Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-08/0-5571-1		

4. Title and Subtitle	5. Report Date
MEASURES, METHODS, AND APPLICATION OF A MOBILITY MONITORING PROCESS FOR SMALL TO MEDIUM-SIZED COMMUNITIES	Published: December 2007
	6. Performing Organization Code
7. Author(s) William L. Eisele, Jason A. Crawford, and Rachael L. Stensrud	8. Performing Organization Report No. Report 0-5571-1
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. Project 0-5571
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080	13. Type of Report and Period Covered Technical Report: September 2006 – August 2007
	14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

Project Title: Congestion Monitoring Measures and Procedures for Small to Medium-Sized Communities

URL: http://tti.tamu.edu/documents/0-5571-1.pdf

16. Abstract

Many TxDOT districts struggle with congestion issues in growing small to medium-sized communities (SMSCs). Congestion in these communities is often highest along state highways that also serve major local travel functions. The objective of this one-year research project was to develop and test a framework for congestion monitoring in SMSCs, including economical (low-cost) monitoring techniques and the normal range of improvements for SMSCs. This report summarizes the activities and results for this one-year project.

Researchers developed a six-step framework for performing on-going mobility monitoring in SMSCs. The framework was applied in two pilot study locations—one in a small-sized community (less than 50,000 population with no metropolitan planning organization [MPO] presence), and another in a medium-sized community (greater than 100,000 population with a MPO presence). Researchers collected travel time data using test vehicles instrumented with global positioning system (GPS) equipment, pneumatic tube traffic volume data, and performed videologs of the 14 (total) corridors. Researchers performed a stopped delay study at one location. Researchers developed methods to effectively communicate mobility monitoring results to both technical and non-technical audiences. A survey of SMSCs was performed to obtain a better understanding of congestion definitions, monitoring activities, and when, where, and why congestion occurs in SMSCs.

Researchers developed numerous outreach materials including a guidebook entitled *Guidebook for Mobility Monitoring in Small to Medium-Sized Communities: A How-To Guide* for technical audiences, a companion (smaller) document for non-technical audiences, tri-fold brochure for the general public, one-page overview of the framework, interactive CD with PowerPoint® presentations to technical and non-technical audiences and an interactive case study, and preliminary workshop lesson plans. The results documented in this research report, and the associated outreach materials will be useful for TxDOT staff in small to medium-sized communities as well as TxDOT's partnering agencies, including MPOs, municipalities, and counties.

17. Key Words	18. Distribution Statement
Mobility Monitoring, Congestion Monitoring, Congestion Measures, System Performance, Travel Time Data Collection, Small Communities, Medium-Sized Communities	No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	340	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

MEASURES, METHODS, AND APPLICATION OF A MOBILITY MONITORING PROCESS FOR SMALL TO MEDIUM-SIZED COMMUNITIES

by

William L. Eisele, Ph.D., P.E.
Research Engineer
Texas Transportation Institute

Jason A. Crawford, P.E.
Associate Research Engineer
Texas Transportation Institute

and

Rachael L. Stensrud, E.I.T.
Graduate Assistant Research
Texas Transportation Institute

Report 0-5571-1
Project 0-5571
Project Title: Congestion Monitoring Measures and Procedures for Small to Medium-Sized Communities

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

Published: December 2007

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

DISCLAIMER

ACKNOWLEDGMENTS

The authors would like to thank the Texas Department of Transportation (TxDOT) and Federal Highway Administration for sponsoring this research.

The authors appreciate the on-going assistance and guidance of the project director, Mr. Robert Appleton, P.E., Director of Transportation Planning and Development of the Bryan TxDOT District, as well as that of the program coordinator, Mr. Robert Stuard, P.E., Deputy District Engineer of the Austin TxDOT District. Also making valuable contributions and providing insight into the project were the remaining members of the Project Monitoring Committee (PMC):

- Mr. Andrew Canon, Director, Hidalgo County Metropolitan Planning Organization
- Mr. Peter Eng, P.E., Director of Transportation Operations, TxDOT Tyler District
- Mr. Ken Fogle, P.E., Transportation Planner, City of College Station
- Mr. Blair Haynie, P.E., Director of Transportation Planning and Development, TxDOT Abilene District

The authors would like to thank Dr. Duncan Stewart, P.E. and Ms. Loretta Brown of TxDOT's Research and Technology Implementation Office for their exceptional support and guidance on this project.

The authors would like to thank the following local transportation professionals in the Bryan-College Station and Huntsville areas, who provided oversight, support, and guidance for the mobility monitoring pilot studies performed in their communities.

- Mr. Bart Benthul, Bryan-College Station MPO
- Mr. Bill Conaway, College Station Independent School District
- Mr. John Dean, City of Bryan
- Mr. Ken Fogle, P.E., City of College Station
- Ms. Linda Huff, City of Bryan
- Ms. Mary Martin, City of Bryan
- Mr. Mike Parish, Bryan Independent School District
- Mr. Michael Parks, Brazos Valley Council of Governments
- Mr. Brad Partee, TxDOT Huntsville Area Office
- Mr. Troy Rother, City of College Station
- Mr. Grady Slaydon, Bryan Independent School District
- Mr. Steve Stacy, P.E., City of Huntsville
- Mr. David Stephens, P.E., TxDOT Area Office
- Ms. Jennifer Timms, Bryan-College Station MPO
- Mr. David Welch, City of Huntsville
- Mr. Bobby Wells, TxDOT Huntsville Area Office
- Ms. Lynn Wiggs, Transportation Services, Texas A&M University

The authors would like to thank Ms. Pam Rowe for her assistance in word processing this document and the Project Summary Report. The authors would also like to thank the numerous individuals from TTI's Communications Group that assisted with creative design and development of the product (0-5771-P1). The authors would like to thank the numerous TTI students and staff who assisted in the extensive data collection, data reduction, and data analysis performed for this project.

TABLE OF CONTENTS

Page

Table of Contents, Continued

Page

Table of Contents, Continued

Page

Table of Contents, Continued

Page

LIST OF FIGURES

List of Figures, Continued

Page

List of Figures, Continued

Page

List of Figures, Continued

Page

List of Figures, Continued

Page

List of Figures, Continued

Page

List of Figures, Continued

Page

List of Figures, Continued

List of Figures, Continued

Page

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

Many TxDOT districts struggle with congestion issues in growing small to medium-sized communities (SMSCs). Congestion in these communities is often highest along state highways that also serve major local travel functions. While there are extensive resources and literature dedicated to measuring, monitoring, and improving large urban area congestion, there is a need for guidance for small to medium-sized communities (population <250,000) to better understand and alleviate congestion before the problems escalate. Potential solutions and performance measure targets necessarily are much different for smaller communities than those identified in the literature for urban areas.

TxDOT, and its local partnering agencies, will benefit from a framework for performing mobility monitoring in SMSCs that establishes local community congestion targets and establishes baseline conditions for a continued monitoring effort.

1.2 PROJECT OBJECTIVE

The primary objective of this research was to develop and test a framework for congestion monitoring in SMSCs, including economical (low-cost) monitoring techniques and the normal range of improvements for SMSCs.

1.3 WORK PLAN

Five tasks were performed to satisfy the project objective in section 1.2. These tasks are described in the subsections of this section.

1.3.1 Task 1: Examination of Related Material

The first task was an examination of material related to the research. The objective of this task was to build upon the research team's extensive knowledge of literature related to, or that could be adopted for, mobility monitoring in SMSCs. The research team targeted literature that assisted in guiding the user through the key steps of a mobility analysis targeted for smaller communities. In this task, the research team identified resources that addressed the following sampling of questions:

- What is important to small to medium-sized communities?
- What are typical needs/uses of congestion monitoring in small to medium-sized communities?
- What are common causes of congestion in small to medium-sized communities?
- When does congestion occur in small to medium-sized communities?
- How can data be best collected in a cost-effective manner for small to medium-sized communities?
- What are the benefits to these communities for having on-going congestion monitoring?

- What is the normal range of improvements in small to medium-sized communities, and what is the relative cost scale?
- How are congestion monitoring results best communicated to appropriate audiences in small to medium-sized communities?
- How are on-going congestion monitoring efforts best planned and programmed to ensure implementation and future monitoring in small to medium-sized communities?

The research team held a kick-off meeting with the Project Monitoring Committee (PMC) during this task. At the conclusion of this task, an executive summary of the state-of-the-practice review was documented in a technical memorandum that will be sent to the project director (PD), with a copy to the TxDOT Research and Technology Implementation (RTI) Office.

1.3.2 Task 2: Framework Development

The second task was to develop the framework for mobility monitoring in SMSCs. The framework leads the user through the key questions for developing and implementing a low-cost mobility monitoring program. The framework development was built from the literature identified in Task 1, and the experiences of the research team in the area of mobility monitoring. The framework was ultimately developed to guide the user through the appropriate steps that must be included in a mobility analysis targeted to SMSCs.

