | 46 | 21 | 40 |
| Watt Avenue & Kentfield Way | 16 | 31 | 18 | 30 | 5 | 9 | 9 | 0 |
| Watt Avenue & Chenu/Kings Way | 45 | 31 | 52 | 70 | 18 | 23 | 50 | 20 |
| Watt Avenue & Marconi Avenue | 50 | 53 | 67 | 70 | 55 | 46 | 50 | 60 |
| Watt Avenue & Whitney Avenue | 11 | 31 | 30 | 10 | 32 | 43 | 65 | 40 |
| Watt Avenue & Edison Street | 66 | 64 | 61 | 60 | 26 | 17 | 18 | 30 |
| Watt Avenue & Auburn Blvd. | 79 | 69 | 70 | 70 | 68 | 69 | 85 | 50 |
| Watt Avenue & Longview Drive | 16 | 25 | 15 | 0 | 18 | 17 | 12 | 30 |
| Watt Avenue & I-80 Off-Ramp | 24 | 31 | 39 | 30 | 37 | 49 | 18 | 30 |
| | Non-TSP Intersections | | | | | | | |
| Station Road & Watt Avenue | 66 | 64 | 61 | 80 | 92 | 80 | 82 | 70 |
| Watt Avenue & Folsom Blvd. | 71 | 78 | 73 | 100 | 100 | 89 | 88 | 80 |
| Folsom Blvd. & Manlove Road | 21 | 22 | 27 | 0 | 42 | 43 | 47 | 60 |
| Folsom Blvd. & Starfire Street | 42 | 36 | 39 | 30 | 39 | 29 | 32 | 40 |
| Folsom Blvd. & La Riviera | 87 | 89 | 91 | 80 | 42 | 51 | 71 | 70 |
| La Riviera Drive & Salmon Falls | 24 | 17 | 18 | 10 | 24 | 20 | 15 | 10 |
| La Riviera Drive & Watt Avenue Ramp | 63 | 64 | 61 | 90 | 39 | 26 | 68 | 30 |
| Arden Way & Professional Street | 16 | 31 | 27 | 10 | 11 | 34 | 65 | 20 |
| Arden Way & Morse Avenue | 39 | 58 | 76 | 30 | 84 | 91 | 97 | 90 |
| Morse Avenue & Alta Arden | 79 | 69 | 91 | 60 | 82 | 69 | 85 | 80 |
| Morse Avenue & Ped. Crossing | 32 | 22 | 12 | 20 | 5 | 6 | 12 | 0 |
| Morse Avenue & Cottage Way | 66 | 53 | 48 | 40 | 68 | 77 | 65 | 60 |
| Watt Avenue & Ped. Crossing | 0 | 0 | 6 | 0 | 0 | 0 | 9 | 10 |
| Watt Avenue & Sierra View Lane | 11 | 0 | 6 | 0 | 3 | 3 | 0 | 0 |

**Table 2-17. Average Number of Stops at Red Lights per Run**

| Time Measure | Average Number of Stops at Red Lights per Run | |
|---|---|---|
| | Northbound | Southbound |
| AM Peak | 12.26 | 11.76 |
| Midday Peak | 12.94 | 12.37 |
| PM Peak | 14.12 | 13.53 |
| Off-Peak* | 11.40 | 11.80 |
| Overall | 12.66 | 12.46 |

**Table 2-18. Number of Red Light Running and Signal Failure Occurrences**

| Intersection Name | Number of Red Light Running Occurrences | | Number of Signal Failure Occurrences | |
|---|---|---|---|---|
| | TSP Intersections | | | |
| | NB | SB | NB | SB |
| Watt Avenue & Fair Oaks Boulevard | 0 | 1 | 13 | 0 |
| Watt Avenue & Northrop Avenue | 0 | 0 | 0 | 0 |
| Watt Avenue & Hurley Way | 0 | 0 | 0 | 0 |
| Watt Avenue & Arden Way | 4 | 0 | 0 | 0 |
| Butano Drive & Watt Avenue | 1 | 0 | 2 | 0 |
| Watt Avenue & Country Club | 0 | 0 | 1 | 0 |
| Watt Avenue & El Camino Avenue | 1 | 2 | 0 | 0 |
| Watt Avenue & Kentfield Way | 0 | 0 | 0 | 0 |
| Watt Avenue & Chenu/Kings Way | 0 | 0 | 1 | 0 |
| Watt Avenue & Marconi Avenue | 0 | 0 | 1 | 1 |
| Watt Avenue & Whitney Avenue | 0 | 0 | 1 | 0 |
| Watt Avenue & Edison Street | 0 | 0 | 1 | 0 |
| Watt Avenue & Auburn Boulevard | 0 | 1 | 8 | 1 |
| Watt Avenue & Longview Drive | 0 | 0 | 0 | 0 |
| Watt Avenue & I-80 Off-ramp | 1 | 0 | 0 | 0 |
| | Non-TSP Intersections | | | |
| Station Road & Watt Avenue | 1 | 0 | 2 | 3 |
| Watt Avenue & Folsom Boulevard | 0 | 1 | 2 | 4 |
| Folsom Boulevard & Manlove Road | 0 | 1 | 1 | 1 |
| Folsom Boulevard & Starfire Street | 0 | 1 | 0 | 0 |
| Folsom Boulevard & La Riviera Drive | 1 | 1 | 0 | 0 |
| La Riviera Drive & Salmon Falls | 1 | 0 | 1 | 0 |
| La Riviera Drive & Watt Avenue On-Ramp | 5 | 0 | 5 | 0 |
| Arden Way & Professional Street | 0 | 0 | 0 | 0 |
| Arden Way & Morse Avenue | 0 | 1 | 0 | 0 |
| Morse Avenue & Alta Arden | 1 | 1 | 0 | 0 |
| Morse Avenue & Ped. Crossing | 0 | 0 | 0 | 0 |
| Morse Avenue & Cottage Way | 0 | 1 | 0 | 0 |
| Watt Avenue & Ped. Crossing | 0 | 0 | 0 | 0 |
| Watt Avenue & Sierra View Lane | 0 | 0 | 1 | 1 |

### 2.2.3 Part 3 – Summary Data at Bus Stops

In addition to the previous MOEs, ridership and payment methods data were also collected at each bus stop. Other information provided in this section might be helpful in determining why buses are delayed at some bus stops. Table 2-19 provides the average number of riders on-board the bus between bus stops. Tables 2-20 and 2-21 summarize the number of riders paying cash, the number of riders using a form of bus pass, the number of riders who needed wheelchair use, and the number of riders who used the bike rack. It should be noted that RT's buses have a maximum capacity of 60 passengers, with 40 seated and 20 standing.

Again, this baseline information was analyzed to provide a basis for comparison with similar data that will be collected during the post-deployment period.

**Table 2-19. Average Number of Transit Riders Onboard**

| Northbound | | Southbound | |
|---|---|---|---|
| Bus Stop Number | Average Number of Riders Onboard | Bus Stop Number | Average Number of Riders Onboard |
| 1NB | 6 | 1SB | 12 |
| 2NB | 6 | 2SB | 12 |
| 3NB | 7 | 3SB | 13 |
| 4NB | 8 | 4SB | 13 |
| 5NB | 8 | 5SB | 13 |
| 6NB | 8 | 6SB | 12 |
| 7NB | 8 | 7SB | 12 |
| 8NB | 8 | 8SB | 11 |
| 9NB | 8 | 9SB | 11 |
| 10NB | 8 | 10SB | 11 |
| 11NB | 8 | 11SB | 11 |
| 12NB | 8 | 12SB | 10 |
| 13NB | 8 | 13SB | 10 |
| 14NB | 8 | 14SB | 10 |
| 15NB | 8 | 15SB | 10 |
| 16NB | 8 | 16SB | 10 |
| 17NB | 8 | 17SB | 9 |
| 18NB | 8 | 18SB | 9 |
| 19NB | 9 | 19SB | 9 |
| 20NB | 9 | 20SB | 9 |
| 21NB | 9 | 21SB | 9 |
| 22NB | 9 | 22SB | 9 |

| Northbound | | Southbound | |
|---|---|---|---|
| Bus Stop Number | Average Number of Riders Onboard | Bus Stop Number | Average Number of Riders Onboard |
| 23NB | 9 | 23SB | 9 |
| 24NB | 9 | 24SB | 9 |
| 25NB | 9 | 25SB | 9 |
| 26NB | 9 | 26SB | 10 |
| 27NB | 9 | 27SB | 10 |
| 28NB | 9 | 28SB | 10 |
| 29NB | 10 | 29SB | 10 |
| 30NB | 10 | 30SB | 10 |
| 31NB | 12 | 31SB | 10 |
| 32NB | 12 | 32SB | 10 |
| 33NB | 11 | 33SB | 10 |
| 34NB | 12 | 34SB | 10 |
| 35NB | 12 | 35SB | 5 |
| 36NB | 12 | 36SB | 5 |
| Average | 8.9 | Average | 10.1 |

**Table 2-20. Ridership and Method of Payment Summary (Northbound)**

| Bus Stop Number | Number of Riders Paying Cash | Number of Riders Using Pass | Number of Riders Getting Off | Number of Times Wheelchairs On/Off | Number of Times Bikes On/Off |
|---|---|---|---|---|---|
| 1NB | 12 | 64 | 2 | 0 | 1 |
| 2NB | 5 | 17 | 13 | 0 | 0 |
| 3NB | 13 | 105 | 6 | 1 | 0 |
| 4NB | 32 | 41 | 20 | 0 | 2 |
| 5NB | 8 | 13 | 4 | 0 | 0 |
| 6NB | 0 | 2 | 6 | 0 | 0 |
| 7NB | 3 | 20 | 9 | 0 | 0 |
| 8NB | 4 | 21 | 19 | 0 | 0 |
| 9NB | 3 | 3 | 25 | 0 | 0 |
| 10NB | 3 | 2 | 35 | 0 | 0 |
| 11NB | 23 | 18 | 61 | 2 | 0 |
| 12NB | 14 | 42 | 33 | 0 | 2 |

| Bus Stop Number | Number of Riders Paying Cash | Number of Riders Using Pass | Number of Riders Getting Off | Number of Times Wheelchairs On/Off | Number of Times Bikes On/Off |
|---|---|---|---|---|---|
| 13NB | 10 | 14 | 13 | 0 | 0 |
| 14NB | 1 | 22 | 5 | 0 | 0 |
| 15NB | 22 | 19 | 15 | 1 | 1 |
| 16NB | 0 | 3 | 10 | 0 | 1 |
| 17NB | 23 | 75 | 89 | 0 | 1 |
| 18NB | 20 | 38 | 29 | 0 | 0 |
| 19NB | 35 | 52 | 43 | 3 | 0 |
| 20NB | 0 | 6 | 15 | 0 | 0 |
| 21NB | 4 | 8 | 28 | 1 | 1 |
| 22NB | 14 | 80 | 52 | 7 | 2 |
| 23NB | 17 | 46 | 24 | 3 | 0 |
| 24NB | 1 | 2 | 1 | 1 | 0 |
| 25NB | 6 | 10 | 15 | 1 | 0 |
| 26NB | 2 | 22 | 25 | 0 | 0 |
| 27NB | 6 | 13 | 39 | 1 | 0 |
| 28NB | 18 | 72 | 68 | 1 | 1 |
| 29NB | 57 | 229 | 229 | 6 | 3 |
| 30NB | 22 | 51 | 31 | 0 | 0 |
| 31NB | 66 | 225 | 141 | 9 | 0 |
| 32NB | 0 | 2 | 1 | 0 | 0 |
| 33NB | 3 | 9 | 15 | 0 | 0 |
| 34NB | 41 | 110 | 78 | 2 | 1 |
| 35NB | 26 | 96 | 191 | 3 | 3 |
| 36NB | 11 | 18 | 32 | 0 | 1 |
| 37NB | 0 | 4 | 21 | 0 | 0 |
| Average | 14.2 | 42.5 | 39.0 | 1.1 | 0.5 |

**Table 2-21. Ridership and Method of Payment Summary (Southbound)**

| Bus Stop Number | Number of Riders Paying Cash | Number of Riders Using Pass | Number of Riders Getting Off | Number of Times Wheelchairs On/Off | Number of Times Bikes On/Off |
|---|---|---|---|---|---|
| 1SB | 2 | 10 | 0 | 0 | 1 |
| 2SB | 17 | 88 | 58 | 2 | 8 |
| 3SB | 54 | 110 | 126 | 1 | 0 |
| 4SB | 46 | 67 | 103 | 0 | 0 |
| 5SB | 5 | 14 | 22 | 0 | 0 |
| 6SB | 54 | 153 | 276 | 5 | 0 |
| 7SB | 2 | 30 | 93 | 0 | 1 |
| 8SB | 22 | 243 | 346 | 6 | 1 |
| 9SB | 18 | 42 | 78 | 1 | 0 |
| 10SB | 6 | 26 | 60 | 1 | 0 |
| 11SB | 0 | 5 | 17 | 0 | 0 |
| 12SB | 0 | 0 | 9 | 0 | 0 |
| 13SB | 27 | 70 | 158 | 2 | 1 |
| 14SB | 5 | 34 | 12 | 0 | 0 |
| 15SB | 7 | 10 | 11 | 0 | 0 |
| 16SB | 6 | 44 | 101 | 0 | 2 |
| 17SB | 7 | 39 | 103 | 2 | 0 |
| 18SB | 13 | 58 | 91 | 0 | 1 |
| 19SB | 1 | 8 | 13 | 0 | 0 |
| 20SB | 0 | 19 | 24 | 0 | 0 |
| 21SB | 19 | 9 | 38 | 2 | 0 |
| 22SB | 0 | 5 | 6 | 0 | 0 |
| 23SB | 4 | 26 | 18 | 0 | 0 |
| 24SB | 19 | 21 | 65 | 1 | 2 |
| 25SB | 1 | 3 | 1 | 0 | 0 |
| 26SB | 27 | 114 | 39 | 0 | 1 |
| 27SB | 12 | 37 | 14 | 0 | 0 |
| 28SB | 4 | 28 | 6 | 4 | 0 |
| 29SB | 1 | 21 | 13 | 0 | 0 |
| 30SB | 9 | 21 | 27 | 0 | 0 |
| 31SB | 1 | 2 | 10 | 0 | 0 |
| 32SB | 0 | 2 | 41 | 0 | 1 |
| 33SB | 6 | 13 | 23 | 0 | 0 |

| Bus Stop Number | Number of Riders Paying Cash | Number of Riders Using Pass | Number of Riders Getting Off | Number of Times Wheelchairs On/Off | Number of Times Bikes On/Off |
|---|---|---|---|---|---|
| 34SB | 0 | 3 | 17 | 0 | 0 |
| 35SB | 5 | 16 | 568 | 2 | 0 |
| 36SB | 1 | 8 | 25 | 1 | 0 |
| 37SB | 0 | 6 | 220 | 0 | 6 |
| Average | 10.8 | 38.0 | 76.5 | 0.8 | 0.7 |

# 3. TRAFFIC MOBILITY AND EFFICIENCY

For the traffic mobility and efficiency portion of the evaluation, it was hypothesized that improvements in transit mobility and travel time reliability will translate into increased transit mode share, which will lead to an overall reduction in the use of single-occupancy automobiles. Consequently, this will result in reductions in overall vehicle delay and travel times throughout the corridor. Other aspects of the project are also expected to impact the overall performance of the corridor. For example, it was hypothesized that providing additional green time to the mainline as a result of TSP will lead to an overall improvement in arterial traffic conditions on the mainline, but may negatively affect the performance of cross-streets. It will therefore be important to document baseline traffic conditions for non-transit vehicles in the study area to provide a basis for comparison with data collected during the post-deployment period. This will allow the Evaluation Team to determine how arterial traffic on the mainline and cross-streets were impacted.

This section is organized as follows:

- 3.1 Data Collection Approach
- 3.2 Findings from Baseline Data Collection

## 3.1 DATA COLLECTION APPROACH

The goal of this study is to collect data to assess the overall traffic performance of Watt Avenue and its cross-streets during peak periods. These data will serve as the baseline data collected prior to deployment (with the bus priority system inactive or TSP off). These data will later be compared with data collected after the bus priority system is activated and, potentially, after the arterial management and traveler information systems have been added. It is still unclear when these components will be added. The data collected will allow the Evaluation Team to assess the baseline performance of the arterial and provide additional data to help control for traffic pattern changes over time. The following section provides details on the format, assumptions, and collection methods used in gathering non-transit data to evaluate the performance of the deployed TSP components along Watt Avenue.

### 3.1.1 Data Elements Collected

- Arterial and cross-street passenger car travel times using floating vehicles equipped with GPS loggers.
- Non-transit average vehicle occupancy (AVO).
- Intersection signal timings.
- Traffic volumes from Watt Avenue/cross-street loop detectors/hose counts.

**Data Collection Notes:**

- Traffic data were collected from March 9 to March 14, 2003, and on March 20, 2003. Data were collected during the AM (7:00am-9:00am), mid-day (11:00am-1:00pm), and PM (4:00pm-6:00pm) peak periods.
- Passenger car travel times were collected using the GPS-based GeoLogger™ devices mounted on Evaluation Team vehicles, and using software developed by Sacramento County. Data were collected on Watt Avenue between Arden Way and Auburn Boulevard, and on Watt Avenue's five cross-streets (Arden Way, El Camino Avenue, Marconi Avenue, Edison Avenue, and Auburn Boulevard).
- Region-wide non-transit AVO data were obtained from the latest SACOG travel model.
- Main arterial traffic volume data were collected from loop detectors on Watt Avenue northbound and southbound, between Arden Way and Auburn Boulevard.
- Cross-street traffic volumes were obtained from loop detectors at Arden Way, El Camino Avenue, Marconi Avenue, Edison Avenue, or Auburn Boulevard approaching Watt Avenue.
- GPS data were collected in five-second intervals, with traffic volume data aggregated into 15-minute periods.
- The collected data were summarized in Microsoft® Access or Microsoft® Excel format.

### 3.1.2 Travel Time Data Collection Methodology

As mentioned in the previous section, travel time data were collected using floating cars fitted with GPS-based loggers. As shown in Figure 3-1, the GPS-logger is a small device that requires no human interaction during the drive other than to alert the user when the battery is low or the memory is full. Two vehicles were used during the study: one traveling on Watt Avenue northbound and southbound, and one traveling on a 'serpentine' route covering five of Watt Avenue's cross-streets. Figures 3-2 and 3-3 show the vehicle routes as recorded by the GPS loggers. In the interest of gathering enough data to provide a statistically significant sample size, the Evaluation Team decided to limit the boundaries of the travel time runs in order to conduct more runs. The Evaluation Team decided to concentrate data collection on the northern portion of the project area, between Arden Way and Auburn Boulevard. This portion was chosen as it includes 10 of the 15 intersections where TSP will be deployed, and it is therefore expected that greater impact will be observed in these sections of the study area. Therefore, the travel time runs did not include Segment I, and only included Segment II as far as the intersection of Arden Way and Watt Avenue. The Watt Avenue project segments included in this study area are as follows:

- Segment II – Arden Way intersection only (throughput analysis).

- Segment III – Alta Arden Way to Butano Drive.
- Segment IV – Country Club Center to Auburn Boulevard.


**Figure 3-1. A GPS-Based Logger.**

The “serpentine” route was a continuous route used to maximize the amount of cross-street data collected. As shown in Figure 3-3, it minimized the number of U-turn maneuvers. The two streets parallel to Watt Avenue that were used to complete the route were Eastern Avenue and Fulton Avenue. Later, during the post-processing of the data, entries from these streets were discarded, leaving the Evaluation Team with only the cross street data.

The data from the GPS loggers contained the following identifiers:

- GPS coordinates (longitude/latitude)
- Heading
- Date (Greenwich Mean Time - GMT)
- Time (GMT)
- Point speed

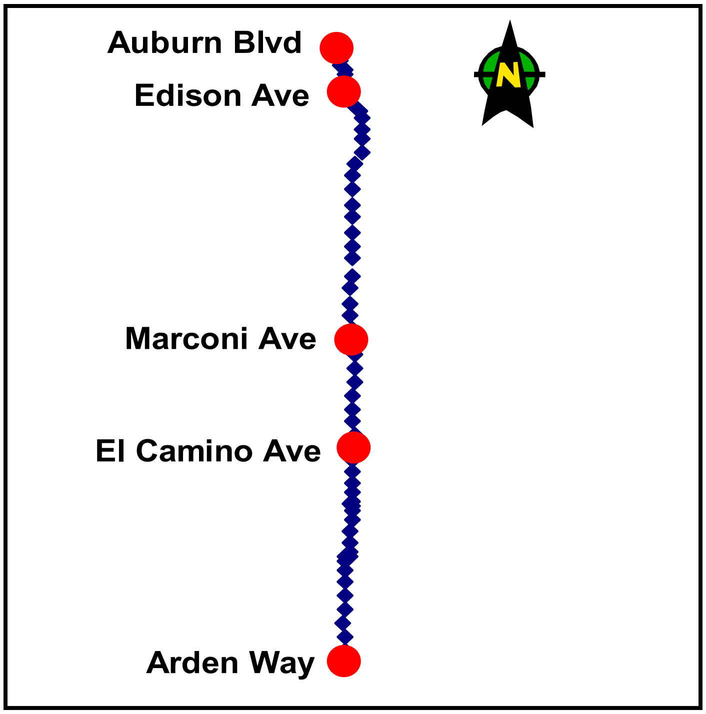



**Figure 3-2. Watt Avenue Route.**

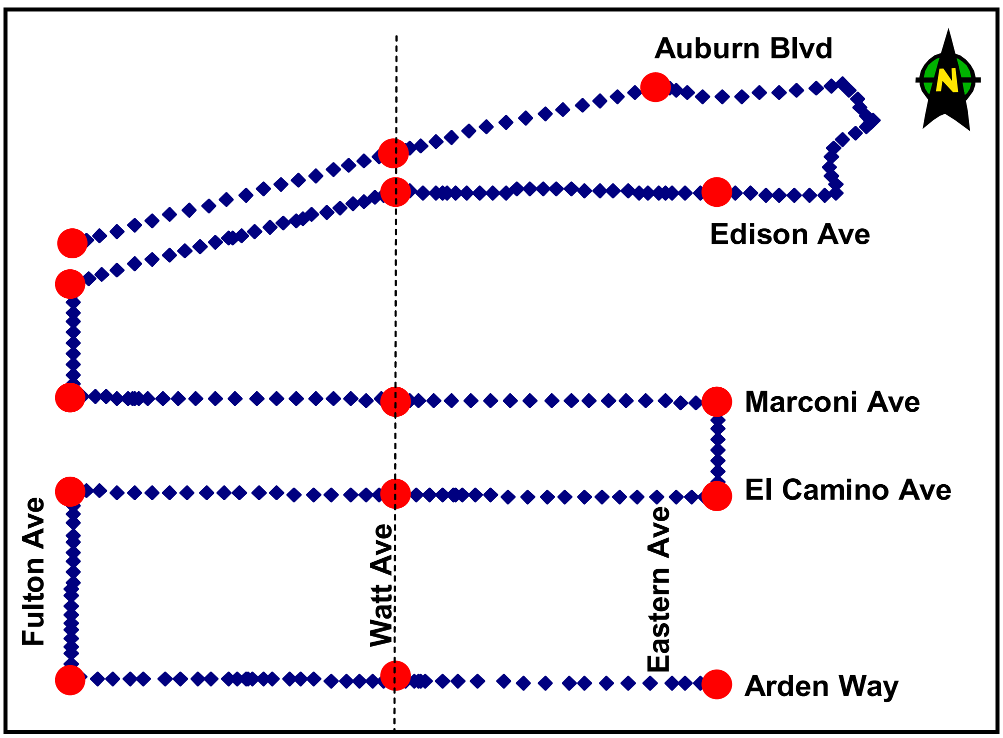



**Figure 3-3. Cross Street "Serpentine" Route.**

Point speed data were not used for analysis, since they cannot accurately represent the total travel time between the pre-set boundaries of the study area. Therefore, the evaluation derived the travel time from the recorded timestamps at the beginning and end of each run. The typical traffic patterns on Watt Avenue are shown on the speed profile and time-space diagram in Figures 3-4 and 3-5.

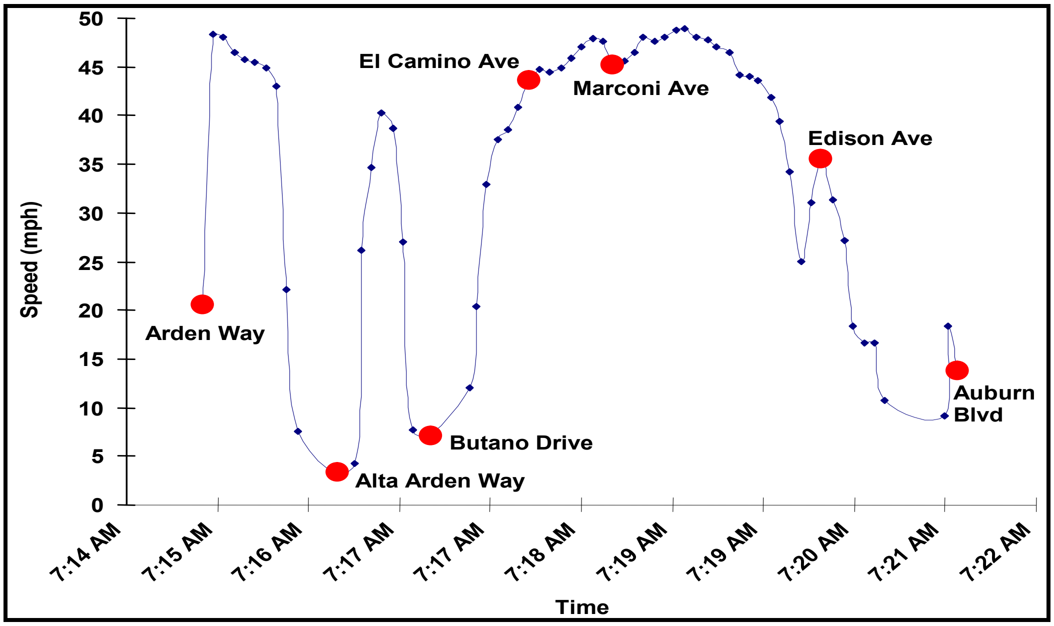



**Figure 3-4. Typical Watt Avenue Northbound Speed Profile.**

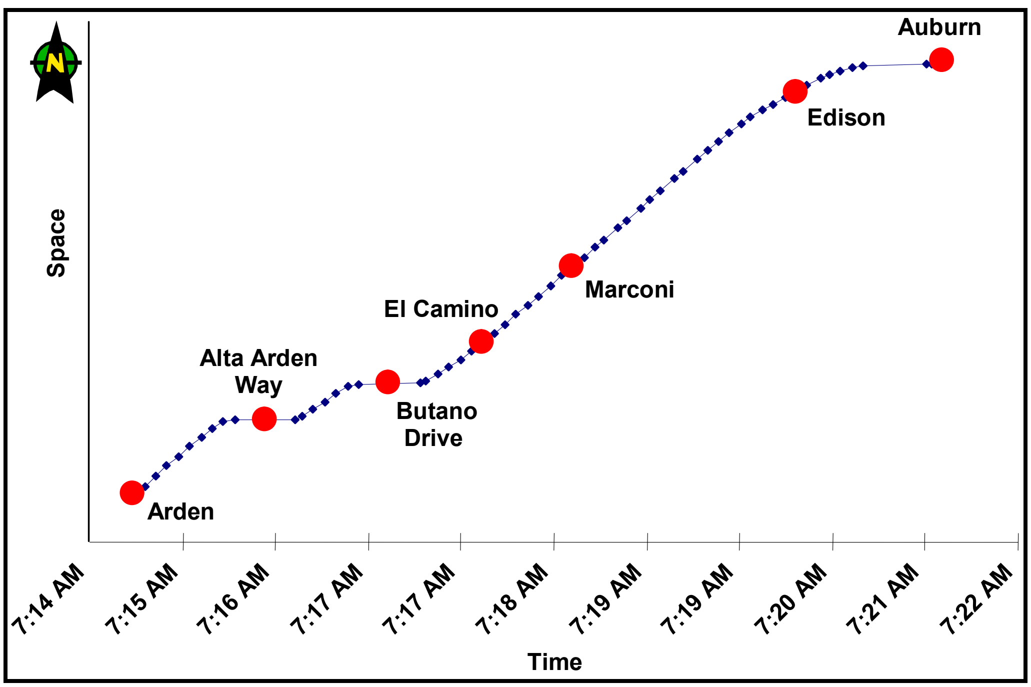



**Figure 3-5. Typical Watt Avenue Northbound Time-Space Diagram.**

The Evaluation Team collected additional travel time data that captured traffic signal and signal delays on six of the 15 peak periods (AM, PM, and mid-day peak periods collected for five consecutive days), using custom software developed by Sacramento County. Sacramento County personnel accompanied the Evaluation Team in one of the floating vehicles and operated the software using a laptop computer. While this is outside the scope of the original data collection plans, the data collected may prove useful in analyzing the impacts of TSP since it provides additional detail. Table 3-1 summarizes the sample size of traffic data collected using both the GPS logger and the Sacramento County software (e.g., In the northbound direction on Watt Avenue in the AM peak period, 29 data sets were collected with the GPS logger, and five data sets were collected using the Sacramento County software).

**Table 3-1. Summary of Data Collection Sample Size**

| Corridor/Direction | AM | MD | PM |
|---|---|---|---|
| **Watt Avenue** | | | |
| NB | 29 (5) | 29 (6) | 22 (2) |
| SB | 33 (6) | 30 (7) | 24 (4) |
| **Arden Way** | | | |
| EB | 3 (1) | 5 (1) | 5 (1) |
| WB | 3 (2) | 5 (3) | 6 (3) |
| **El Camino Avenue** | | | |
| EB | 9 (3) | 10 (4) | 11 (3) |
| WB | 8 (1) | 9 (1) | 8 (1) |
| **Marconi Avenue** | | | |
| EB | 8 (1) | 9 (1) | 8 (1) |
| WB | 8 (3) | 10 (4) | 7 (2) |
| **Edison Avenue** | | | |
| EB | 8 (4) | 10 (4) | 7 (2) |
| WB | 8 (1) | 9 (1) | 8 (1) |
| **Auburn Boulevard** | | | |
| EB | 5 (1) | 5 (1) | 5 (1) |
| WB | 3 (2) | 4 (2) | 5 (1) |

Note: xx = Sample size from the GPS loggers
(xx) = Sample size from the Sacramento County software

## 3.2 FINDINGS FROM BASELINE DATA COLLECTION

### 3.2.1 Non-Transit Traffic Performance

A summary of the non-transit traffic performance on Watt Avenue is presented in the following tables. Table 3-2 summarizes the travel time data, while Table 3-3 presents the speed summary. Additionally, Table 3-4 presents the average travel time delay attributed to the traffic signals (for the Watt Avenue corridor, it is the average of total signal delays within each project segment, while for the Watt Avenue cross-streets it is the signal delay at Watt Avenue).

**Table 3-2. Summary of Non-Transit Travel Time Performance (in Minutes)**

| Corridor/ Direction | AM | | MD | | PM | |
|---|---|---|---|---|---|---|
| | Average | Std Dev | Average | Std Dev | Average | Std Dev |
| **Watt Avenue – Segment III (Alta Arden Way – Butano Drive)** | | | | | | |
| NB | 1:14 | +/-0:29 | 1:46 | +/-0:50 | 1:32 | +/-0:49 |
| SB | 1:30 | +/-0:20 | 1:21 | +/-0:20 | 1:25 | +/-0:18 |
| **Watt Avenue – Segment IV (Country Club Center – Auburn Blvd.)** | | | | | | |
| NB | 5:48 | +/- 2:15 | 6:15 | +/- 1:17 | 6:11 | +/- 1:38 |
| SB | 5:03 | +/- 1:45 | 4:52 | +/- 1:44 | 4:18 | +/- 1:00 |
| **Arden Way (Eastern Ave to Fulton Ave)** | | | | | | |
| EB | 6:37 | +/- 1:38 | 4:46 | +/- 0:21 | 6:06 | +/- 0:41 |
| WB | 5:00 | +/- 1:11 | 5:29 | +/- 0:58 | 5:02 | +/- 0:59 |
| **El Camino Avenue (Eastern Ave to Fulton Ave)** | | | | | | |
| EB | 4:49 | +/- 0:46 | 4:52 | +/- 0:51 | 6:14 | +/- 1:34 |
| WB | 5:34 | +/- 0:24 | 5:53 | +/- 1:07 | 6:00 | +/- 1:01 |
| **Marconi Avenue (Eastern Ave to Fulton Ave)** | | | | | | |
| EB | 4:26 | +/- 1:02 | 4:56 | +/- 0:45 | 6:23 | +/- 0:52 |
| WB | 5:37 | +/- 1:40 | 5:9 | +/- 0:50 | 4:43 | +/- 0:57 |
| **Edison Avenue (Eastern Ave to Fulton Ave)** | | | | | | |
| EB | 6:45 | +/- 1:50 | 5:23 | +/- 0:34 | 6:00 | +/- 0:51 |
| WB | 6:16 | +/- 1:26 | 6:01 | +/- 0:52 | 6:04 | +/- 0:51 |
| **Auburn Blvd. (Eastern Ave to Fulton Ave)** | | | | | | |
| EB | 3:41 | +/- 0:52 | 4:09 | +/- 0:43 | 8:08 | +/- 3:00 |
| WB | 6:24 | +/- 2:03 | 5:04 | +/- 0:38 | 4:29 | +/- 0:38 |

Note: AM = morning peak, from 7:00am to 9:00am;

MD = mid-day, from 11:00am to 1:00pm; and

PM = afternoon peak, from 4:00pm to 6:00pm.