Researchers met with the PMC in December 2006 to discuss the framework development. At the conclusion of this task, researchers documented and summarized the framework in a technical memorandum that was sent to the PD, with a copy to the TxDOT (RTI) Office.

1.3.3 Task 3: Selection of Pilot Study Locations to Test Framework

The objective of this task was to select the two pilot study locations where the framework would be applied along numerous on-system roadways in SMSCs. The pilot studies provided for subsequent fine-tuning of the framework based upon field applications. Along with the framework developed in Task 2, the lessons learned from the pilot studies provided valuable content for the guidebook.

Researchers tested the framework at two case studies—one in a small-sized community (<50,000 with no metropolitan planning organization [MPO] presence), and another in a medium-sized community (>100,000 and <250,000 with MPO presence). This approach allowed the research team to identify framework lessons learned at different ends of the population scale. The Bryan-College Station, Texas, community was selected as the medium-sized community with MPO presence, while Huntsville, Texas, was selected as the small-sized community.

At the conclusion of this task, the research team documented and summarized the reasoning for the final selection of the specified communities. This documentation was in the form of a technical memorandum sent to the PD, with a copy to the TxDOT RTI Office.

1.3.4 Task 4: Pilot Study Applications of Framework

The objective of Task 4 was the application of the framework developed in Task 2 to the two pilot study locations identified in Task 3. The pilot studies provided two opportunities to implement the framework by determining the typical needs/uses of a congestion monitoring effort for a small to medium-sized community, identifying the subsequently appropriate performance measures, collecting appropriate data (e.g., travel time runs, traffic counts, etc. to satisfy local mobility goals/concerns) on selected corridors, performing subsequent analysis, and developing methods to best communicate the results to the different users. The pilot studies also provide the foundation for annual mobility monitoring reports in the TxDOT district/community evaluated.

The research team met with the PMC at the end of this task (June 2007) to discuss findings and conclusions related to the data collection, data reduction, data analysis, generated graphics for communicating results, and lessons learned for both pilot study locations.

At the conclusion of this task, the research team documented and summarized the key recommendations and conclusions for congestion monitoring in small to medium-sized communities resulting from the development and application of the framework. This documentation was in the form of a technical memorandum to the PD, with a copy to the TxDOT RTI Office.

1.3.5 Task 5: Develop Guidebook, PowerPoint® Presentations, Interactive CD, Preliminary Lesson Plans, and Research Reports

The purpose of this task is to produce the deliverables (product, reports, PowerPoint® presentations, preliminary lesson plans) that TxDOT personnel and TxDOT's partnering agencies can use to implement mobility monitoring in small to medium-sized communities. The deliverables include the following:

Guidebook

The guidebook provides "how-to" instruction from start to finish for performing on-going mobility monitoring for small to medium-sized communities (*1*). The guidebook leads the user through the six steps of the framework by prompting the user to answer key questions that arise during the process of monitoring mobility in SMSCs. The guidebook is intended to target a technical audience, and steps through each step using an invented case study scenario.

A companion document is included in the guidebook. The companion document provides information on mobility monitoring to a broader audience that may not be interested in the level of detail shown in the guidebook. The companion document presents the highlights of the framework for general audiences. A tri-fold brochure is also included in the guidebook to target the general public, and encourage public input into the mobility monitoring process. The CD also includes an overview quick reference of the framework steps on one page.

There is also an interactive CD at the end of the guidebook. The CD includes PowerPoint® presentations to both a technical and a non-technical audience about how to implement mobility monitoring in an SMSC using the framework and techniques identified in this guidebook. The CD also includes an interactive element that allows the viewer to navigate through the invented case study scenario. The CD also includes related web links, and PDF files of the guidebook, companion document, tri-fold, overview page, and research reports.

A pocket at the back of the guidebook serves for the user to store notes and other reference materials as well.

Preliminary Lesson Plans

Because research implementation is the primary goal of any research project, researchers developed a preliminary lesson plan to illustrate how the project materials could be presented in a workshop setting to TxDOT district staff as part of a follow-up implementation project. The research team has extensive experience in the development and instruction of workshops, seminars, and courses for TxDOT and other sponsors, and the materials will lend themselves to a workshop setting. Some of the items included in the lesson plan are:

- an outline of the topical areas covered,
- who would attend such workshops, and
- possible exercises.

The completed preliminary lesson plans were included in a technical memorandum to the PD, with a copy to the TxDOT RTI Office.

Research Report and Project Summary Report

The research methodologies and findings were documented in this report, and also in a Project Summary Report (*2*).

1.4 REPORT ORGANIZATION

This report is organized into nine chapters, as described below:

- Chapter 1, Introduction: Provides an overview of the research objective, tasks, and report organization.
- Chapter 2, Examination of Related Material: Provides an overview of the literature review.
- Chapter 3, Small to Medium-Sized Community Mobility Monitoring Framework: Describes the development of the framework and provides an overview of the framework steps.
- Chapter 4, Case Studies and Collected Data: Highlights the case studies and data sources.
- Chapter 5, Data Reduction, Analyses, and Findings: Provides an overview of the data reduction, analyses, and findings of the framework applications.
- Chapter 6, Communicating Mobility Monitoring Results: Introduces methods for presenting mobility monitoring information to technical and non-technical audiences.
- Chapter 7, Implementation Resources: Provides an overview of the implementation resources available as a result of this project.
- Chapter 8, Conclusions and Discussion: Provides concluding comments summarized from each chapter.
- Chapter 9, References: Provides a listing of the references used in this report.

CHAPTER 2
EXAMINATION OF RELATED MATERIAL

2.1 INTRODUCTION

This project was designed to provide TxDOT with a framework for determining mobility monitoring measures and procedures for SMSCs. The framework will provide insight into how mobility monitoring can be used to establish local community congestion targets and establish baseline conditions for a continued mobility monitoring effort.

To this end, the literature review described below highlights key findings and research with a focus on SMSCs organized into the following sections:

- defining congestion and congestion trends,
- congestion performance measures,
- typical causes of congestion,
- typical processes for mobility monitoring by population size,
- locations for mobility monitoring in SMSCs,
- travel time data collection,
- responsible parties for mobility monitoring and on-going funding,
- typical congestion improvements,
- communicating monitoring results,
- selected case studies of mobility monitoring,
- arterial travel time estimation models and methods,
- mobility monitoring frameworks, and
- concluding remarks.

For reference, recall that for the purposes of this research, "small-sized communities" are classified as areas with a population of less than 100,000 and "medium-sized communities" are classified as areas with a population between 100,000 and 250,000.

2.2 DEFINING CONGESTION AND CONGESTION TRENDS

Title 23, Part 500, Section 500.109 of the Transportation Equity Act for the 21st Century (TEA 21) provides a qualitative definition of congestion as "*the level at which transportation system performance is no longer acceptable due to traffic interference.*" A more technical definition is "*the inability to reach a destination in a satisfactory time due to slow travel speeds*" (*3*). Congestion is best defined through the eyes of the delayed—what constitutes congestion in one location may be different in another location.

Nationally, congestion has increased significantly over the last 20 years. The Texas Transportation Institute's (TTI) annual Urban Mobility Report (*4*) monitors congestion in 85 metropolitan areas in the United States by population size. This report estimates total delay in 1982 was 0.7 billion hours compared to an estimated 3.7 billion hours in 2003. The magnitude of this increase is shown in Figure 2-1.

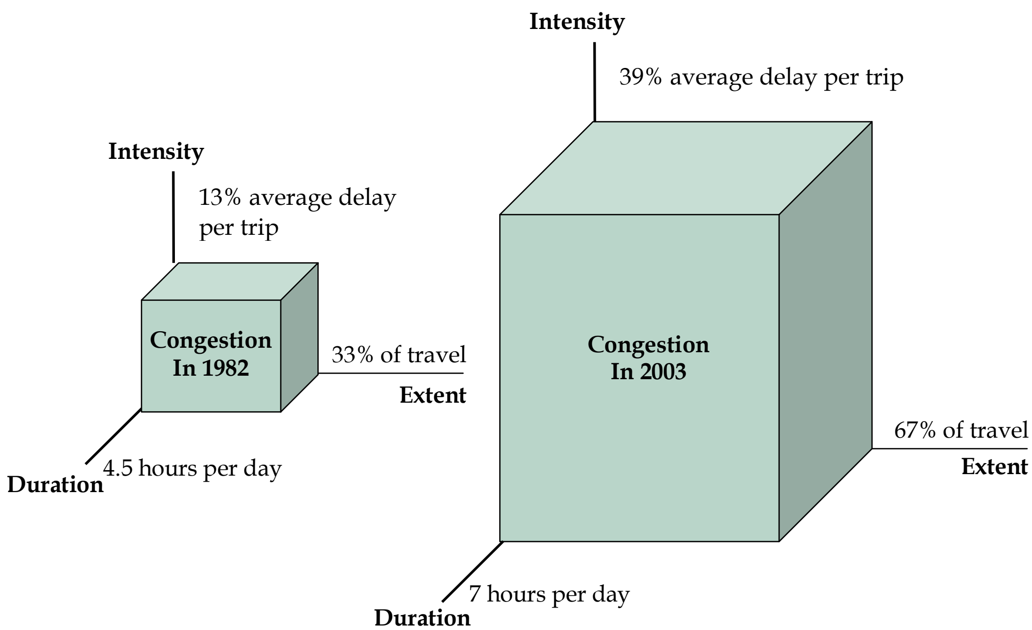


Figure 2-1. Magnitude of Urban Congestion Increase (Reference *5*).