**Table 3-3. Summary of Non-Transit Speed Performance (in mph)**

| Corridor/ Direction | AM | | MD | | PM | |
|---|---|---|---|---|---|---|
| | Average | Std Dev | Average | Std Dev | Average | Std Dev |
| **Watt Avenue – Segment III (Alta Arden Way – Butano Drive)** | | | | | | |
| NB | 31.2 | +/- 11.8 | 23.1 | +/- 10.7 | 26.7 | +/- 12.2 |
| SB | 23.0 | +/- 5.1 | 25.7 | +/- 5.8 | 24.5 | +/- 5.2 |
| **Watt Avenue – Segment IV (Country Club Center – Auburn Blvd.)** | | | | | | |
| NB | 23.4 | +/- 8.1 | 20.0 | +/- 4.4 | 20.9 | +/- 6.3 |
| SB | 26.1 | +/- 7.3 | 26.8 | +/- 6.7 | 28.9 | +/- 4.5 |
| **Arden Way (Eastern Ave to Fulton Ave)** | | | | | | |
| EB | 18.9 | +/- 4.6 | 25.3 | +/- 1.8 | 19.8 | +/- 2.0 |
| WB | 24.9 | +/- 5.8 | 22.4 | +/- 3.6 | 24.6 | +/- 4.8 |
| **El Camino Avenue (Eastern Ave to Fulton Ave)** | | | | | | |
| EB | 25.6 | +/- 5.1 | 25.3 | +/- 4.3 | 20.2 | +/- 4.5 |
| WB | 21.6 | +/- 1.5 | 21.1 | +/- 4.4 | 20.5 | +/- 3.8 |
| **Marconi Avenue (Eastern Ave to Fulton Ave)** | | | | | | |
| EB | 28.4 | +/- 6.6 | 24.8 | +/- 3.7 | 19.1 | +/- 2.7 |
| WB | 22.7 | +/- 5.3 | 23.8 | +/- 3.7 | 26.3 | +/- 4.9 |
| **Edison Avenue (Eastern Ave to Fulton Ave)** | | | | | | |
| EB | 19.9 | +/- 4.1 | 24.0 | +/- 2.7 | 21.7 | +/- 3.4 |
| WB | 21.2 | +/- 4.2 | 21.7 | +/- 3.4 | 21.4 | +/- 3.1 |
| **Auburn Blvd. (Eastern Ave to Fulton Ave)** | | | | | | |
| EB | 33.9 | +/- 6.8 | 29.7 | +/- 5.7 | 16.9 | +/- 7.5 |
| WB | 20.3 | +/- 7.6 | 24.0 | +/- 3.1 | 27.2 | +/- 3.8 |

**Table 3-4. Summary of Traffic Signal Delays (in Minutes)**

| Corridor/Direction | AM | MD | PM |
|---|---|---|---|
| **Watt Avenue Segment III (Alta Arden – Butano Drive)** | | | |
| **NB** | 0:41 | 1:04 | 2:18 |
| **SB** | 0:59 | 1:05 | 1:04 |
| **Watt Avenue Segment IV (Country Club – Auburn Blvd)** | | | |
| **NB** | 2:09 | 2:11 | 4:11 |
| **SB** | 2:01 | 1:38 | 2:00 |
| **Arden Way (at Watt Ave)** | | | |
| **EB** | 1:34 | 1:14 | 0:45 |
| **WB** | 0:52 | 0:53 | 1:37 |
| **El Camino Avenue (at Watt Ave)** | | | |
| **EB** | 0:44 | 0:43 | 1:56 |
| **WB** | 1:07 | * | * |
| **Marconi Avenue (at Watt Ave)** | | | |
| **EB** | 0:57 | 0:19 | 0:59 |
| **WB** | 2:19 | 0:38 | 0:40 |
| **Edison Avenue (at Watt Ave)** | | | |
| **EB** | 1:35 | 1:25 | 1:06 |
| **WB** | 0:39 | 1:39 | * |
| **Auburn Blvd. (at Watt Ave)** | | | |
| **EB** | * | * | 3:56 |
| **WB** | 1:20 | 0:41 | 0:32 |

*Not large enough sample size to present conclusive results.

Initially, the GPS data were categorized by the following characteristics:

- Peak period (AM, Mid-Day, and PM)
- Route
- Direction
- Day of week (Monday/Friday vs. Tuesday-Thursday)

The Evaluation Team initially expected that traffic patterns might vary by day of week (Monday/Friday versus Tuesday/Wednesday/Thursday). However, after comparing the travel time and speed data in both categories, the Evaluation Team found no statistically significant differences in traffic performance. Therefore, all data were grouped together for the purposes of this study, regardless of the day of week. Figure 3-6 illustrates the result of the day of the week comparison for traversing across all segments of Watt Avenue. Similarly, traffic patterns on the cross-streets were approximately the same on all days.

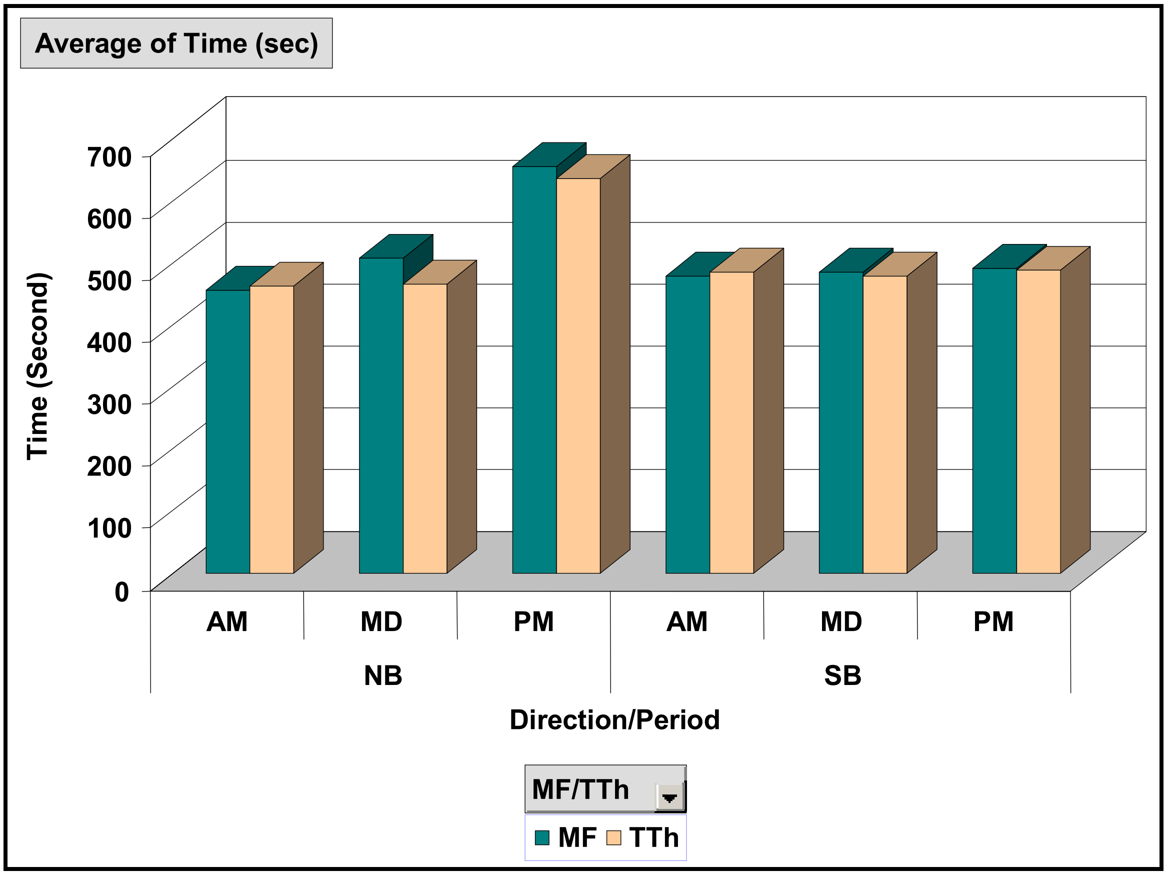



**Figure 3-6. Watt Avenue Day-of-Week Travel Time Comparison.**

Figures 3-7 and 3-8 show the average travel time and speed on Watt Avenue's Segments III and IV. Segment III, which runs between Alta Arden Way and Butano Drive (a half-mile segment) appeared heaviest during the mid-day and PM peaks in the northbound direction, averaging about 1.5 minutes. Segment III is less congested during the AM peak period, perhaps since the majority of the stores in this commercial district are still closed during this time period. Overall, the northbound direction experienced heavier congestion compared to the southbound direction.

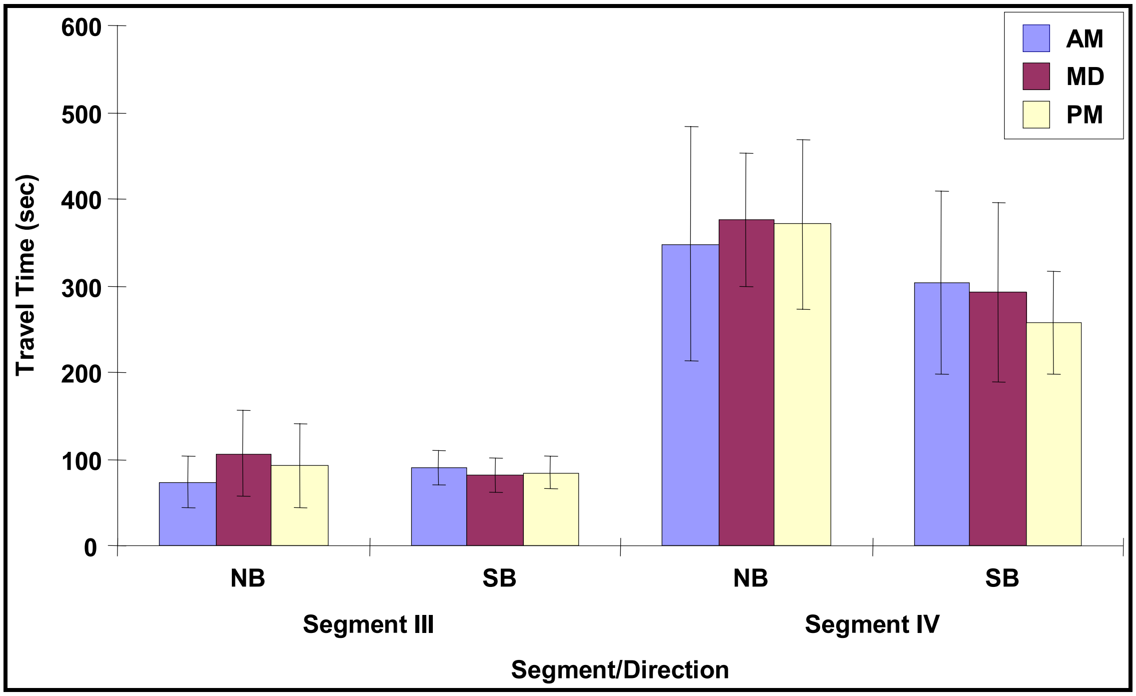



**Figure 3-7. Watt Avenue Travel Time Summary (With Standard Deviations Indicated).**

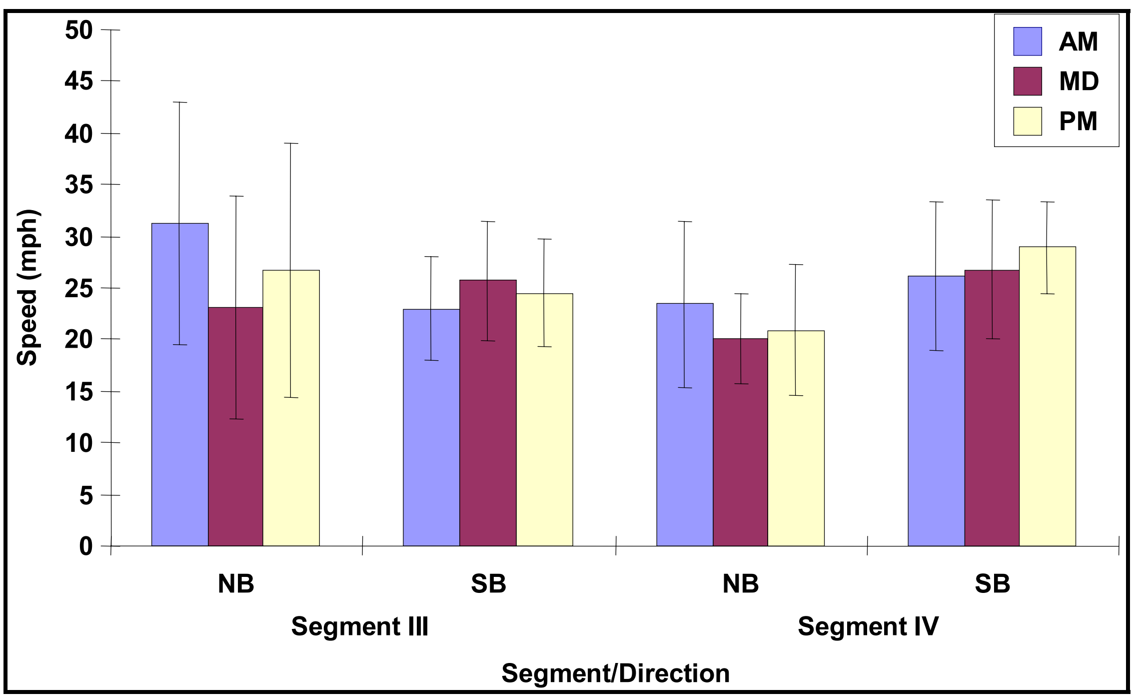



**Figure 3-8. Watt Avenue Speed Summary (With Standard Deviations Indicated).**

Segment IV, running from Country Club Center to Auburn Boulevard is about two miles long, running through the more residential areas of Watt Avenue. Unlike Segment III, average travel times in this segment do not vary much by time of day (approximately six minutes for the northbound direction and 4.5 minutes for the southbound direction).

The reliability of travel time and speed are represented by the upper and lower tick marks on each bar. They indicate travel time and speed at *one standard deviation* above and below the average, respectively. In both segments, Watt Avenue northbound is slightly less reliable compared to the southbound direction, suggesting that the signal coordination on Watt Avenue might be optimized for the southbound direction.

Commuters on Watt Avenue may travel as fast as 50 mph at times, although the corridor has a 40 mph speed limit. However, taking into account the stops at signalized intersections, the average speed on Watt Avenue is about 25 mph.

Figure 3-9 and Figure 3-10 illustrate the travel time and speed summary on Watt Avenue's cross-streets. Traffic patterns on the cross-streets remained relatively static throughout the day, except for Auburn Boulevard eastbound during the PM peak, where additional delays and travel time unreliability were incurred from the heavy traffic movements from a nearby I-80 Business Loop off-ramp, often doubling the typical travel time (from an average of four minutes to about eight minutes during AM and mid-day peaks). The same is true of Auburn Boulevard westbound during the AM peak, where freeway on-ramp queues often spilled over to Auburn Boulevard and beyond.

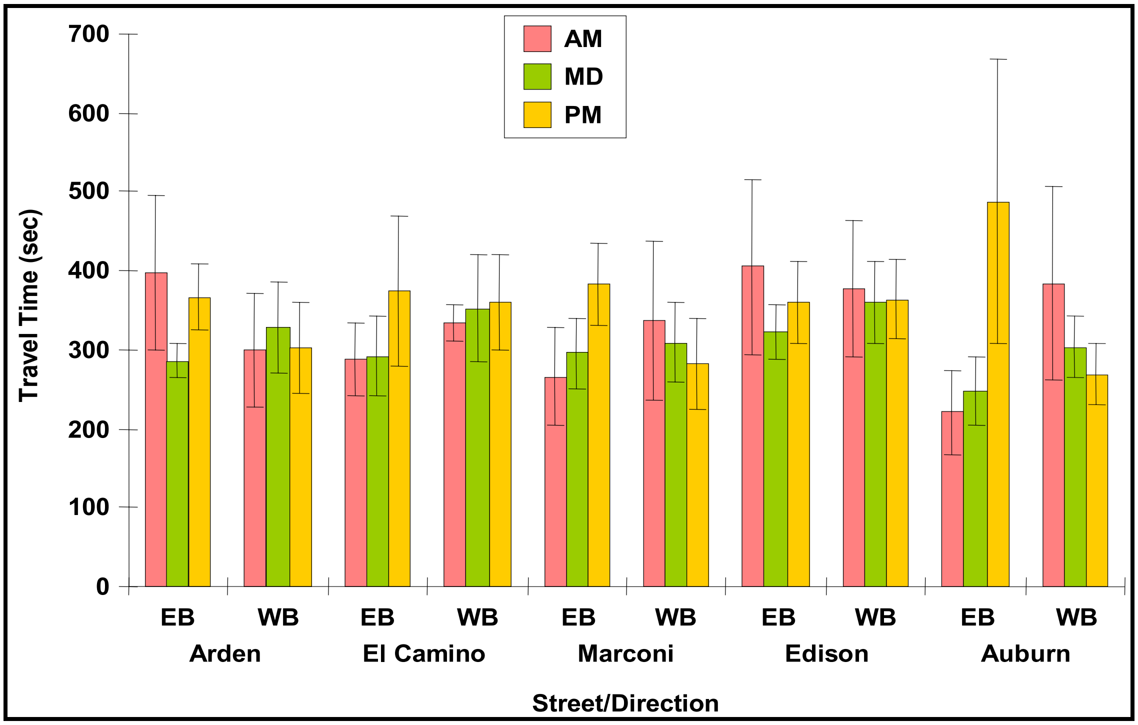



**Figure 3-9. Cross Street Travel Time Summary (With Standard Deviations Indicated).**

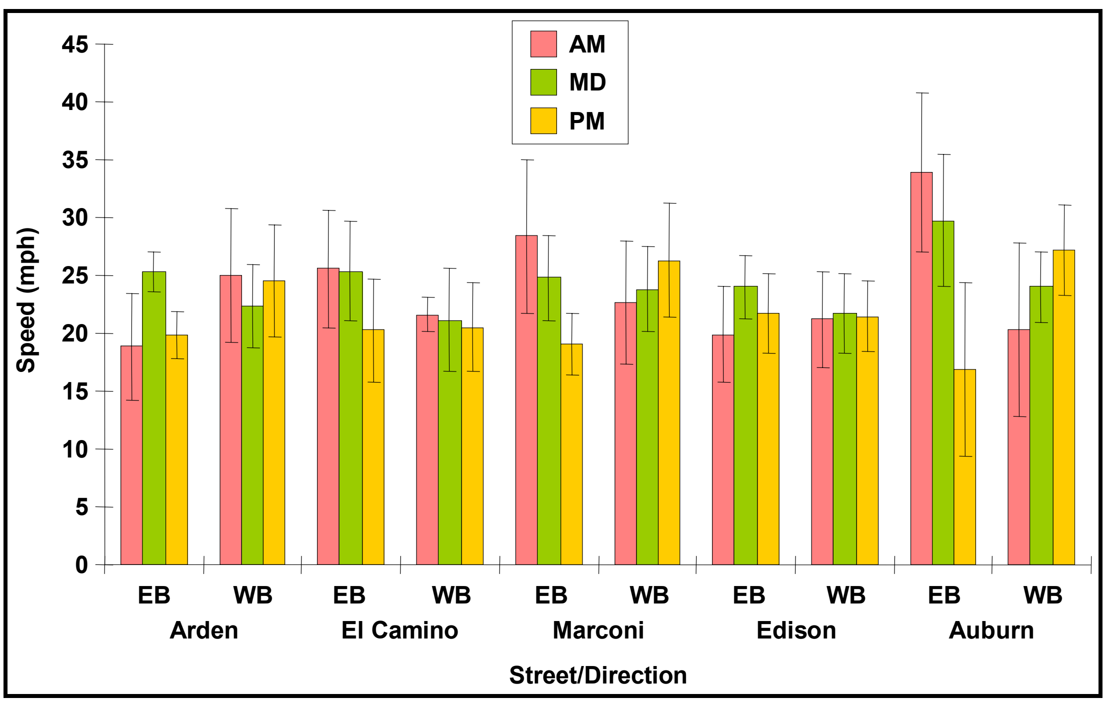



**Figure 3-10. Cross Street Speed Summary (With Standard Deviations Indicated).**

Also, the schools located on Edison Avenue were attracting substantial traffic during the AM peak period, affecting the travel time and travel time reliability in both directions. Travel time on Edison Avenue is typically between five to six minutes, but sometimes approaches seven minutes during the AM peak.

The traffic signals on Watt Avenue are actuated and coordinated for the Watt Avenue thru movements, with cycle lengths ranging from 110 seconds (1:50 minutes) to 150 seconds (2:30 minutes). Depending on traffic demand, the traffic signal controllers are able to increase or decrease the cycle lengths and green times for each movement. Because Watt Avenue has higher priority over the cross-streets, travel times on the cross-streets are noticeably less reliable. The travel time unreliability on the cross-streets may reach as high as three minutes, found at Auburn Boulevard eastbound during the PM peak.

Using the Sacramento County software, detailed travel time information including the traffic signal delays was also obtained. Figure 3-12 illustrates the average of the Watt Avenue total traffic signal delay in Segments III and IV. Traffic signal delay on Watt Avenue is consistent in both directions and for all peak periods, with the exception of Watt Avenue northbound during the PM peak. During the PM peak, the shopping centers located on Watt Avenue between Arden Way and El Camino Avenue generate heavy traffic, causing the total signal delay to increase to about 2 minutes in Segment III, and to about four minutes in Segment IV.

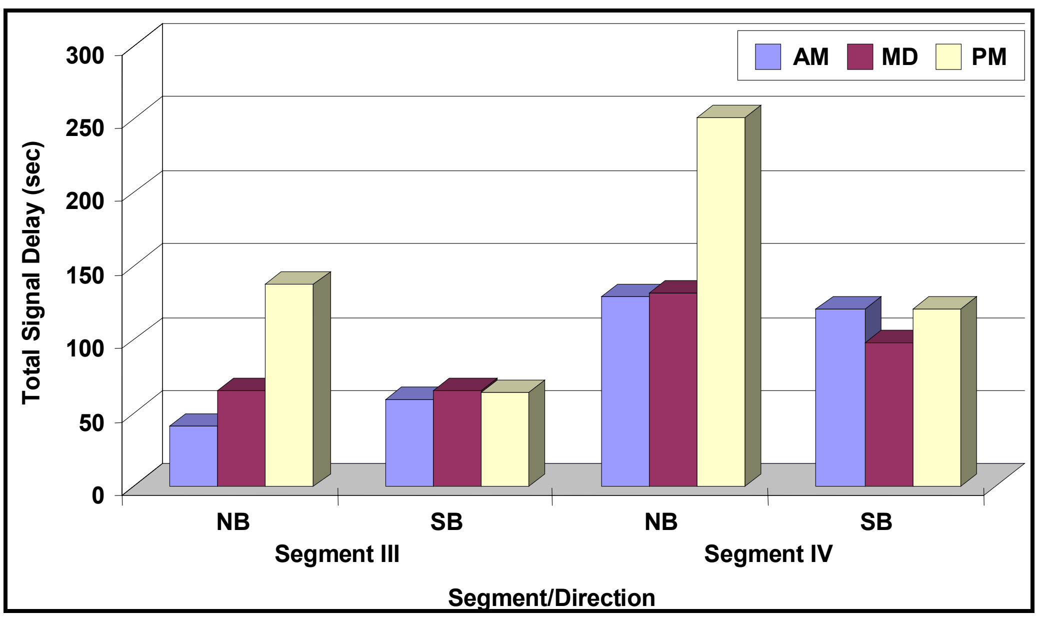



**Figure 3-11. Watt Avenue Average Total Signal Delay.**

Figure 3-12 shows the cross street traffic signal delay for each of Watt Avenue's cross streets in the study area. While the signal delays can vary widely depending on the time of arrival, Auburn Boulevard eastbound at Watt Avenue experience long signal delays during the PM peak due to the heavy traffic from the I-80 Business Loop off-ramp. At several approaches, including Auburn Boulevard eastbound during the AM and mid-day peaks, Edison Avenue westbound during the PM peak, and El Camino

Avenue during the mid-day and PM peaks, the number of observations is too low to generate conclusive results.

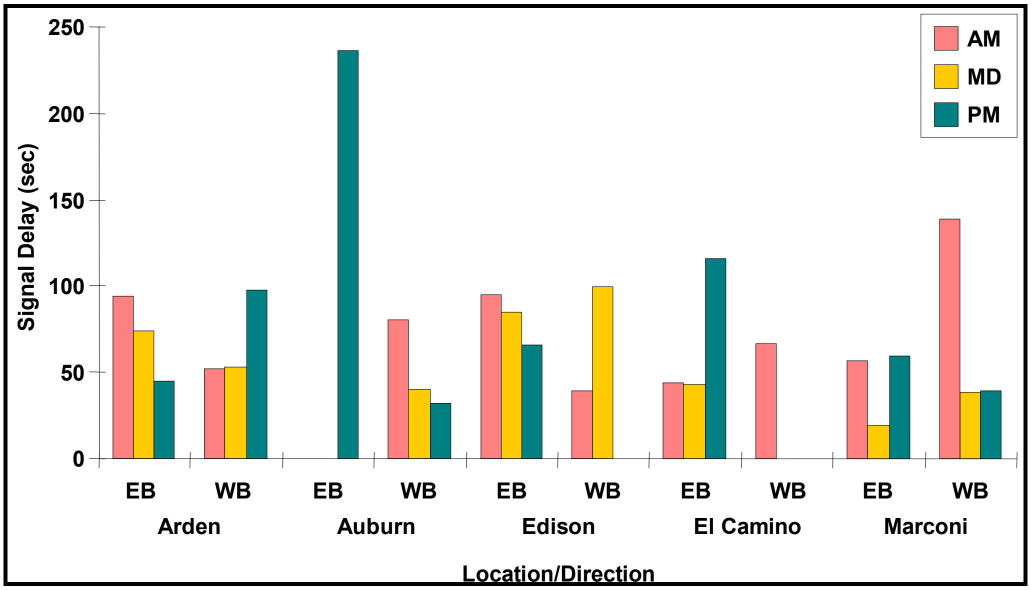



**Figure 3-12. Cross-Street Signal Delay Summary.**

### Corridor Throughput

Traffic volumes for Watt Avenue and its cross-streets were obtained from the advance loop detectors located at selected intersections. Because not all intersections have detection coverage, volume data are only available at selected intersections. Also, because not all travel lanes have loop detectors, volumes were estimated based on traffic volume patterns shown at a nearby intersections with complete detection coverage. The summary of traffic volumes is presented in Table 3-5. Because most of the intersections in Segment III are small driveways providing access to shopping centers, data obtained from the loop detectors were incomplete and unreliable, prompting the Evaluation Team to exclude volume data from this segment.

**Table 3-5. Summary of Total Vehicle Throughput per Peak Period**

| Corridor/Direction | AM | MD | PM |
|---|---|---|---|
| **Segment II** | | | |
| NB (Watt Ave) | 6,208 | 5,715 | 7,353 |
| SB (Watt Ave) | 6,302 | 6,651 | 7,269 |
| WB (Cross-streets) | 2,761 | 1,649 | 1,611 |
| EB (Cross-streets) | 1,225 | 2,479 | 2,957 |
| **Segment IV** | | | |
| NB (Watt Ave) | 4,613 | 5,672 | 6,081 |
| SB (Watt Ave) | 5,981 | 5,222 | 5,460 |

| | | | |
|---|---|---|---|
| WB (Cross-streets) | 2,951 | 2,529 | 2,802 |
| EB (Cross-streets) | 2,162 | 2,685 | 2,928 |

According to SACOG, the AVO for passenger cars during commute hours is 1.3 persons per vehicle. This figure is useful for comparing the person-mobility (instead of vehicle throughput) between transit and passenger vehicles. Based on this information, the summary of person-mobility on Watt Avenue is presented in Table 3-6.

**Table 3-6. Summary of Person-Mobility per Peak Period**

| Corridor/Direction | AM | MD | PM |
|---|---|---|---|
| **Segment II** | | | |
| NB | 8,070 | 7,430 | 9,559 |
| SB | 8,193 | 8,647 | 9,450 |
| WB | 3,589 | 2,144 | 2,094 |
| EB | 1,593 | 3,223 | 3,844 |
| **Segment IV** | | | |
| NB | 5,997 | 7,374 | 7,906 |
| SB | 7,775 | 6,789 | 7,098 |
| WB | 3,837 | 3,288 | 3,642 |
| EB | 2,811 | 3,491 | 3,806 |

In general, Watt Avenue is busiest during the PM peak, carrying about 14,500 vehicles in Segment II and 11,500 vehicles in Segment IV. The northbound/southbound volume split on Watt Avenue is roughly equal, indicating that Watt Avenue is a major thruway between the two freeways with no peak direction. Likewise, the cross-streets in Segments II and IV carry between 4,500 and 5,500 vehicles during the PM peak, but in this case, there is evidence of directional peaking, with traffic mostly heading westbound (towards downtown Sacramento) during the AM peak, and eastbound (away from downtown) during the PM peak. This indicates that commuters sometimes use the arterials crossing Watt Avenue as alternate routes to I-80 Business and U.S. 50. Since the general traffic volumes and patterns in Segments II and IV are similar, Watt Avenue's northbound/southbound volumes in Segment III are expected to be the same. Cross-street volumes in Segment III, which consists of driveways to the shopping centers, however, are expected to behave differently than cross-streets from Segments II and IV, which consists of major arterials such as Arden Way, El Camino Avenue, and Auburn Boulevard.

Figures 3-13 and 3-14 illustrate the average traffic volumes on Watt Avenue and the cross-streets in Segments II and IV. The Evaluation Team found little correlation between the traffic volume and travel time data presented in the previous section. Rather, travel time is more dependent on the signal delay, suggesting that there is excess capacity on Watt Avenue, and that the speed and flow at which vehicles travel on the corridor are governed by the traffic control devices. Based on the evidence, it will be interesting to see how the application of TSP would impact the traffic operations on Watt Avenue and its cross-streets.