The congestion trends of eight selected SMSCs in Texas are shown in Figure 2-2 based upon TTI analysis from 1994 to 2003 (the last year of available data). The 2003 populations of these cities are shown in the figure and range from 60,000 (Galveston) to 210,000 (Lubbock). Figure 2-2 shows the relatively steady increase in congestion as measured by the Travel Time Index—an index that compares the peak-period travel rate to the free-flow travel rate. The result of the analysis is clear—congestion levels are increasing in small to medium-sized communities in Texas.

2.3 CONGESTION PERFORMANCE MEASURES

A myriad of congestion performance measures are available. Congestion measures should be developed only after an examination of the uses and audiences to be served, the full consideration of program goals and objectives, and the nature of likely solutions (*3*). Rarely is there just one congestion measure that can communicate all that is needed to all users. Congestion itself has been described as having three components as follows (*3*):

- Duration—the length of time during which congestion affects the travel system.
- Extent—the number of people or vehicles affected by congestion and by the geographic distribution of congestion.
- Intensity—the severity of congestion that affects travel is a measure from an individual traveler's perspective.

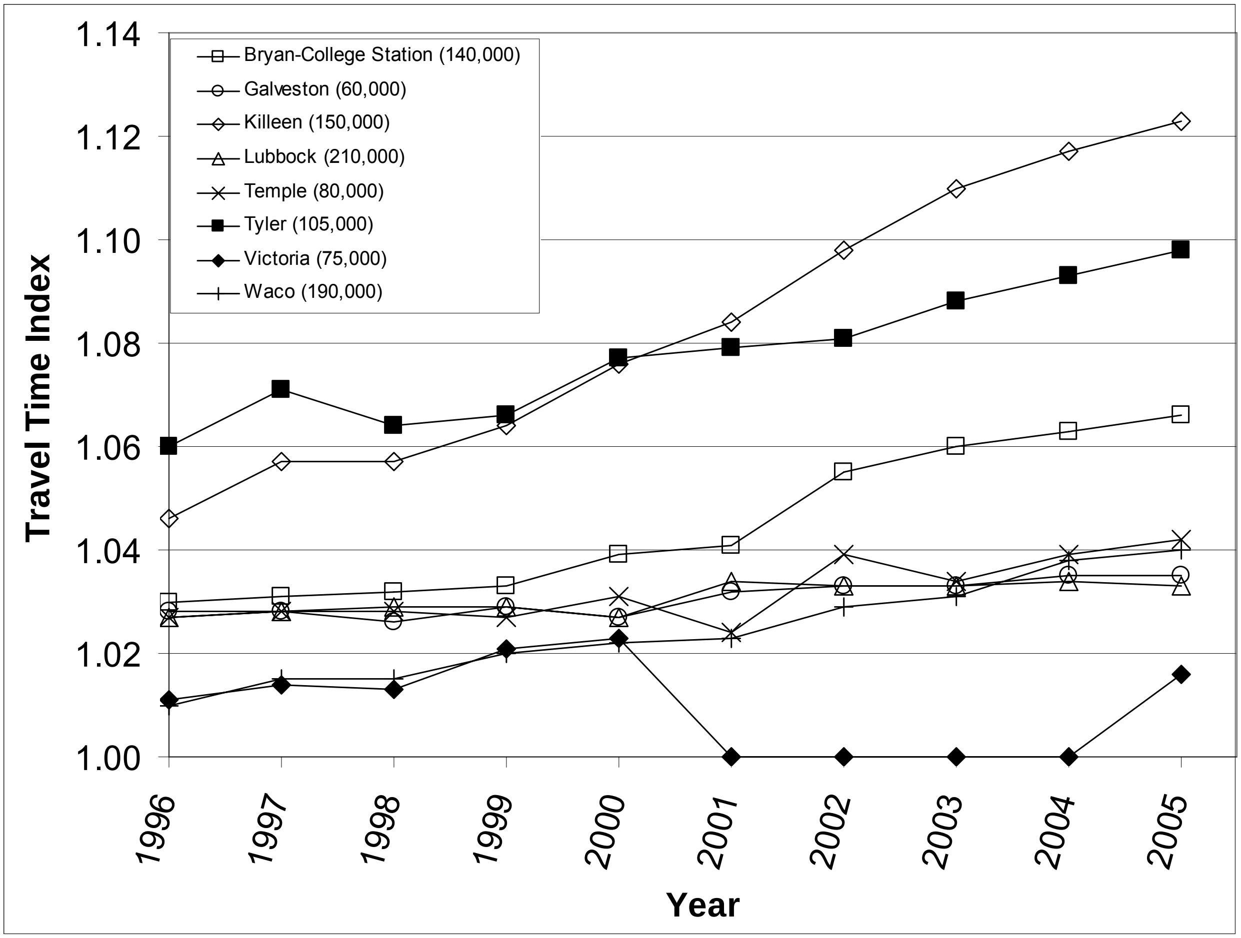


Figure 2-2. Travel Time Index for Small to Medium-sized Texas Cities (Source: TTI Analysis).

Traditional measures of congestion include the volume-to-capacity ratio (V/C) and level-of-service (LOS). Historically, the evaluation of infrastructure projects was performed with volume and capacity data. Traffic volume and roadway capacity based measures do work well for some applications, but they do have limitations. They tend to be “engineering-based” and are difficult to communicate to the general public. Multimodal mobility analysis is important, and such measures are good for counting vehicles, but not persons.

Alternatively, the National Cooperative Highway Research Program Report (NCHRP) 398, *Quantifying Congestion* indicates that travel time based measures are more flexible, and more useful for a broad range of uses and audiences (*6*,*7*). They are far easier to communicate to the public. Many MPOs and states have adopted travel time based measures.

Table 2-1 presents both individual and areawide travel time based mobility measures as defined in TTI's *The Keys to Estimating Mobility in Urban Areas.* The report provides readers with instruction on selecting mobility measures, identifying mobility objectives and performance measure target values, describing a process for monitoring mobility, performing data collection, and communicating results (*3*). The report includes a chapter on the application and interpretation of congestion measures for different types of analyses (e.g., comparing modes, comparing operational treatments, various geographic scopes, real-time data applications), including accompanying spreadsheets for computation. All of these chapters, and the accompanying spreadsheets, are useful for developing a framework to establish mobility monitoring in small to medium-sized communities.

A recent study by ICF Consulting investigated the innovative practices of various congestion management systems (CMSs) for the New York State Association of MPOs (*8*). Areas over 200,000 in population are required to have a congestion management system in place to manage congestion and improve mobility of traffic, people, and goods. The study identified several MPOs in New York State that were using more traditional measures of V/C and LOS. In addition, several MPOs in New York State were identified that augment traditional count data with travel demand model data to estimate vehicle-hours of delay or person-hours of delay as well as excess delay computations. Table 2-2 provides a summary of some of the selected MPOs cited in the ICF Consulting work, and the measures they are using that go beyond the traditional V/C and LOS-based congestion measures. Table 2-2 provides a good sampling of how selected MPOs are supplementing traditional V/C and LOS-based congestion measures with travel time based measures. Additional case studies are investigated in more detail in a latter section of the literature review.

2.3.1 Defining and Monitoring Travel Time Reliability

Travel time reliability is becoming a more important term in mobility monitoring. It is defined as "*the level of consistency in transportation service hour-to-hour and day-to-day*" (*3*). In more laymen's terms, it is how travel times vary over time and the confidence a traveler has in completing a trip within a reasonable time. This confidence is challenged by non-recurring congestion events (e.g., incidents). As travelers lose confidence in completing their trip within a reasonable time, they behaviorally add more time to make the trip (e.g., 15 minutes in lieu of 10 minutes previous). Figure 2-3 illustrates that traditionally monitored average conditions do not monitor this day-to-day variability. The Buffer Index is a typical measure of travel time reliability, which is computed as the difference between the 95th percentile travel time and the average travel time, divided by the average travel time. A Buffer Index of 40 percent means that for a trip that usually takes 20 minutes, an additional 8 minutes should be added to the trip travel time to ensure on-time arrival (*9*).

Table 2-1. Travel Time Based Mobility Measures (Adapted from Reference 3).