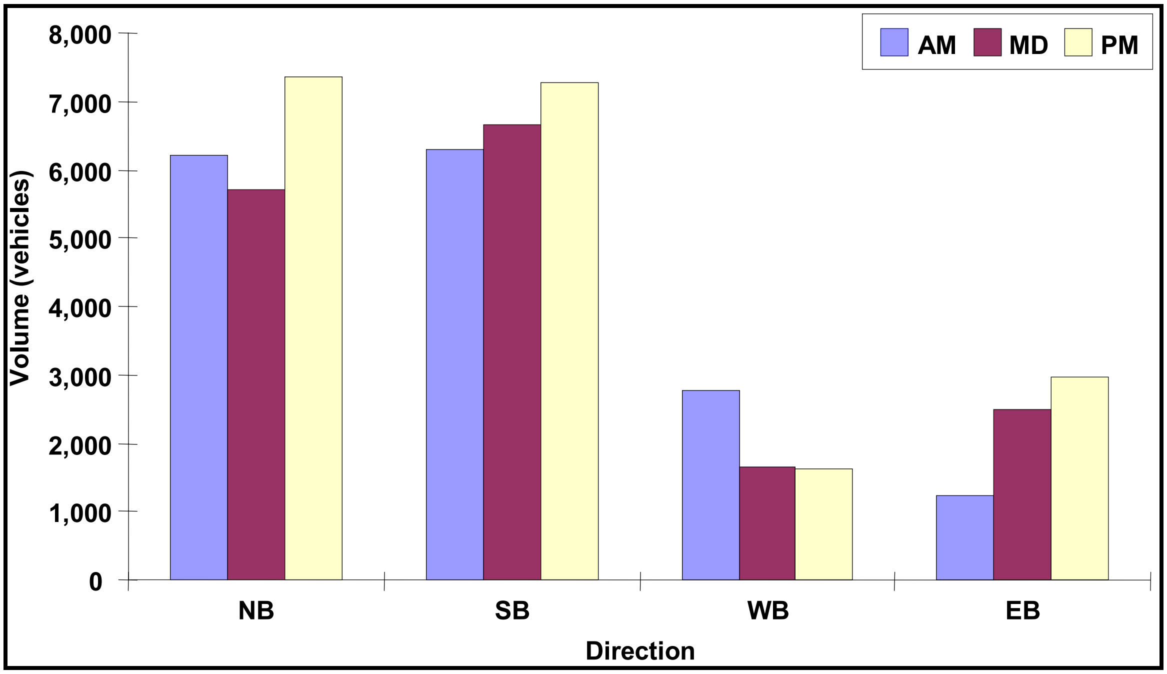



**Figure 3-13. Segment II Average Peak Period Volume.**

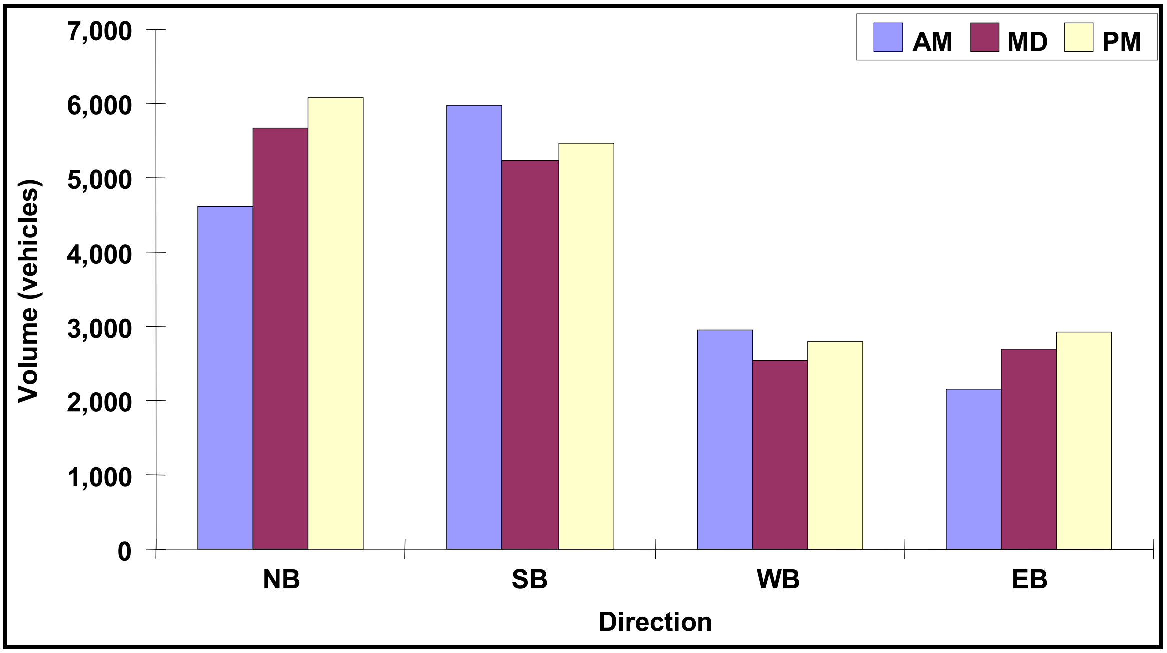



**Figure 3-14. Segment IV Average Peak Period Volume.**

# 4. CUSTOMER SATISFACTION STUDY

The goal of the customer satisfaction portion of the evaluation was to collect and analyze data related to changes in bus riders' perceptions of service as a result of the addition of TSP. Three measures of effectiveness were identified:

- Riders' perceptions of system mobility (delay).
- Riders' perceptions of system efficiency and schedule reliability.
- Riders' overall satisfaction with transit service in the corridor.

In order to test the impact of the system on riders' behaviors and perceptions, an understanding of riders' baseline perceptions was required. This baseline information has been analyzed to provide a basis for comparison with data to be collected during the post-deployment period.

In addition, it should be noted that the evaluation goals were recently modified to include the perceptions of bus drivers and traffic operations personnel. As a result, Phase III of the evaluation will include interviews (or focus groups, depending on the number of drivers RT identifies as being appropriate for this) with bus drivers who are assigned to Routes 80 and 84. The goal of this will be to measure the impact of the system qualitatively, by speaking with the drivers who have first-hand experience with the Watt Avenue corridor. This portion of the evaluation is contingent on when the TSP system becomes completely functional since drivers' routes are reassigned each quarter (the next scheduled driver rotation is December 2003), and it will be important to obtain the perceptions of drivers who drove the route in the timeframes both before and after the TSP deployment. The Evaluation Team will also be conducting interviews with traffic operations personnel to obtain their insight into their thoughts about the system and its impact on traffic mobility. Therefore, the two additional measures of effectiveness that have been identified are:

- Perceptions of bus drivers' regarding impacts of the TSP system
- Perceptions of traffic operations personnel regarding impacts of the TSP system

This section is organized as follows:

- 4.1 Data Collection Approach
- 4.2 Findings from Baseline Data Collection

## 4.1 DATA COLLECTION APPROACH

Transit riders' perceptions were evaluated through an intercept survey conducted on-board buses operating within the study corridor along Watt Avenue. The survey was conducted in cooperation with the Regional Transit (RT) agency in Sacramento.

Surveys were administered during AM and PM peak traffic periods when bus ridership is also generally at its peak. Survey staff were instructed to ask all passengers (with the exception of children) boarding, or already on board, buses operating in the study area to complete the survey form. Survey forms were distributed and collected on-board buses operating both northbound and southbound trips on Routes 80 and 84.

Riders were approached and told that surveyors were conducting a customer satisfaction survey of the Watt Avenue bus service. First, riders were asked whether they had completed this survey before. If not, they were asked if they would mind answering a few questions while riding the bus to their destination. Riders who agreed to participate were given a copy of the survey to complete. A total of 368 surveys were completed over a period of three days in October 2002. A copy of the baseline Watt Avenue survey can be found in Appendix C.

### 4.1.1 Perceived Mobility

One of the goals of the customer satisfaction evaluation is to assess riders' perceptions of system mobility on the TSP portion of Watt Avenue. It was hypothesized that TSP would improve the mobility of transit vehicles in the corridor. Project partners reported that they anticipated that the TSP system would lead to reductions in transit travel times and signal delay (resulting in improved transit mobility). From the transit perspective, the partners hope that this will translate into increased ridership and increased mode share for transit.

Several questions on the survey were formulated to determine riders' perceptions of signal-related delay on Watt Avenue, with the objective of identifying statistically significant changes in riders' perceptions of delay at signalized intersections after the TSP is deployed.

### 4.1.2 Perceived System Efficiency and Schedule Reliability

Another goal of the TSP evaluation was to assess riders' perceptions of system efficiency and schedule reliability. It was hypothesized that riders would perceive an increase in system efficiency and schedule reliability in terms of on-time performance. The project partners reported that they expected that reductions in transit travel times and signal delay would improve travel time reliability, allowing RT to develop improved transit schedules. The survey included several questions formulated to measure users' perceptions of system efficiency and schedule reliability in terms of on-time performance.

### 4.1.3 Perceived Overall Satisfaction

A few survey questions were formulated to determine users' overall satisfaction with transit service along Watt Avenue. In formulating the survey questions, it was considered that while much of a riders' level of satisfaction with the bus system may have to do with their perceptions of mobility, schedule reliability, and efficiency, there may be other factors that influence bus riders' perception of service quality (e.g., safety).

## 4.2 FINDINGS FROM BASELINE DATA COLLECTION

Baseline intercept surveys were administered Monday, October 7, 2002 through Wednesday, October 9, 2002 (RT and Sacramento County did not make any significant changes to either signal timings or transit schedules between October 2002 and March 2003, when the traffic and transit data were collected). Surveyors boarded buses (Routes 80 and 84) at one end of the study area and distributed and collected surveys while on the bus. Surveys were administered to any passengers on-board the bus within the study area (with the exception of children) during the morning peak (6:30am-10:00am), and the evening peak (3:30pm-8:30pm). Table 4-1 shows the number of completed surveys obtained by time of day.

**Table 4-1. Number of Completed Baseline Customer Satisfaction Surveys**

| Bus Route | Direction | Number of Completed Surveys (October 2002) | |
|---|---|---|---|
| | | 6:30–10:00 AM | 3:30–8:30 PM |
| Route 80 | Northbound | 78 | 57 |
| | Southbound | 46 | 30 |
| Route 84 | Northbound | 37 | 32 |
| | Southbound | 28 | 60 |
| Total Number of Completed Surveys | | 189 | 179 |

### 4.2.1 Demographic Information

Figure 4-1 illustrates the reported frequency with which respondents ride the bus. Almost 60 percent of respondents reported that they ride the bus *almost every day*. About 18 percent indicated that they ride the bus a *few times per week*, and about 12 percent reported that they ride the bus a *few times per month*. A little over 4 percent reported that they *almost never* ride the bus, and less than 3 percent reported that it was their *first time* riding one of the Watt Avenue buses. Just over 5 percent did not respond to this question.

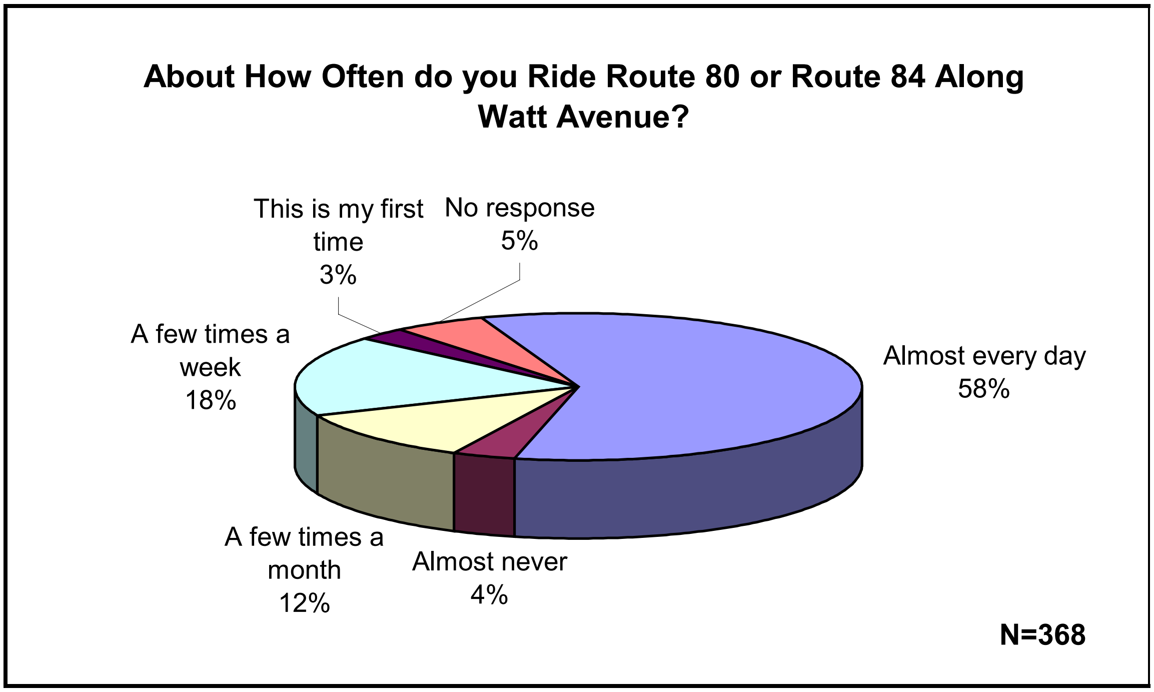



**Figure 4-1. Frequency with which Respondents Ride Watt Avenue Buses.**

Respondents were also asked to indicate for which trip purposes they most often ride the bus. Respondents were asked to mark all response choices that applied. Trip purposes included: *work*, *school*, *shopping*, *visiting friends or family, medical or dental appointments*, and *other*. The responses are shown in Figure 4-2 according to the most frequent trip purpose selected.

Almost half of respondents (49 percent) indicated that they rode the bus most frequently for *work* trips. About 21 percent of respondents reported that they ride the bus most frequently for *school* trips, and another 11 percent indicated that they ride the bus for *shopping* related trips. Less than 10 percent of respondents reported riding the bus for purposes other than work, school, or shopping.

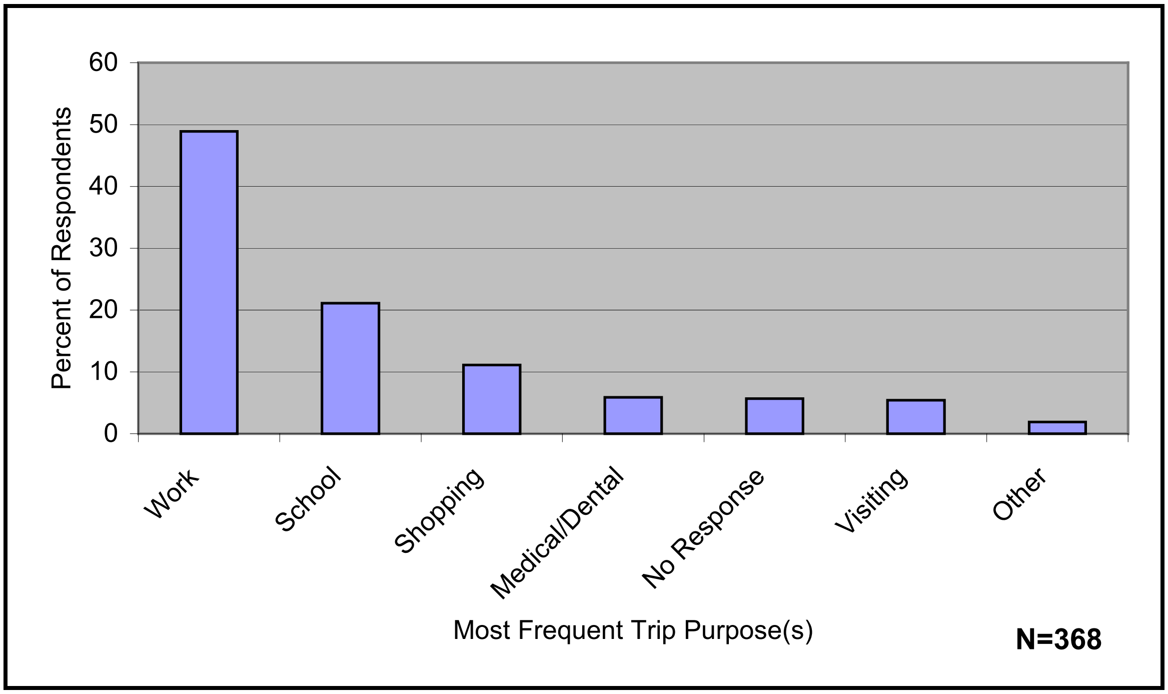



**Figure 4-2. Distribution of Most Frequent Trip Purposes.**

As mentioned earlier, Routes 80 and 84 both include a 9.8-mile segment on Watt Avenue that runs between the LRT station at the north end and the LRT station at the south end (with a scheduled travel time of 38 minutes between the two stations). Respondents were asked to indicate how often they use Routes 80 or 84 to connect with light rail service.

Sacramento RT was particularly interested in the results of this question for the purposes of future planning. As shown in Figure 4-3, 51 percent of respondents indicated that they use Routes 80 or 84 to connect with LRT at least *a few times per week*, while 21 percent reported that they *almost never* use Route 80 or 84 to connect with LRT.