INDIVIDUAL MEASURES[1]	
Delay per Traveler[2]	$\text{Delay per Traveler (annual hours)} = \dfrac{\left(\text{Actual Travel Time (minutes)} - \text{FFS or PSL Travel Time (minutes)}\right) \times \text{Vehicle Volume (vehicles)} \times \text{Vehicle Occupancy (persons/vehicle)} \times \dfrac{250 \text{ weekdays}}{\text{year}} \times \dfrac{\text{hour}}{60 \text{ minutes}}}{\text{Vehicle Volume (vehicles)} \times \text{Vehicle Occupancy (persons/vehicle)}}$
Travel Time	$\text{Travel Time (person – minutes)} = \text{Actual Travel Rate (minutes per mile)} \times \text{Length (miles)} \times \text{Vehicle Volume (vehicles)} \times \text{Vehicle Occupancy (persons/vehicles)}$
Travel Time Index or Travel Rate Index[3,4]	$\text{Trave Time Index or Travel Rate Index} = \dfrac{\text{Actual Travel Rate (minutes per mile)}}{\text{FFS or PSL Travel Rate (minutes per mile)}}$
Buffer Index[3]	$\text{Buffer Index (\%)} = \left[\dfrac{\text{95th Percentile Travel Time (minutes)} - \text{Average Travel Time (minutes)}}{\text{Average Travel Time (minutes)}}\right] \times 100\%$
Planning Time Index[3]	$\text{Planning Time Index (no units)} = \dfrac{95^{th} \text{ Percentile Travel Time (minutes)}}{\text{FFS or PSL Travel Time (minutes)}}$
AREA MOBILITY MEASURES[1]	
Total Delay	$\text{Total Segment Delay (person - minutes)} = \left[\text{Actual Travel Time (minutes)} - \text{FFS or PSL Travel Time (minutes)}\right] \times \text{Vehicle Volume (vehicles)} \times \text{Vehicle Occupancy (persons/vehicle)}$
Congested Travel	$\text{Congested Travel (vehicle - miles)} = \sum \left(\text{Congested Segment Length (miles)} \times \text{Vehicle Volume (vehicles)}\right)$
Percent of Congested Travel	$\text{Percent of Congested Travel} = \left[\dfrac{\sum_{i=1}^{n}\left(\left(\text{Actual Travel Time}_i \text{ (minutes)} - \text{FFS or PSL Travel Time}_i \text{ (minutes)}\right) \times \left(\text{Vehicle Volume}_i \text{ (vehicles)} \times \text{Vehicle Occupancy}_i \text{ (persons/vehicle)}\right)\right)_{\text{Each congested segment}}}{\sum_{j=1}^{m}\left(\text{Actual Travel Rate}_j \text{ (minutes per mile)} \times \text{Length}_j \text{ (miles)} \times \text{Vehicle Volume}_j \text{ (vehicles)} \times \text{Vehicle Occupancy}_j \text{ (persons/vehicle)}\right)_{\text{All segments}}}\right] \times 100$
Congested Roadway	$\text{Congested Roadway (miles)} = \sum \text{Congested Segment Length (miles)}$
Accessibility	$\text{Accessibility (opportunities)} = \sum \text{Objective Fulfillment Opportunities (e.g., jobs), where Travel Time} \leq \text{Target Travel Time}$

[1]"Individual" measures are those measures that relate best to the individual traveler, whereas the "area" mobility measures are more applicable beyond the individual (e.g., corridor, area, or region). Some individual measures are useful at the area level when weighted by PMT (Passenger Miles Traveled) or VMT (Vehicles-miles of Travel).
[2]As a practical matter, total delay (in person-minutes) is usually computed first (see definition in the table), and is useful as an area mobility measure. The total delay is then converted to delay per traveler (in annual hours) as shown here by dividing by the number of peak-period travelers. Note that the vehicle volumes multiplied by the vehicle occupancy do not, therefore, cancel out.
[3]Can be computed as a weighted average of all sections using VMT or PMT.
[4]Referred to as a "travel rate index" when the data source does not include incident conditions (e.g., using non-continuous data such as test vehicles for travel time estimation).
Note: FFS = Free-flow speed, PSL = Posted speed limit. Where FFS or PSL occur in the equations above, typically the prevailing travel rate (or travel time) is used during light traffic (not to be lower than the travel time at the posted speed limit).

Table 2-2. Characteristics of Selected MPOs Using Travel Time Based Congestion Measures (Adapted from Reference *8*).

MPO Name / Location	Applications Included and Travel Time Based Measures Used	Additional Detail
Atlanta Regional Council, Atlanta, Georgia	Goods movement, land use connectivity, intermodal connectivity, transit service, commuter-potential transit, safety, environmental justice, committed investments	V/C still used; these broader measures are used for identifying high-priority corridors.
Capital Area Metropolitan Planning Organization (CAMPO), Austin, Texas	Went to travel-speed-related measures to identify congested locations. CAMPO has defined minimum threshold acceptable speeds, based on roadway type and area (i.e., lower speeds are more acceptable in central business district).	Travel time based measures allow for multimodal analysis. Global positioning system (GPS)-enabled vehicles used to measure travel times using the floating car method. Intersection delay also investigated.
Hillsborough County MPO, Tampa, Florida	Uses tiered performance measures. First tier includes basic roadway performance measures (V/C, transit ridership, sidewalk and bicycle facility extent); second tier for identified congested corridors including modal data, travel time surveys, pedestrian counts, rideshare programs, and transit on-time performance; third tier is system-wide measures collected every three to five years.	Effectively monitors transportation system while expending monitoring resources efficiently.
Greenville South Carolina MPO	Percent of time at free-flow. Travel time surveys for 33 routes using GPS technology.	Roadways grouped into tiers based on congestion severity.
Pioneer Valley Planning Council, Springfield, Massachusetts	Travel time measures of delay and congestion indices.	Uses travel demand model to develop V/C ratios for all corridors, and supplements this with travel time runs.
Regional Transportation Commission, Southern Nevada, Las Vegas, Nevada	V/C for initial identification of roadway congestion; also V/C or percent reduction in speed (intensity), number of hours congestion exceeds a given threshold (duration), number of persons or vehicles affected (extent), and reliability calculated based on crash rates.	Weights for the four components and a scoring process for each component was developed on a 0 to 100 scale to assist in the prioritization.
Rhode Island Statewide Planning, Providence, Rhode Island	Travel time measures include: percent under posted speed, incident clearance time, travel time index, delay reduction, delay cost, and percent of congested travel.	Analysis performed for three time periods: peak, off-peak, and seasonal.

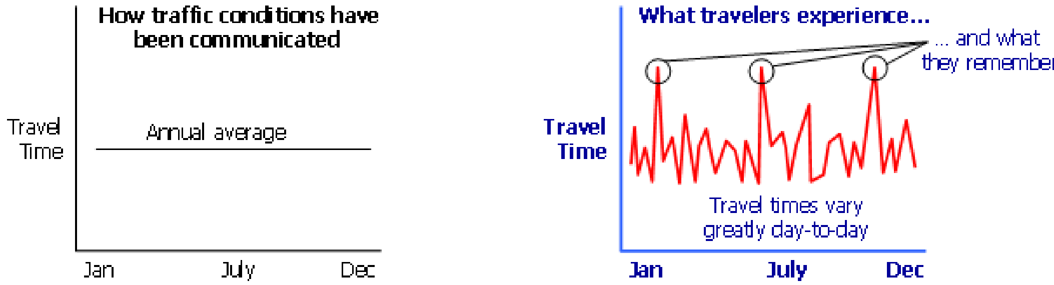


Figure 2-3. Average Conditions Do Not Capture Day-to-Day Variability (Reference *9*).

Monitoring travel time reliability requires continuous data sources (e.g., automatic vehicle identification, inductance loop data) that provide operational data from day-to-day and hour-to-hour. Typically, such data sources are only available on primary freeway routes in larger urban areas. TTI with Cambridge Systematics is currently monitoring mobility trends, including reliability measures, using continuous data sources in 29 cities as documented in the last Mobility Monitoring Program (MMP) report for the Federal Highway Administration (FHWA) (*10*). While most small to medium-sized communities may not currently have continuous data sources available, they should be aware of the importance of reliability measures and incorporating them in future mobility monitoring efforts.

2.4 TYPICAL CAUSES OF CONGESTION

A recent report by Cambridge Systematics with TTI (*5*) for FHWA notes seven root causes for urban congestion. The causes identified are:

1. Physical Bottlenecks—Limited capacity of the roadway, including physical constraints (lane configurations) at intersections;
2. Traffic Incidents—Events that disrupt the normal flow of traffic, usually by physical impedance in the travel lanes;
3. Work Zones—Construction activities on the roadway that result in physical changes to the highway environment;
4. Weather—Environmental conditions can lead to changes in driver behavior that affect traffic flow;
5. Traffic Control Devices—Excess demand for the control device to handle properly;
6. Special Events—A special case of demand fluctuations whereby traffic flow in the vicinity of the event will be radically different from “typical” patterns; and
7. Fluctuations in Normal Traffic—Day-to-day variability in demand leads to some days with higher traffic volumes than others.

These factors also cause congestion in small to medium-sized communities. Typical examples of physical bottlenecks (item #1 above) in small to medium-sized communities include increasing highway traffic volumes, increased trucks, and new businesses that need truck deliveries from the street where there is limited roadway capacity. Another example is the "classic case" of large "big box" developments (e.g., Wal-Mart, Home Depot, Best Buy) being developed and opened prior to adequate infrastructure being built. Not unlike large urban areas, in small and medium-sized communities, this "classic case" begins with the fact that many people wish to remain outside of the city to maintain their rural living conditions and quality of life. As smaller communities continue to grow and increase their population, their demographic characteristics will surpass certain thresholds that attract the attention of, and will sustain, these bigger developments.

Smaller communities typically face challenges dealing with, and planning for, these types of development. These challenges might include:

- Lack of staff experience familiar with the traffic implications of these developments.
- Absence of appropriate ordinances and regulations in place to adequately plan for such development (particularly those communities <50,000 in population). For example, without requirements for a traffic impact analysis (TIA), the developer might be allowed to build their large retail center, thus substantially increasing the traffic on the adjacent road, but not be required to build mitigating improvements to the infrastructure to handle the new development.
- Unfamiliarity with appropriate measures and methods of monitoring congestion along key growth corridors.

Causes of congestion will certainly vary by city size. Congestion itself certainly is relative by city size, and the potential solutions and performance measure targets necessarily are much different for smaller communities than for large urban areas. How a community locally defines congestion, and how it assesses its transportation system performance, are key elements for how it chooses to both monitor and address congestion.

2.5 TYPICAL PROCESSES FOR MOBILITY MONITORING BY POPULATION SIZE

CMSs are meant to manage congestion and improve mobility of traffic, people, and goods. Congestion management systems were first required for transportation management areas (TMAs) under the Intermodal Surface Transportation Efficiency Act (ISTEA) and reaffirmed in both the TEA-21 and the Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). Congestion management system requirements do not extend to areas less than 200,000 population. Areas of less than 200,000 in population certainly could adapt a CMS to meet their monitoring needs, and would then have a tool for measuring and monitoring congested corridors in the region.

Urban system monitoring is a growing federal concern. The SAFETEA-LU legislation includes the Surface Transportation Congestion Relief Solutions program. One focus of this program is congestion management and reporting. The legislation also increases emphasis on performance measurement. Implementation of performance measures is growing in large metropolitan areas and is expected to extend to smaller metropolitan areas. A sampling of the questions/issues that arise are:

- What are the community goals and objectives?
- What should be measured (spatially/temporally/modally) related to those goals and objectives?
- What are good measures?
- How should they be monitored to ensure useful results
- How are results communicated most effectively?

2.6 LOCATIONS FOR MOBILITY MONITORING IN SMALL TO MEDIUM-SIZED COMMUNITIES

In SMSCs, major roads with existing or anticipated congestion are the likely candidates of mobility monitoring. Commuting routes into or from the community or from the community to a larger metropolitan area may feel or appear congested as people travel to and from work each day. Smaller communities may have limited transportation capacity both leading into and within the community. This limited capacity can become congested at festival times or as traffic for special events (e.g., high school football games) in other distant cities passes through the community or is destined for their community. Likewise, intercity (through-movement) commodity flows on surface streets may cause congestion along particular roadways that can be targeted for mobility monitoring.

Fringe areas around communities or metropolitan areas may experience, or may be planned for, high growth. Typically in these growth areas, the transportation system has not developed to a level to support the increasing transportation demand placed upon it.

Finally, SMSCs may be concerned with movement between important origin-destination points. These may be retail centers, employment centers, medical centers, or residential areas. Community leaders may seek to preserve or improve the travel mobility and reliability between these points.

2.7 TRAVEL TIME DATA COLLECTION

Effective mobility monitoring relies on data that provide insight into the duration, extent, and intensity of congestion in a community. As discussed previously, travel time and speed measures tend to communicate the congestion message most effectively. In locations where intelligent transportation systems (ITS) instrumentation is available (e.g., inductance loop detectors, probe vehicles), travel time and speed data can be obtained directly from real-time data sources. When such data are not immediately available, travel time data can be collected using a "test vehicle method."

The test vehicle method includes a data collection vehicle where an observer records cumulative travel time at predefined checkpoints along a travel route. Different test vehicle techniques are available, including *(11)*:

- Manual—A passenger in the test vehicle manually records the elapsed time at predefined checkpoints, or the driver (alone) voice records marks at predefined checkpoints.

- Distance Measuring Instrument (DMI)—A travel time along a corridor is processed based upon speed and distance information recorded by an electronic DMI connected to the test vehicle's transmission.
- Global Positioning System (GPS)—Computer software processes the travel time from data recorded by instrumentation that determines the test vehicle position and speed by using signals from earth-orbiting satellites.

Manual methods require two individuals in the vehicle, the test vehicle driver and a recorder. Manual techniques might include use of a pen and paper or a tape recorder. Travel time data collection using DMI or GPS can typically be performed using only a driver for the test vehicle. Manual methods require manual data input and reduction. Data collected by DMI or GPS technologies do require software to reduce the data; however, such software can automate the data reduction process, particularly if monitoring is performed on a periodic basis. Further, such software packages provide consistent methods for report generation.

The *Travel Time Data Collection Handbook*, produced by TTI for FHWA, provides guidance to transportation professionals and practitioners for the collection, reduction, and presentation of travel time data (*11*). It presents the advantages/disadvantages of different travel time data collection methods, including staffing requirements and costs. Table 2-3 provides a comparison of the test vehicle travel time techniques mentioned in the discussion above.

Table 2-3. Comparison of Test Vehicle Travel Time Data Collection Techniques (Adapted from Reference *11*).

Instrumentation Level	Costs			Skill Level		Level of Data Detail	Data Accuracy	Automation Potential
	Capital	Data Collection	Data Reduction	Data Collection	Data Reduction			
Manual: Pen & paper	Low	Moderate	High	Low	Moderate	Low	Low	Low
Tape recorder	Low	Low	High	Low	Moderate	Low	Low	Low
DMI	High	Low	Low	Moderate	Low	High	Moderate	High
GPS	High	Low	Low	Moderate	Low	High	High	High

Note: Rating scale (high, moderate, low) is relative among the instrumentation levels shown.

SMSCs would likely use low-cost techniques like test vehicles in the traffic stream for travel time data collection in lieu of more expensive instrumentation in or along roadways. It is likely that with continued mobility monitoring, the initial costs are justified for the ease of data collection, reduction, and report preparation.

2.8 RESPONSIBLE PARTIES FOR MOBILITY MONITORING AND ON-GOING FUNDING

The responsibility for mobility monitoring may be with one agency or shared among many agencies. For areas with an MPO, the MPO is the likely office of primary responsibility. This has been the case in much of the literature found and discussed in this literature review. The MPO is responsible for regional planning and executes this work through the Unified Planning Work Program (UPWP). MPO staff may be directly involved in mobility monitoring, or may partner with other agencies or use contracts to collect and analyze these data. Other likely agencies include TxDOT's local district office or possibly the Transportation Planning and Programming Division, or the local county or municipality. Agreements may be needed to share costs and resources.

Communities not within an MPO (<50,000 population) would likely rely on the local TxDOT district office, local municipality, or county to act as the office of primary responsibility. This could also be the case with some communities that have MPO representation as well. Again, agreements may be needed to share costs and resources.

One practical consideration for reducing data collection costs is to incorporate mobility monitoring data collection into other projects that can use the same data. Partnerships with neighboring cities may be another option to subsidize data collection. The literature highlighted in the following two paragraphs also shed light on additional practical possibilities for reducing costs and identifying continued funding sources.

The CMS employed by the Hartford Capitol Region Council of Governments (CRCOG) provides practical insights for reducing travel time data collection costs by using MPO staff. The CMS includes both an arterial and freeway analysis. Archived ITS data are used as a data source for the freeway analysis, while the arterial analysis is facilitated by the use of GPS travel time runs. The CRCOG uses GPS because it provides for direct download of the GPS data for analysis. To reduce data collection costs, CRCOG utilized current staff on their normal commute trips along key corridors at peak times to obtain mobility monitoring data (*8*). Therefore, CRCOG does not rely on a consultant for data collection.