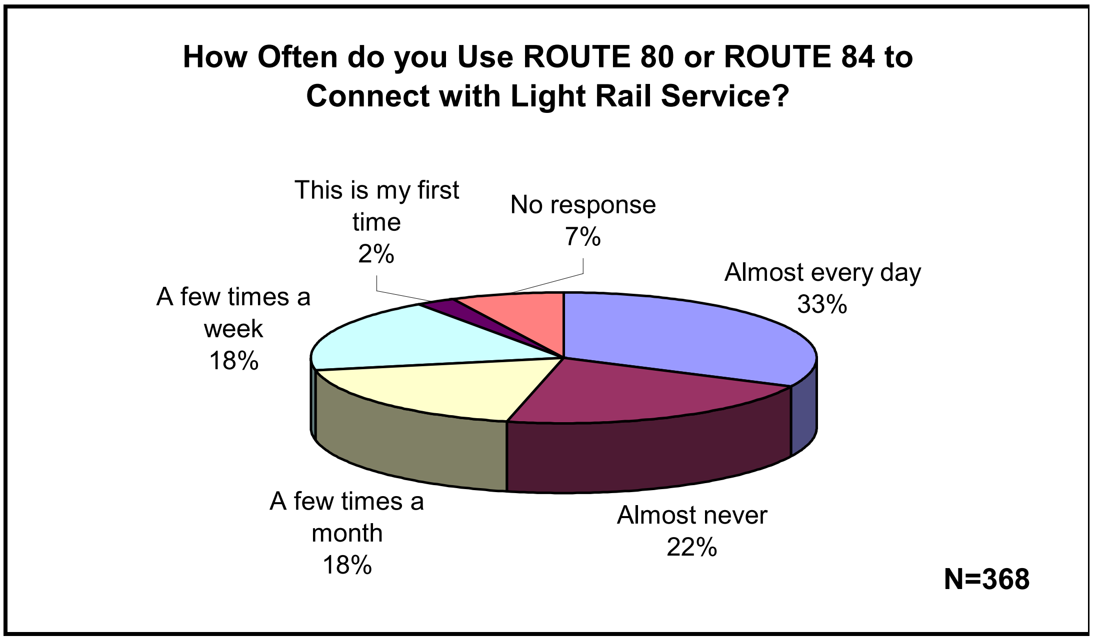



**Figure 4-3. Frequency with which Respondents Use Buses to Connect to LRT.**

Respondents were also asked to indicate how long they have been using the bus service on Watt Avenue. This question was asked to determine how many respondents were "seasoned" users, or users who had been using the service for at least 6 months, who would be familiar with the service on Watt Avenue. The majority of survey respondents (71 percent) reported that they had been using Watt Avenue buses for at least 6 months. The responses to this question are illustrated in Figure 4-4.

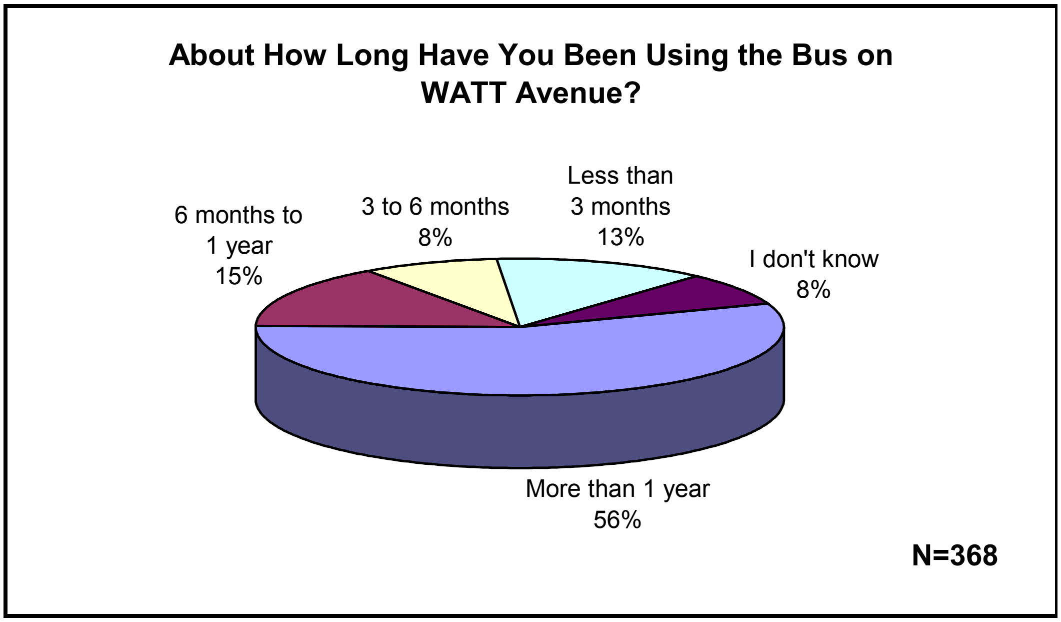



**Figure 4-4. How Long Respondents Have Been Using Watt Avenue Bus Service.**

### 4.2.2 Riders' Perceptions of System Mobility, Reliability, and Efficiency

Respondents were asked:

> *How satisfied are you with the following aspect of the bus service ALONG WATT AVENUE?*

- Number of stops for traffic lights
- Amount of time stopped for traffic lights
- On-time arrival of buses at bus stops

In response to the level of satisfaction with the number of times the bus is required to stop for traffic signals, 47 percent of respondents indicated that they were either *satisfied* or *very satisfied*. Almost half of the respondents seemed to be satisfied with the bus service in terms of the number of times that the bus is required to stop for traffic signals on Watt Avenue[4]. Only 13 percent of respondents reported that they were either *not satisfied* or *not at all satisfied* with the number of stops. Over a third of those surveyed - thirty-four (34) percent - reported that they were either *neutral* (i.e., neither satisfied nor dissatisfied) or *not sure*. As this percentage is quite high, it will be interesting to see if it changes after implementation of the TSP system.

Regarding the level of satisfaction with the amount of time the bus is required to stop for traffic signals, 41 percent of respondents indicated that they were either *satisfied* or *very satisfied*. Only 14 percent of respondents reported that they were either *not satisfied* or *not at all satisfied* with the number of stops for traffic lights. Twenty-nine (29) percent of respondents reported that they were either *neutral* or *not sure*.

In response to the level of satisfaction with the on-time arrival of buses at bus stops on Watt Avenue, 47 percent of respondents indicated that they were either *satisfied* or *very satisfied*. Twenty-six (26) percent of respondents reported that they were either *not satisfied* or *not at all satisfied* with the buses on-time arrivals at bus stops, and 23 percent of respondents reported *neutral* or *not sure*. The results of this question are shown in Figure 4-5 below.

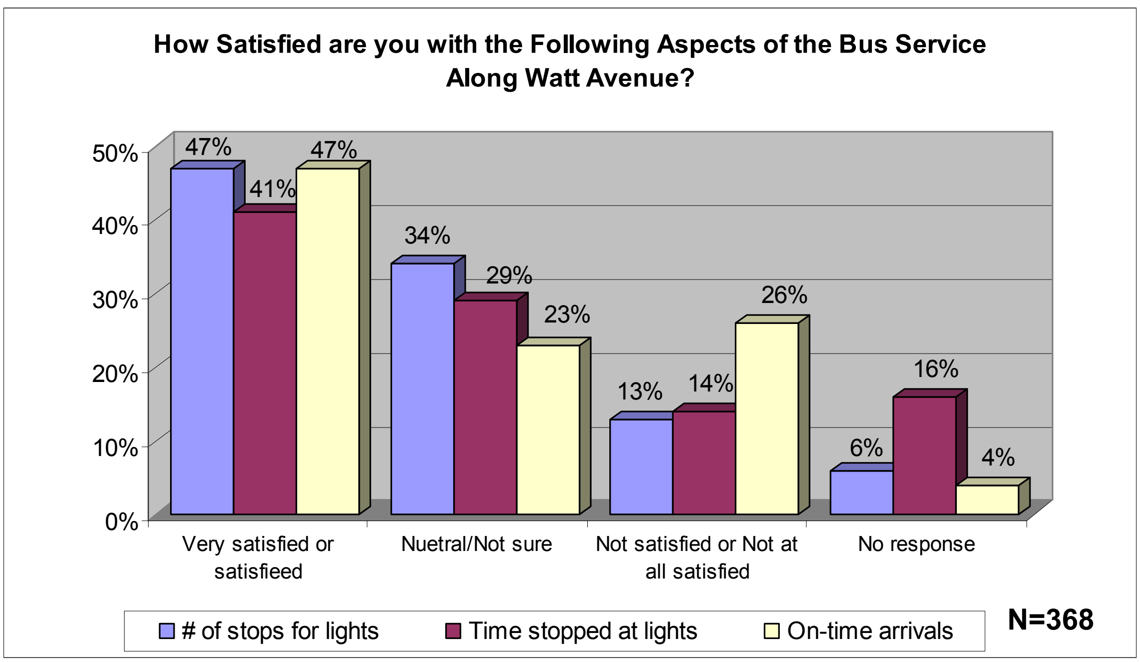



**Figure 4-5. Respondents' Level of Satisfaction with Watt Avenue Bus Service.**

[4] The term "traffic lights" was used to survey the general public. For the purposes of this technical report, the term "traffic signals" is also used. Therefore, these terms should be considered interchangeable throughout this report.

Respondents were asked how often they believe the buses on Watt Avenue run on-time according to the schedule. The responses to this question are shown in Figure 4-6. Forty-one (41) percent indicated that the buses are either *almost always* or *frequently* on time. Twenty-five (25) percent indicated that the buses were *sometimes* on time. Eighteen (18) percent reported that the buses are either *almost never or not often* on time.

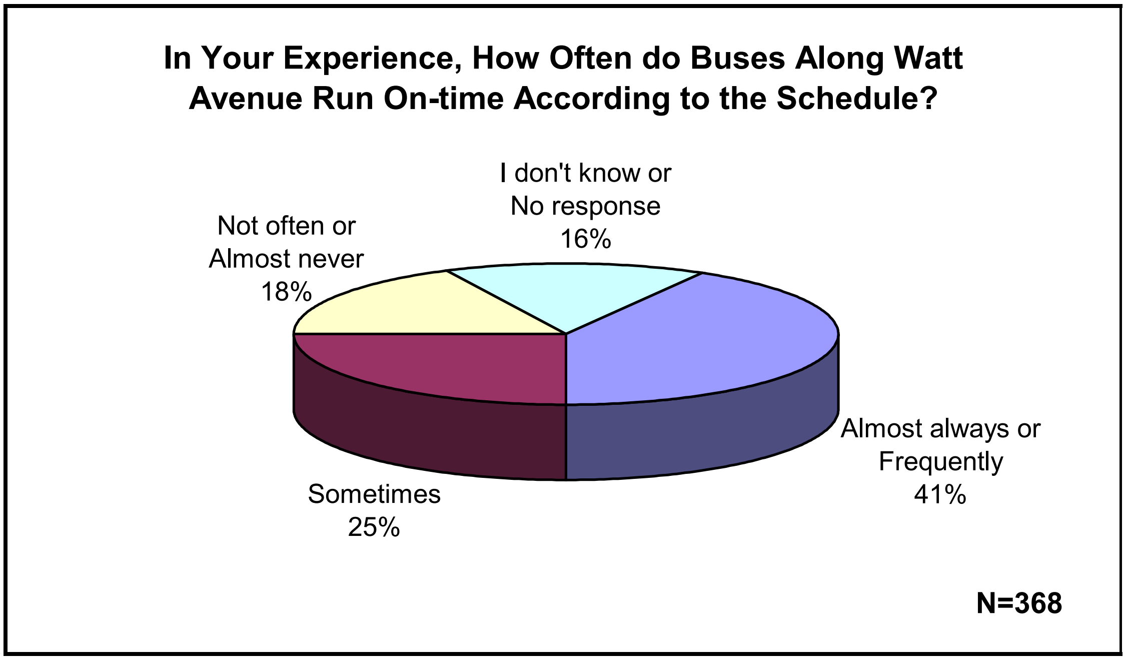



**Figure 4-6. Respondents' Perceptions of On-Time Arrival of Buses.**

The survey also asked respondents who have been riding buses along Watt Avenue for more than one year to indicate their perceptions of the service reliability compared to the previous year. As shown in Figure 4-7, a little over 15 percent of respondents indicated that bus services along Watt Avenue are *more reliable* than one year ago. Only a little over 11 percent reported that bus services are *less reliable* than one year ago. About 28 percent felt that services are the *same as 1 year ago*, and 20 percent were *not sure*.

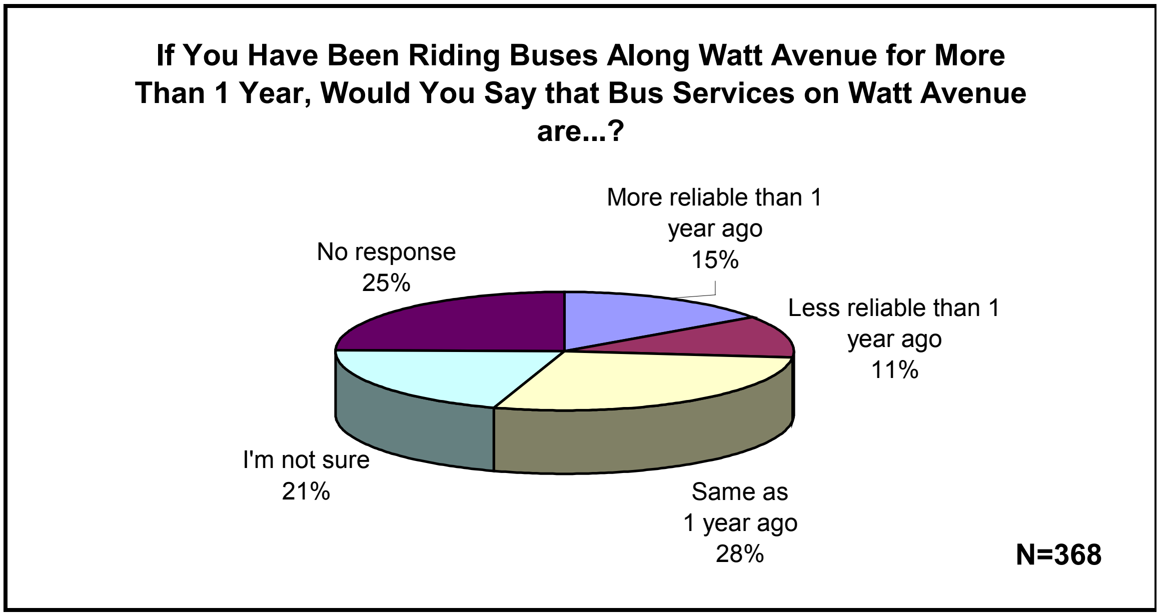



**Figure 4-7. Respondents' Perceptions of Service Reliability.**

One of the survey questions provided respondents with several statements and they were asked to select the one that best describes their experiences with bus service on Watt Avenue. The question stated, "*If you routinely board Route 80 or 84 on Watt Avenue or at one of the light rail stations, which of the following statements most closely describes your experience? (Please mark ONLY ONE)".*

In response to this question, 32 percent of respondents indicated that they could rely on the bus arriving within a few minutes of a certain time. Thirty-five (35) percent reported that they never know if the bus will be on time so they arrive at the bus stop early or they take an earlier bus. Twelve (12) percent reported that they do not rely on bus schedules, and that they just go to the bus stop and wait for the next bus. Finally, 14 percent reported that they are usually transferring and have no choice but to wait for the next bus. The results are shown in Figure 4-8.