In 2000 the Capital Area MPO in Raleigh, North Carolina, investigated alternative funding sources to federal metropolitan planning funds for the MPO. Possible sources included new locally generated, dedicated funding sources (sales and use tax, property tax, occupancy tax, rental car tax, vehicle title tax, motor fuels retail sales tax), private sector partnering (leasing/selling land or facilities, special benefit assessment districts, cost sharing, tax increment financing), and transportation-based revenue sources (toll facilities and congestion pricing, shadow tolling) (*12*). Incremental adjustments in existing taxes were investigated to study cash flow possibilities. Possible forecast revenues were produced for future years to illustrate possible additional funding. The study highlighted the components of developing a financial plan including estimation techniques, project cost estimates, and inflation adjustments. Though there are legislative and practical hurdles to using funds from many of the stated sources for on-going mobility monitoring, they do provide possibilities. In Texas, one possibility might be the use of the Texas Economic Development Sales Tax.

2.9 TYPICAL CONGESTION IMPROVEMENTS

The myriad of possible congestion mitigation techniques and tools are highlighted by the Institute of Transportation Engineers (ITE) under the broad headings (chapters) of getting the most out of the existing system—highways, building new road capacity, providing public transportation services, managing transportation demand, integrating ITS into regional transportation, and implementation (funding and institutional measures) (*13*). Many MPOs have taken these strategies and packaged them into their CMS strategies. For example, the Mid-America Regional Council (MARC), in Kansas City, Missouri, uses the following strategies (*8*):

- highway projects (e.g., HOV lanes),
- transit projects (e.g., implementing park-and-ride lots),
- bicycle and pedestrian projects (e.g., design guides for pedestrian-oriented development),
- travel demand management strategies (e.g., telecommuting centers),
- ITS/operations strategies (e.g., ramp metering),
- access management strategies (e.g., curb cut restrictions),
- land development strategies (e.g., mixed-use development incentives), and
- parking management strategies (e.g., reduced parking requirements in specific locations).

Some MPOs, such as St. Louis, Missouri (East-West Gateway Coordinating Council), and Chicago, Illinois (Chicago Area Transportation Study), have outlined possible strategies according to CMS guidance as (*8*,*14*,*15*):

- transportation demand management (TDM) measures,
- traffic operational improvements,
- measures to encourage high-occupancy vehicle (HOV) use,
- Transit capital improvements,
- transit operational improvements,
- measures to encourage the use of non-motorized modes,
- congestion pricing,
- growth management,
- access management,
- incident management,
- intelligent transportation systems (ITS), and
- general-purpose capacity expansion.

The range of transportation improvements in SMSCs is quite different than those implemented in larger urban areas. Two primary factors cause this fact: (1) the extent of the congestion they are initially intended to mitigate is typically smaller, and (2) financial resources are limited for "large-scale" improvements.

TTI published a toolbox of selected congestion mitigation techniques for communities by population size (*16*). For SMSCs, the research identified traffic flow improvements (e.g., signal improvements, intersection improvements, construction of additional travel lanes, access management) as the more common solution. The research also documented case studies from around the country and the range of relative improvement costs for these improvements. Travel time as a mobility monitoring performance measure is able to evaluate the effects of such improvements.

2.10 COMMUNICATING MONITORING RESULTS

Careful consideration is needed to choose the proper method for communicating mobility monitoring results. Three types of audiences will use the information reported from the monitoring system:

- The *public*, which does not possess basic mobility monitoring technical knowledge, so other means must be used to inform them. Information might be designed for lower comprehension levels and/or a wide array of tools may be used.
- *Elected officials and MPO policy boards* may understand some technical issues, but they prefer to receive explanations in laymen's terms. Like the public, this group would prefer to receive information with measures to which they are easily able to relate (e.g., travel time or speed).
- The *technical group* is able to understand and use more advanced reporting techniques.

TTI research (*3*) suggests various graphical illustrations. Graphical presentation should relate both spatial (place) and temporal (time) performance depending upon the initial goals and objectives of the monitoring efforts.

2.11 SELECTED CASE STUDIES OF MOBILITY MONITORING

This section provides additional detail on selected case studies identified from the literature. These case studies provide insightful lessons and useful perspective for the framework outline.

2.11.1 Hidalgo County MPO, Hidalgo County, Texas

The Hidalgo County MPO in south Texas has an established congestion management system to monitor the Hidalgo County transportation network. According to the most recent congestion management system report (Spring 2004), the MPO performs traffic studies each year that are rotated seasonally (*17*). Travel time runs were performed on approximately 450 miles of roadway in Hidalgo County. The study purpose is to identify problem areas on the roadway network and provide recommendations along targeted corridors.

Travel time runs are performed using the "floating car" method where the driver of the vehicle attempts to safely pass as many vehicles as they are passed by. GPS technology is used to collect the travel time data, and two travel time runs are performed in each direction during each peak period.

The Hidalgo County MPO has developed and historically used a congestion measure called the congestion index (CI). In concept, it is very similar to the Travel Time Index (see Table 2-1). The CI is computed as the actual travel time divided by the theoretical travel time, where the theoretical travel time is the segment length divided by the posted speed. The congestion index criteria are broken down into CI<0.75 (congestion), CI of 0.75 to 0.99 (stable flow), and CI>0.99 (free flow).

The final product of the study includes a ranking of prioritized routes and what recommendations are made. Typical improvement recommendations include signal timing optimization, access management, STOP-controlled converted to signalized control, and roadway widening. Maps of the transportation system by the CI performance measure are also produced.

The Hidalgo County MPO provides an example of a successful and continued mobility monitoring effort that can serve as a model for the development of the model for SMSCs.

2.11.2 City of Grand Junction, Colorado

TTI performed a "field testing" of the measures and methods included in *The Keys to Estimating Mobility in Urban Areas* (*3*) in Grand Junction, Colorado, a community with a population of approximately 45,000 (*18*). The purpose of the study was to obtain a mobility level for the roadways in Grand Junction and to refine the methodology for use in other cities within the state.

Travel time runs were performed using the stopwatch method, and traffic count data were collected along seven key mobility corridors. Data collection was focused on the peak and off-peak periods, and the travel rate index (TRI) was the selected performance measure (see Equation 2-1). The travel rate index is similar to the Travel Time Index except the TRI does not include incident conditions.

$$\text{Travel Rate Index} = \frac{\begin{array}{c}\text{Actual Travel Rate}\\ \left(\text{minutes per mile}\right)\end{array}}{\begin{array}{c}\text{Travel Rate Based on Free-flow Speed}\\ \left(\text{minutes per mile}\right)\end{array}} \qquad \text{(Equation 2-1)}$$

Several lessons learned from the work in Grand Junction are directly applicable to the data collection:

- develop a data collection plan for the study process,
- perform an early inventory of data sources and collection capabilities prior to data collection,
- schedule pre- and post-collection meetings,
- obtain sufficient geographic coverage of traffic counts, and
- include local interpretation of the results.

2.11.3 City of Lincoln, Nebraska

The City of Lincoln, Nebraska, has performed several efforts that include updates to their local travel demand model, monitor congestion, and before-and-after assessments of signal timing improvements. These studies provide lessons on data collection methods, performance measures, and communication tools.

The first study included the use of the stopwatch method to perform travel time runs in the morning and afternoon peak and off-peak along 423.5 miles of sampled roadways from the major functional classes in the city (*19*). Three runs per period were collected using the "average vehicle driving method" whereby the driver tries to maintain the average speed of the traffic stream, relative to all other cars on the roadway. The purpose of the study was to identify congestion problems and to update the travel demand model. Speed and travel time measures were computed by link.

Another effort conducted by the City of Lincoln included a before-and-after assessment of signal timing improvements (*20*). Speed was again the performance measure identified, and threshold speeds were used. The first threshold speed value was 18 mph, below which an action plan to improve the traffic conditions on the problem arterial would be studied and developed. A second speed threshold of 16 mph was applied to neighborhood-type streets. These speeds approximate Level-of-Service (LOS) C, which was the stated goal of the city for street operation. The results of the study were communicated via graphics on 11 in. x 17 in. pages showing the travel time by time period in the time periods of interest. Figure 2-4 shows an example of how the data were presented. When presented in color, such a graphic allows the viewer to quickly see if conditions along the corridor and on each link improved (green) or became worse (red). The example in Figure 2-4 shows increasing speeds for each link. Speeds by link are provided, as well as average speeds for the corridor in the before-and-after period.

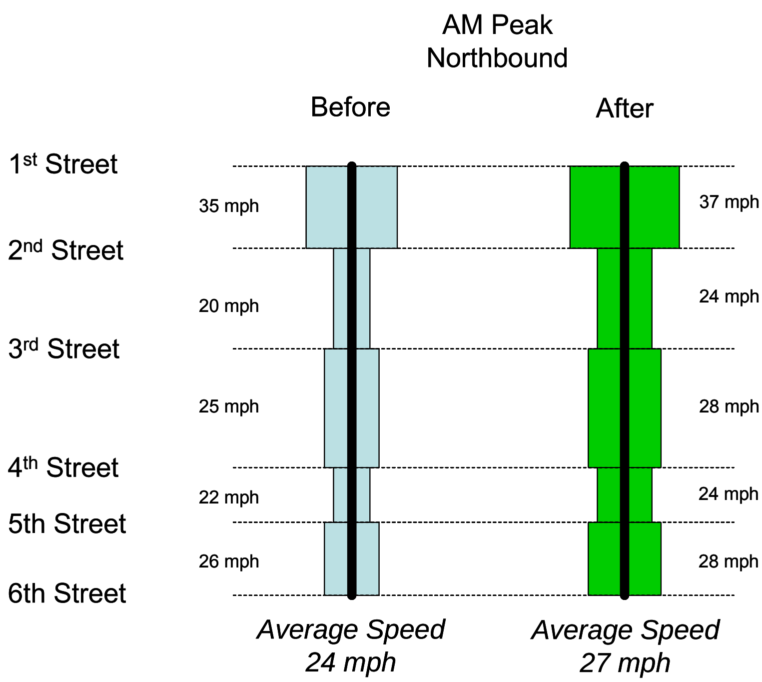


Figure 2-4. Sample Travel Time Data Reporting from Lincoln Study (Adapted from Reference *20*).

2.11.4 Lexington Area MPO, Lexington, Kentucky

The Lexington Area MPO, a study presented earlier, developed a CMS for identifying congested segments of the roadway network and prioritizing projects for improvement (*21*). Average speed was used as a performance measure, and congestion categories (ranges) for different levels of congestion were developed. The travel rate index was also used. Using the floating car method and GPS and personal digital assistants (PDAs), travel time data were collected along primary corridors in the region. Morning, afternoon, and off-peak time periods were collected.

Staff from the MPO and/or other volunteers were used for the data collection to keep costs low. Travel time runs performed during non-incident and good weather were desired. With the available resources, the MPO found that it took one to two months to obtain the ten desired runs per corridor.

The primary lessons learned in the study were that closer to six runs would have been sufficient for the analysis performed. The software to reduce the data was found to be critical—facilitating the reduction of the data. There was a need for a steady supply of volunteer drivers; typically drawn from the MPO staff. The importance of having MPO technical staff overseeing the data collection was noted. With budgetary constraints, the Lexington Area MPO found that a two-year cycle of data collection and data reduction seemed appropriate. Finally, the study documentation notes that the community must identify their congestion level threshold(s).

2.11.5 Maricopa Association of Governments, Phoenix, Arizona

The Maricopa Association of Governments (MAG) recently completed their 2002-2003 Regional Travel Time and Travel Speed Study (*22*). The primary purpose of the study was to calibrate and validate the regional planning model used by MAG. Another purpose of the study was to compare the current year's data with data from previous years to identify any congestion trends and identify candidate improvement locations.

Over 1,800 centerline miles of primary arterials, freeways, and HOV lanes were included in the study. Travel time data were collected using the floating car method and GPS technology. Travel time runs were performed in the morning, afternoon, and off-peak periods. Over 70,000 miles were driven by the test vehicles for the study. Travel time, speed, percent of posted speed, and the congestion index (CI), which is the actual travel time divided by the travel time at the posted speed, were used as performance measures.

2.12 ARTERIAL TRAVEL TIME ESTIMATION MODELS AND METHODS

Effective mobility monitoring relies on data that provide insight into the duration, extent, and intensity of congestion in a community. To this end, performance measures are developed that reflect the goals and objectives of a community. Data sources for these measures are then identified, and the data are reduced to estimate the performance measures. In transportation applications, there are typically three primary data sources:

- Planning Model Data—travel demand models that typically use traditional four-step processes to estimate roadway flows provide output of delay and vehicle-miles of travel

(VMT) by roadway classification. Such output can be used to estimate regionwide congestion.

- Link-level Data—data sources such as the Highway Performance Monitoring System (HPMS) that contain “ATR-like” data elements including vehicle classification, average daily traffic, number of lanes, and link length. Such output can be used to estimate regionwide congestion levels.
- Real-time Data—intelligent transportation systems such as inductance loop detectors, automatic vehicle identification (toll tags), or automatic vehicle location provide direct estimates of point or link speeds that can be used to develop travel time measures.

Figure 2-5 schematically illustrates these three data sources and how different data processing and quality control procedures are used to estimate the performance measures of interest. Example on-going studies using each data source are also shown in Figure 2-5.

The key point is that some of these techniques provide for direct measurement of the traffic stream (real-time data sources, test vehicle data collection) whereas others are based upon macroscopic planning models, which are not directly applicable to corridor mobility monitoring as desired in this research. For mobility monitoring purposes, directly measured data are most valuable. This is particularly true when candidate improvement projects are being prioritized.

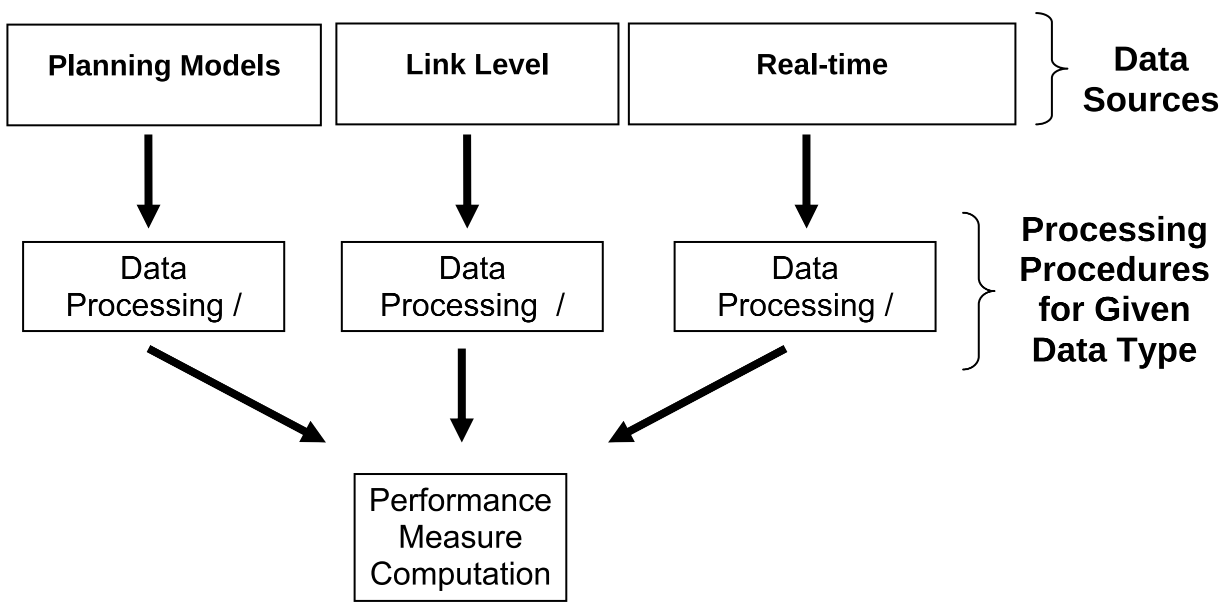


Figure 2-5. Diagram Illustrating Typical Transportation Data Source Origin and Processing (Source: Unpublished TTI Documentation).

It should be noted that there are many travel time and delay estimation techniques available to estimate speed and traffic volumes for freeways and arterials. One source of such techniques is NCHRP Report 387 *(23)*. The methods in NCHRP Report 387 include typical Highway Capacity Manual (HCM)-like parameters to estimate speed. There remains the need to estimate (or collect) critical operational and geometric data.

The literature also contains a myriad of studies focused on predicting real-time travel time and delay along arterial facilities. These studies include models that are generally sensitive to signal parameters to estimate travel time and delay. As real-time signal data become available, such models may become more applicable to SMSC applications.

2.13 MOBILITY MONITORING FRAMEWORKS

In general, mobility monitoring in SMSCs is not a widely adopted practice despite the community concerns for traffic congestion. These areas would greatly benefit from the development of a scalable monitoring framework to match the available resources of the community.

The monitoring framework should possess several distinct elements:

- Outline the decision process for defining the community goals and objectives.
- Provide guidance for selecting performance measures that offer relevant answers to the previously stated goals and objectives.
- Provide a scalable monitoring methodology that describes both basic sampling needs (frequency and duration) and cost-efficient techniques for measuring traffic flow.
- Provide guidance on how the data are reduced and analyzed to create reports and presentation material for policy, technical, and public use with the measures of interest.

As a starting point, one such framework is presented in *The Keys to Estimating Mobility in Urban Areas* (*3*). Table 2-4 lists the steps of the framework along with relevant questions that are likely asked at each step of the process. The steps shown in Table 2-4 guide the user through the appropriate steps, which must be included in a mobility analysis targeted to SMSCs. The framework will be further developed in Task 2 of this project, likely starting with steps shown in Table 2-4, and then adapting it to SMSCs. The existing SMSCs that perform mobility monitoring, including those highlighted in this review, inherently apply all or some of these steps (or similar) though most studies do not have the steps specifically spelled out.