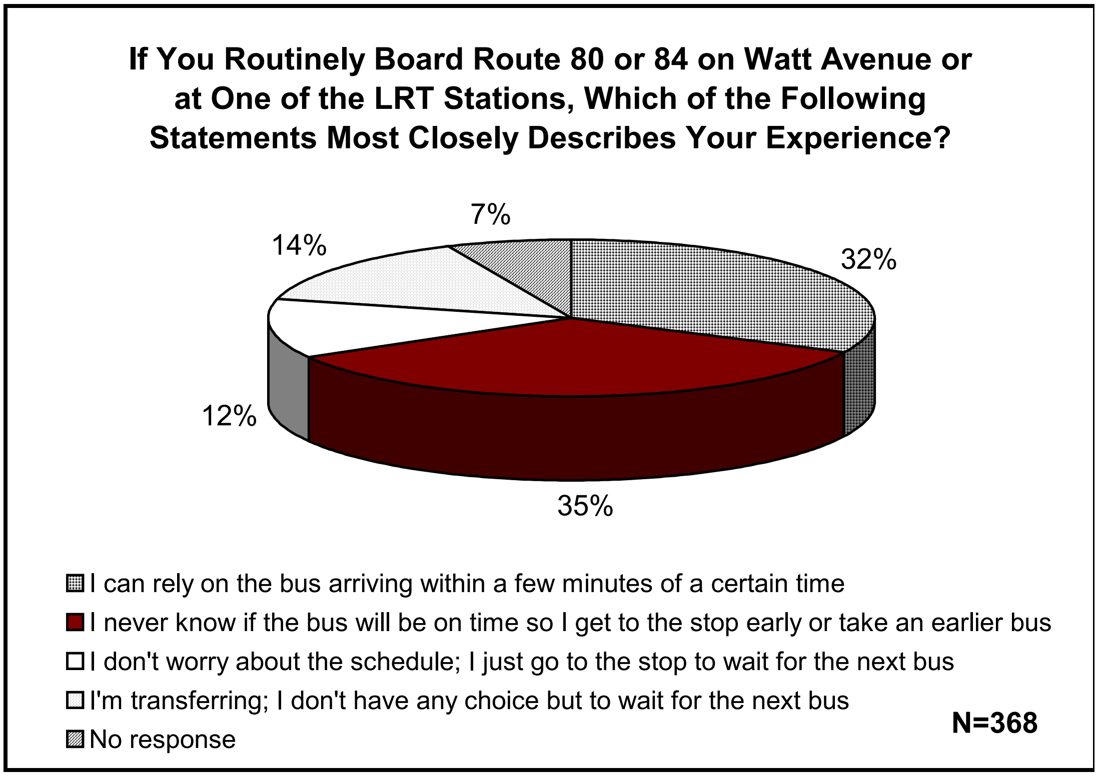



**Figure 4-8. Respondents' Perceptions of Watt Avenue Bus Service.**

### 4.2.3 Riders' Overall Satisfaction with System Service

Finally, respondents were asked to rate how satisfied they were, overall, with the bus service along Watt Avenue. The results are shown in Figure 4-9. Fifty-one (51) percent of respondents indicated that they were either *satisfied* or *very satisfied* with bus service along Watt Avenue, while 19 percent of respondents reported that they were either *not satisfied* or *not at all satisfied* with the service. Twenty-four (24) percent of respondents reported *neutral* or *not sure*.

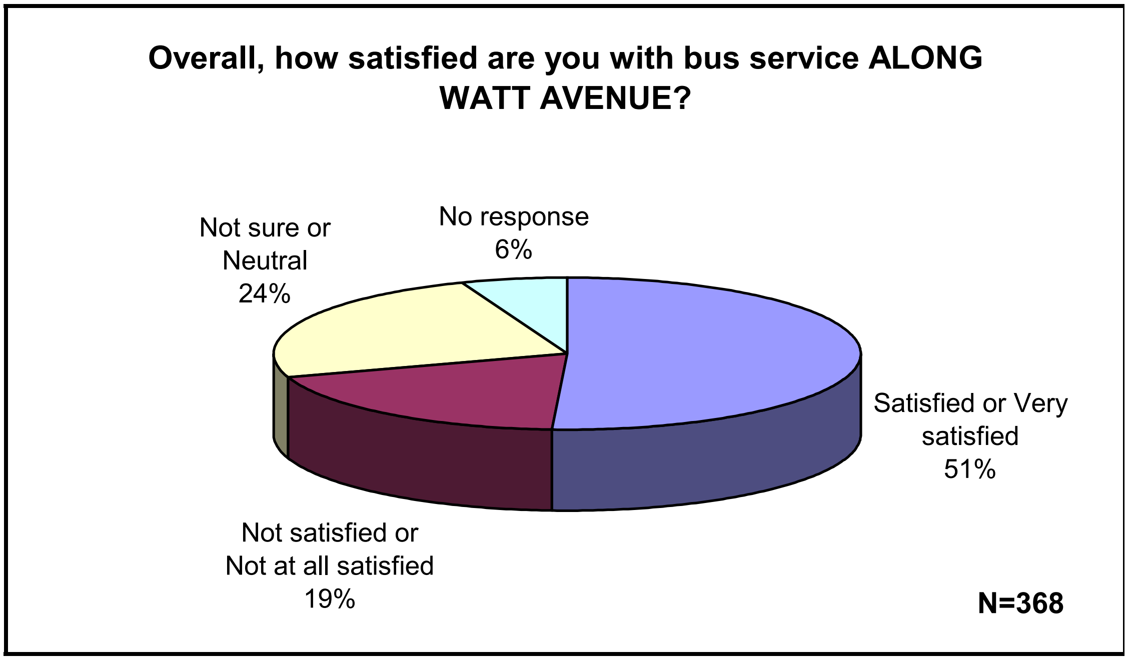



**Figure 4-9. Riders' Overall Level of Satisfaction with Watt Avenue Bus Service.**

**Summary of Survey Findings:**

- In all, 368 surveys were completed.
- About 47 percent of respondents indicated that they were either *satisfied* or *very satisfied* with the number of times that Watt Avenue buses are required to stop for traffic signals. Only about 13 percent of respondents reported that they were either *not satisfied* or *not at all satisfied* with the number of times that Watt Avenue buses are required to stop for traffic signals.
- A little over 41 percent of respondents indicated that they were either *satisfied* or *very satisfied* with the amount of time that Watt Avenue buses are stopped at traffic signals, and only about 14 percent of respondents reported that they were either *not satisfied* or *not at all satisfied* with the amount of time that Watt Avenue buses are stopped at traffic signals.
- When respondents were asked how often buses along Watt Avenue run on-time according to schedule, approximately 42 percent indicated either *almost always* or *frequently*, and approximately 18 percent reported *almost never* or *not often.*

- When respondents were asked how satisfied they were with the buses' on-time arrivals at bus stops, 46.5 percent indicated that they were either *satisfied* or *very satisfied*, and a little over 26 percent of respondents reported that they were either *not satisfied* or *not at all satisfied* with the buses' on-time arrivals at bus stops.

- About 51 percent of respondents indicated that they were either *satisfied* or *very satisfied* with bus service along Watt Avenue, while a little over 19 percent of respondents reported that they were either *not satisfied* or *not at all satisfied* with the service.

# 5. RECOMMENDATIONS

## 5.1 PROJECT STATUS UPDATE

This section briefly discusses the current status of the deployments as well as future deployment plans and schedules.

TSP was deployed in April 2003 and the signal timings recommended by the retained consulting firm were input into the controllers. Range settings for the emitters and detectors that were originally set were re-verified in July 2003, and Sacramento County is continuing to study the range settings to determine if they should be modified. The system is currently operating in traffic responsive mode. A laptop has been used to download TSP call histories directly from the 3M detector cards in the field. These data are inspected, reformatted, and then placed in a database. The call history information includes: the intersection name, the direction of travel, the request level (this function is not currently being used, but eventually each call could be a high or low request based on certain conditions), a timestamp when a call is dropped (i.e., when the bus has passed the intersection), and the bus id number. Data queries and report structures are currently being developed.

The deployment team continues to struggle with electronics, software, operational performance, and controller logic. However, it is expected that the system will be fully operational by the time the post-deployment data collection would take place during the spring of 2004.

## 5.2 EVALUATION RISK ASSESSMENT AND RECOMMENDATIONS

The purpose of this section is to provide an assessment as to whether or not the Sacramento deployment should be maintained as a Phase III integration evaluation site. This section identifies the opportunities and assesses the risks involved in continuing with a post-deployment evaluation of the Sacramento-Watt Avenue Transit Priority and Mobility Enhancement Demonstration project. Based on this assessment, the recommendations of the Evaluation Team regarding the future opportunities are presented in the following section.

The continuation of the evaluation of the Watt Avenue Transit Priority and Mobility Enhancement Demonstration project offers significant opportunities, with little to no risk. Based on these opportunities and the Evaluation Team's experience developing the Evaluation Plan, working with the project partners, collecting baseline data, and analyzing baseline conditions, the Evaluation Team recommends that the Federal Transit Administration (FTA) Task Manager consider continuing with Phase III evaluation efforts. The Evaluation Team recommends that Phase III of the Sacramento – Watt Avenue TSP evaluation be funded with post-deployment data collection activities taking place in the spring of 2004. This will provide the best opportunity to generate data comparable to the baseline data collected during March of 2003 as these times should be fairly comparable in terms of ridership and traffic.

# REFERENCES

1. Sacramento-Watt Avenue Transit Priority and Mobility Enhancement Demonstration: Final Evaluation Plan, Prepared by Science Applications International Corporation, U.S. Department of Transportation, November 25, 2002.

2. Nash, A.B. and Sylvia, R. Implementation of Zürich's Transit Priority Program, Mineta Transportation Institute, San Jose State University, CA, MTI Report 01-13, October 2001.

3. Garrow, M. and Machemehl, R. Development and Evaluation of Transit Signal Priority Strategies. Journal of Public Transportation, Volume 2, No. 2, 1999.

4. Gross, P.D., and Wright, J.M. (2002). Measured Performance for Sacramento Watt Avenue ITS Transit Signal Priority Improvements. ITE Conference.

# APPENDIX A:

# POWER ANALYSES CONDUCTED TO DETERMINE NUMBER OF TRANSIT RUNS NEEDED TO SHOW MEANINGFUL RESULTS

## Background

The decision as to how large a sample shall be taken is a fundamental aspect of the plan for an investigation that involves data collection efforts. If a difference actually exists between two population means but the samples taken are too small, the observed difference in the sample means may be insignificant. However, somewhat larger samples may have produced significant results. On the other hand, one does not want to take samples larger than necessary to establish the mean difference as this would spend valuable project funding that could have been better expended elsewhere.

For the Sacramento-Watt Avenue Transit Priority and Mobility Enhancement Demonstration project, power analysis was investigated to address the question, *how many transit runs data are needed to show meaningful results?* A transit run is defined as a trip taken by a bus from an origin to a destination point. Meaningful results are the "desired" reductions in transit travel times.

To make the decision of how large a sample size is needed, practical experience must be relied on for answers to these questions:

1. How large a difference (d) would be of practical importance in the population? For the Sacramento-Watt Avenue Transit Priority and Mobility Enhancement Demonstration project, the analyses were conducted for 5, 10, 20, and 30 percent reduction in the transit travel time.

2. What estimate can be made for the sample variance?

3. How much risk can be taken of deciding that a difference exists when it really is zero? This decision is the choice of $\alpha$ (e.g., $\alpha = 0.05$).

4. How much risk can be taken of deciding that a difference is zero when it really is as large as the predetermined value d? This decision is the choice of $\beta$ (e.g., $\beta = 0.6$). A $\beta$ of 0.6 would mean that the probability of detecting a difference between two sample means is 60 percent.

When these four values (d, $\sigma$, $\alpha$, and $\beta$) have been chosen, an individual can determine the necessary sample size (N) by using some algebra. Please refer to the following example for more details.

## Power Analysis Conducted Using Pilot Existing Data

To obtain a more accurate power analysis, it is suggested that some pilot existing data (i.e., before the actual data collection starts) are used to determine the values (d) and ($\sigma$). Therefore, the table below shows a summary of existing data for transit travel times (data were provided by Sacramento County). Please note that those travel times are in minutes and they include the segment from Kings Way to I-80, where most of the variations in transit travel time tend to occur on Watt Avenue. In addition, those travel times include the overall travel time minus the dwell time (i.e., the time the bus spends loading and/or unloading passengers). Please note that the travel times included northbound (NB) runs that were conducted throughout the entire day (i.e., peak times and off-peak times). This is to ensure a larger variation in the data and hence a more conservative in the analysis. Please note that travel times were normally distributed and no transformation in the data was needed.

| | N | Minimum | Maximum | Mean | Std Deviation |
|---|---|---|---|---|---|
| **Total Time** | 26 | 6.15 | 20.883 | **11** | **3.4** |

Let us assume the following: 5, 10, 15, 20, and 30 percent reductions in the transit travel times; $\alpha$ = 0.05 with a two sided test; and $\beta = 0.6$, 0.7, and 0.8. The following equation is then used to determine the number of transit runs needed:

$N = \sigma^2/d^2 * (Z\alpha/2 + Z\beta)^2$, where

$\sigma = 3.4$

d = 11*0.05 or 0.1 or 0.15 or 0.20 or 0.3 (i.e., 5, 10, 15, 20, and 30 percent reductions)

$\alpha$ = 0.05 (for two sided test, look up Z value of 0.975 (i.e., 1-0.05/2=0.975)=1.96

$\beta$ = 0.6, 0.7, and 0.8 = 0.253, 0.525, and 0.842, respectively (look up Z value of 0.4, 0.3, and 0.2 (e.g., 1-0.6=0.4)

The following table summarizes the results for each %reduction and $\beta$:

| **Number of Transit Runs Needed** | **5% (0.55 min)** | **10% (1.1 min)** | **15% (1.65)** | **20% (2.2)** | **30% (3.3)** |
|---|---|---|---|---|---|
| $\beta = 0.6$ | 187 | 47 | 21 | 12 | 5 |
| $\beta = 0.7$ | 236 | 59 | 26 | 15 | 7 |
| $\beta = 0.8$ | 300 | 75 | 33 | 19 | 8 |

This means that based on the existing transit travel times, a total number of 187 transit data runs are needed to have a 60 percent chance of observing an actual 5 percent reduction in transit travel time on Watt Avenue between Kings Way and I-80. As shown in the table, the sample size needed (i.e., the number of bus runs) will increase as the power of the test increases (i.e., $\beta$ of 0.6 to 0.7 to 0.8). Most researchers usually use $\beta$ of 0.7 or 0.8. In addition, the sample size will increase as the reduction difference increases (i.e., from 5 to 10 to 15 percent, etc). This means that a larger sample size is needed to detect a smaller difference in the data. Therefore, we would need a larger sample size to detect a 5 percent reduction in transit travel times compared to a 10 or 20 percent reduction.

The Evaluation Team intends to collect 24 transit runs every day. Therefore, for a period of two weeks, a total number of 24*10=240 transit data runs will be obtained, which should be sufficient to detect a 5 percent reduction difference (60 percent probability). This should be sufficient as the power analysis was conducted based on only 26 transit runs with a large variation. Furthermore, after collecting data during the first week, power analyses will be conducted again to confirm the results obtained in this report.

**Power Analysis Conducted Using Actual Data Collected**

The table below shows a summary of existing data for transit travel times. Please note that those travel times are in minutes and they include the segment IV (Kings Way to I-80) where most of the variations in transit travel time tend to occur on Watt Avenue. In addition, those travel times include the overall travel time minus the dwell time (i.e., the time the bus spends loading and/or unloading passengers). Again, the data for the NB were used as the standard deviation is larger and the analysis will be more conservative. Please note that travel times were normally distributed and no transformation in the data was needed.

| Travel Time | N | Minimum | Maximum | Mean | Std Deviation |
|---|---|---|---|---|---|
| **Northbound** | 117 | 6.65 | 15.43 | **10.32** | **1.96** |
| **Southbound** | 117 | 5.10 | 11.33 | 7.92 | 1.24 |

Let us assume the following: 5, 10, 15, 20, and 30 percent reductions in the transit travel times; $\alpha$ = 0.05 with a two-sided test (a two-sided test was used for purposes of analysis since the direction of expected change could not be specified with certainty); and $\beta$ = 0.6, 0.7, and 0.8. The following equation is then used to determine the number of transit runs needed:

$N = \sigma^2/d^2 * (Z\alpha/2 + Z\beta)^2$, where

$\sigma$ = 1.96

d = 10.3*0.05 or 0.1 or 0.15 or 0.20 or 0.3 (i.e. 5, 10, 15, 20, and 30 percent reductions)

$\alpha$ = 0.05 (for two-sided test, look up Z value of 0.975 (i.e., 1-0.05/2=0.975)=1.96

$\beta$ = 0.6, 0.7, and 0.8 = 0.253, 0.525, and 0.842, respectively (look up Z value of 0.4, 0.3, and 0.2 (e.g., 1-0.6=0.4)

The following table summarizes the results for each percent reduction and β:

<table>
<tr><td rowspan="7">Number of Transit Runs Needed</td><td colspan="5">$\beta = 0.6$</td></tr>
<tr><td>5% (0.52 min)</td><td>10% (1.03 min)</td><td>15% (1.55 min)</td><td>20% (2.06)</td><td>30% (3.09)</td></tr>
<tr><td>70</td><td>18</td><td>8</td><td>5</td><td>2</td></tr>
<tr><td colspan="5">$\beta = 0.7$</td></tr>
<tr><td>88</td><td>23</td><td>10</td><td>6</td><td>3</td></tr>
<tr><td colspan="5">$\beta = 0.8$</td></tr>
<tr><td>112</td><td>29</td><td>13</td><td>8</td><td>4</td></tr>
</table>

This means that based on the existing transit travel times, a total number of 112 transit data runs are needed to have a 80 percent chance of observing an actual 5 percent reduction in transit travel time on Watt Avenue between Kings Way and I-80. As shown in the table, the sample size needed (i.e., the number of bus runs) will increase as the power of the test increases (i.e., β of 0.6 to 0.7 to 0.8). In addition, the sample size will decrease as the reduction difference increases (i.e., from 5 to 10 to 15 percent, etc). This means that a larger sample size is needed to detect a smaller difference in the data. Therefore, we would need a larger sample size to detect a 5 percent reduction in transit travel times compared to a 10 or 20 percent reduction.

Overall, the Evaluation Team collected 117 transit runs in each direction, which based on these analyses, should be sufficient to detect significant and meaningful results, even as low as 5 percent reductions in the travel times.

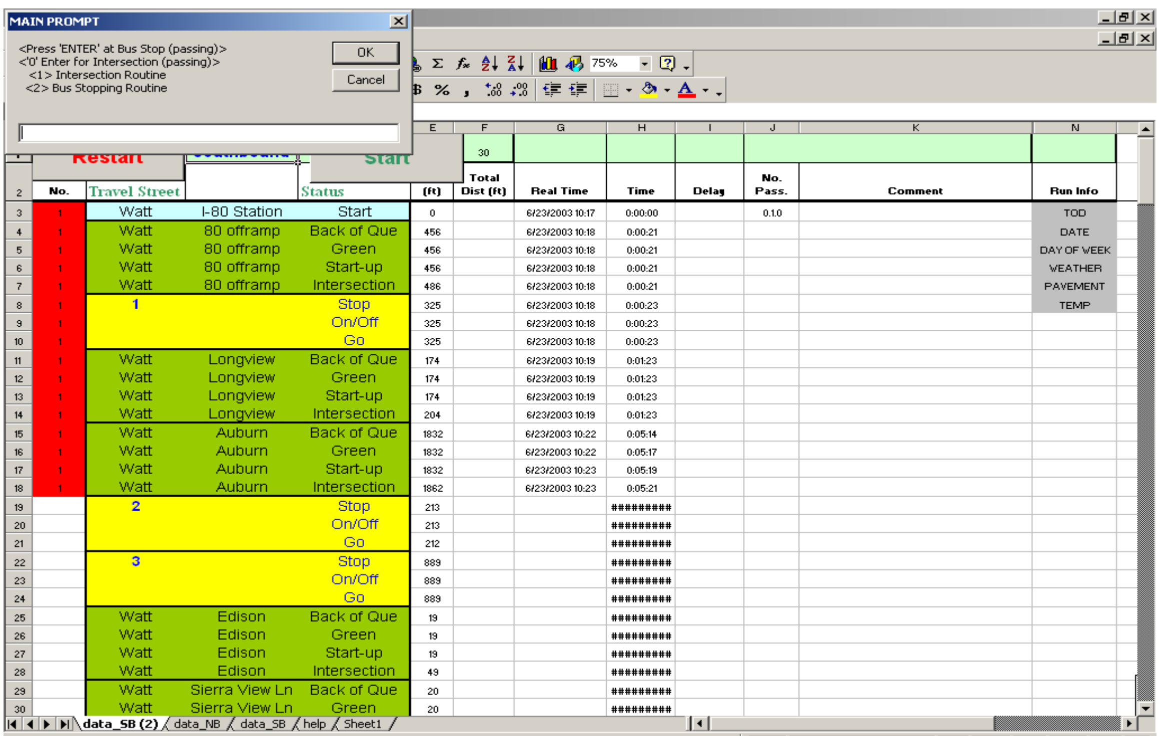
# APPENDIX B:

# DESCRIPTION OF SOFTWARE USED FOR DATA COLLECTION

## Description of Software Used for Data Collection

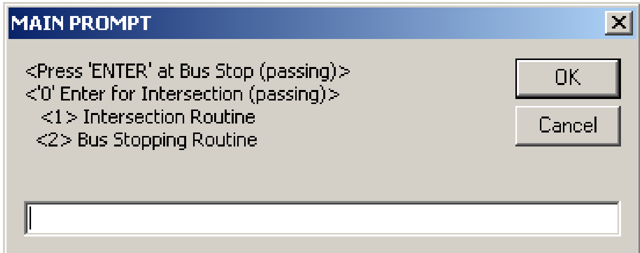
The software used for data collection is solely a Microsoft® Excel spreadsheet with Visual Basic applications. The software was developed primarily to perform the collection of timestamps by implementing a series of keystrokes using an external numeric keypad device. The software was tailored to fit specific events on the bus route allowing the operator to capture a timestamp associated with each event. The program merely utilizes the "now()" function in Excel to produce the timestamp based on the computer's system clock. A Visual Basic-looped routine that uses operator prompts to place now() timestamps in appropriate Excel cells associated with the static list of events. The program assigns each timestamp in a streaming list displayed parallel to the event list allowing the user to monitor the data as it is collected. Figure B-1 shows a screen shot of the program in the "main prompt" mode. The event list is displayed on the left. All intersections are highlighted in green, and bus stops in yellow allowing the user to prepare for the next event.

**Figure B-1: Program Operations**




The program is ultimately broken into four looped routines, which are run at the main prompt (Figure B-2). The main prompt gives the user a choice to access each mode depending on which event is occurring, with subsequent prompts for additional inputs depending on the mode.

**Figure B-2: Main Prompt**




The following list identifies the 4 possible routines at the main prompt:

- Bus Stop (passing mode).
- Bus Stop (stopped mode).
- Intersection (passing mode.)
- Intersection (stopped mode).

**The Bus Stop (passing mode)** option is enabled by pressing the enter key at the main prompt as the transit vehicle passes the bus stop, assigning a timestamp of the same value for each of the three timestamp fields. The three timestamps are all collected simultaneously using a single keystroke.

**The Bus Stop (stopped mode)** is enabled by pressing the number 2 followed by the enter key. The program immediately collects a timestamp identifying when the vehicle stopped and prompts the user to enter the number of passengers boarding and exiting (Figures B-3 and B-4). Several keystrokes were eliminated by the application of a number convention that uses a period-delimited structure to discriminate the boarding and alighting. The user is required to input the data in the following sequence: the number of passengers boarding with a bus pass, the number of passengers boarding with cash, and the number of passengers alighting) The program stores the period-delimited string into a single field that is separated after the data is processed. Again, three timestamps are recorded during a bus stop event:

- The time the bus arrives at the bus stop.
- The time when all passengers have boarded and paid.
- The time the bus re-enters the traffic stream.

**Figure B-3**

**Boarding & Alighting**

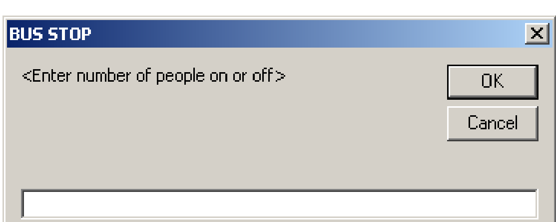
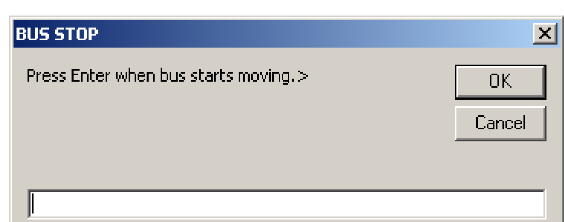



**Figure B-4**

**Re-entry to roadway**



**The Intersection (passing mode)** operates similar to the bus-passing mode such that it records a timestamp for each of the four time elements at the intersection. All four timestamps are identical, generated by typing ‘0’ followed by the enter key at the main prompt.

**The Intersection (stopped mode)** records the four timestamps, yet records them individually as the operator keys them in. An input box prompts the user for the next interval after each entry until all four timestamps have been recorded.

The four timestamps are:

- The time the bus arrives at the back of the queue at the intersection.
- The time the signal turns green.
- The time the bus begins moving (denoting start-up delay).
- The time the bus crosses the intersection stop bar.

Additional routines were introduced to cope with the realities of data collection while riding the bus. Adding a re-start feature allows the operator to suspend normal input for real time editing purposes such as a missed event or an event captured too early. The save feature operated from the keypad was added to prevent any loss of data if a battery failure were to occur. The option to add comments is available for the identification observed events such as wheelchair or bike boarding of which influences the travel time.

The program has been effective in capturing a robust detailed picture of traffic and transit operations. The program captures the timing of events occurring along the route. After the collection, the streaming list of timestamps was finally transferred into a database for further evaluation. Critical information was derived from the delta times or the timing between events. The database is a resource that also functions as a place to store and retrieve all data. The collection software and database both are kept in a simple format to allow others to edit for future changes.

# APPENDIX C:

# CUSTOMER SATISFACTION BASELINE QUESTIONNAIRE

Date: __________ Time: _______ AM PM

Route: 80 84 Direction: NB SB

# RT WATT AVENUE PASSENGER SURVEY

To serve you better, Sacramento Regional Transit and the County of Sacramento Department of Transportation are working together to make travel improvements on Watt Avenue. Your opinions about transit services on Watt Avenue will assist in this effort. Please take a moment to complete both sides of this survey form and return it to the survey worker as you leave the bus. Thank you very much for your time.

1. Overall, how satisfied are you with bus service **ALONG WATT AVENUE**?

| Very Satisfied | Satisfied | Neutral | Not Satisfied | Not at all Satisfied | Not Sure |
|---|---|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ | ❑ | ❑ |

2. How satisfied are you with each of the following aspects of the bus service **ALONG WATT AVENUE**?

| | Very satisfied | Satisfied | Neutral | Not satisfied | Not at all satisfied | Not Sure |
|---|---|---|---|---|---|---|
| On-time arrivals at bus stops | ❑ | ❑ | ❑ | ❑ | ❑ | ❑ |
| Number of stops for traffic lights | ❑ | ❑ | ❑ | ❑ | ❑ | ❑ |
| Amount of time stopped at traffic lights | ❑ | ❑ | ❑ | ❑ | ❑ | ❑ |

3. In your experience, how often do buses **ALONG WATT AVENUE** run on time according to the schedule?

| Almost always | Frequently | Sometimes | Not Often | Almost never | I don't know |
|---|---|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ | ❑ | ❑ |

4. If you routinely board Route 80 or 84 on Watt Avenue or at one of the light rail stations, which of the following statements most closely describes your experience? (Please mark **ONLY ONE**.)

❑ I can rely on the bus arriving within a few minutes of a certain time.

❑ I never know if the bus will be on time so I get to the stop early or take an earlier bus.

❑ I don't worry about the schedule; I just go to the stop to wait for the next bus.

❑ I'm transferring; I don't have any choice but to wait for the next bus.

❑ None of the above, I ________________________________________________________

5. About how long have you been using the bus **ON WATT AVENUE**?

| More than 1 year | 6 months to 1 year | 3 to 6 months | Less than 3 months | I don't know |
|---|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ | ❑ |

6. If you have been riding buses along Watt Avenue for more than 1 year, would you say that **BUS SERVICES ON WATT AVENUE** are:

❑ More reliable than 1 year ago. ❑ Same as 1 year ago.

❑ Less reliable than 1 year ago. ❑ I'm not sure.

**(OVER PLEASE)**

1. About how often do you ride Route 80 or 84 **ALONG WATT AVENUE**?

   - ❑ Almost every day.
   - ❑ A few times a week.
   - ❑ A few times a month.
   - ❑ Almost never.
   - ❑ This is my first time.

2. For what purposes do you most often take the bus **ALONG WATT AVENUE**? (You may mark more than one.)

   - ❑ Work
   - ❑ School
   - ❑ Shopping
   - ❑ Visiting friends or family
   - ❑ Medical or dental appointments
   - ❑ Other________________________

3. How often do you use **ROUTE 80** or **ROUTE 84** to connect with light rail service?

   - ❑ Almost every day.
   - ❑ A few times a week.
   - ❑ A few times a month.
   - ❑ Almost never.
   - ❑ This is my first time.

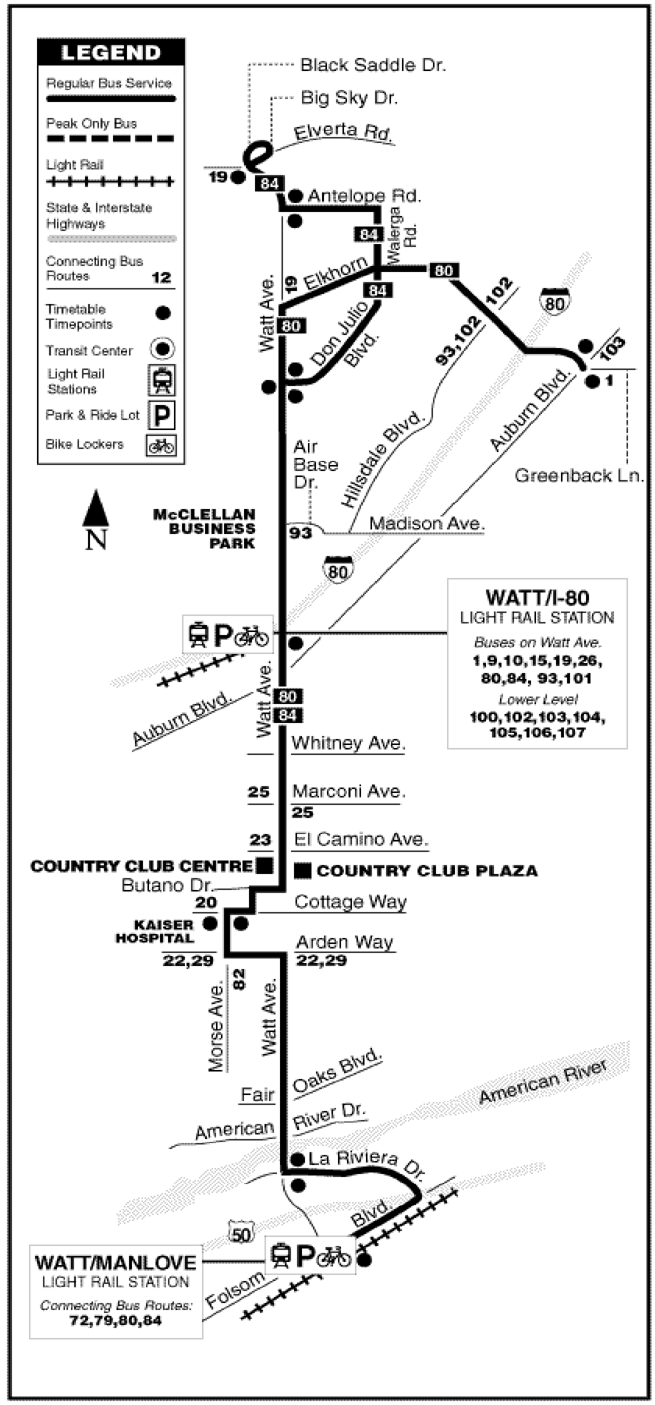
Thinking of the trip you are making right now, use the name of a neighborhood, shopping area, employer area, school, medical facility or intersection to answer the following questions:

4. Where did you start **THIS TRIP?**

   ______________________________________

5. Where do you plan to end **THIS TRIP**?

   ______________________________________




6. Using the map above, please mark an **X** near where you boarded **THIS BUS**

7. Again using the map above, please mark an **O** near when you plan to get off **THIS BUS**.

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Please return this survey form to the survey worker as you leave the bus.

**Thank you very much.**