Table 2-4. Example Steps to Perform Mobility Monitoring (Adapted from Reference *3*).

Step #	Name	Typical Questions Asked
1	Identify community vision and goals	What are the community values and important concerns (e.g., highways, streets, specific areas, transit, job centers, tourist areas, safety, commodity flows)? How are transportation elements analyzed, identified, and updated in the long-range regional plan?
2	Identify the uses and audiences of the mobility monitoring activities	Who are the users? What are the uses? How are results best communicated?
3	Define congestion and identify community thresholds	What are community congestion level targets for the measures (these should be tied to local/regional goals)?
4	Develop a set of performance measures and a set of accompanying analysis procedures	Can all improvement types be included in the measures? Are the measures understandable to all audiences? Do procedures yield reliable information?
5	Collect or estimate data elements	What types of data are necessary? Does the experimental design for data collection provide appropriate spatial/temporal coverage?
6	Identify problem areas and times	Are key times monitored (e.g., Saturday football games, weekend festivals, special events, tourism, typical weekday peaking)? Are well-known problem areas/roads identified through the process (i.e., do results pass a "reasonableness" check)?
7	Test solutions and perform analysis	Are measures sensitive to transportation improvements with cost-scale typical for SMSCs? How can methods be used to identify impacts of new development (big boxes) along key mobility corridors?
8	Communicate results	What are the most effective methods (e.g., tables, graphics, maps) to communicate measures and results to the key users/uses of the monitoring?
9	Implement	How will the monitoring process be planned and programmed to ensure implementation and future monitoring? Who will fund it?

2.14 CONCLUDING REMARKS

The following bullets highlight the key observations taken from the literature that provided a foundation for the remainder of the project:

- Congestion is best defined through the eyes of the delayed—what constitutes congestion in one location may be different in another location.
- Congestion in many SMSCs in Texas is growing.

- Congestion measures should be developed only after an examination of the uses and audiences to be served, the full consideration of program goals and objectives, and the nature of likely solutions.
- Travel time based congestion measures are more flexible and more useful for a broad range of uses and audiences.
- Many metropolitan planning organizations (MPOs) use travel time based congestion measures to supplement traditional measures.
- While most SMSCs may not currently have continuous data sources available, they should be aware of the importance of reliability measures and incorporating them in future mobility monitoring efforts.
- SMSCs would likely use low-cost techniques like test vehicles in the traffic stream for travel time data collection. It is likely that with continued mobility monitoring, the initial costs of GPS travel time data collection are justified. Numerous locations have successfully used GPS technology, and the initial costs of GPS are likely justified for the ease of data collection, reduction, and report preparation, especially when mobility monitoring will be performed on an on-going basis.
- Using existing staff for travel time data collection can reduce costs for SMSCs.
- Funding on-going mobility monitoring might be possible through existing or increased taxing sources or transportation-based revenue sources. Though there are legislative and practical hurdles to using these sources, they do provide possibilities. One possibility might be the use of the Texas Economic Development Sales Tax.
- Typical congestion improvements in SMSCs will include signal improvements, intersection improvements, construction of additional travel lanes, and access management.
- There are many travel time and delay estimation techniques and models available to estimate speed and traffic volumes for freeways and arterials. They still rely on direct data collection of key operational and geometric inputs. As real-time signal systems become more prevalent and cost-effective, such methods may be more promising for SMSCs.
- A nine-step framework was presented from TTI's *Keys to Estimating Mobility in Urban Areas*. The studies cited in this literature review inherently apply to all or some of these steps (or similar) though most studies do not have the steps specifically spelled out. The nine-step framework identified will be enhanced for SMSC application.

CHAPTER 3
SMALL TO MEDIUM-SIZED COMMUNITY MOBILITY MONITORING FRAMEWORK

3.1 INTRODUCTION

This chapter presents the development process of, and the final framework for, monitoring mobility in SMSCs. Each of the framework's steps are identified and briefly discussed.

3.2 FRAMEWORK DEVELOPMENT

Early concepts for the framework were based on flowchart principles with technical considerations provided as content within each step. As the research team progressed with development, it became evident that a less detailed, more reader-friendly product was required. The research team sought input from the PMC on several occasions. As the framework developed it was given a first person point of view to better connect the reader to solving congestion issues in their community. Branding was added to later proofs so that TxDOT and TTI are clearly associated with this document.

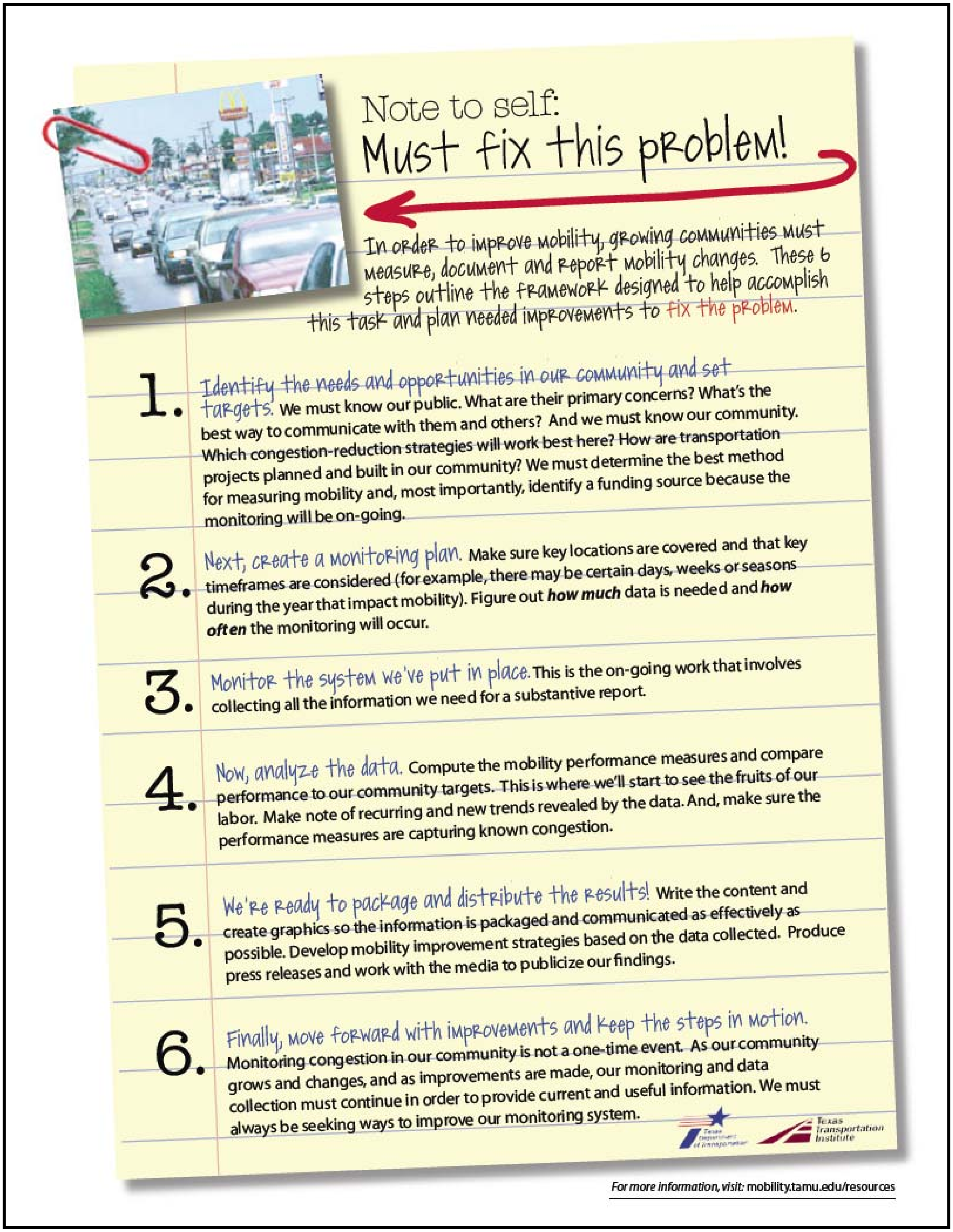
3.3 FRAMEWORK OVERVIEW

The final development consists of six steps that are described in some detail in the next section. Greater detail for each step is provided within the research products (see Section 7.2 for products). These steps were developed to be a continuous process so that improvements would be made in each subsequent monitoring effort.

The research team sought to distill the six steps into a one-page product for technical professionals. That effort is displayed in Figure 3-1. This one-page document quickly connects to the reader, regardless of technical proficiency. It includes a common scene in growing communities that are likely to seek the guidance within this project's research products.

Each step is numbered and introduced in an interesting visual manner. The supporting information behind the step title then uses a first person point of view to engage the reader better. The text asks the questions one would ask when implementing this monitoring framework. It also stresses key points with active language.

Finally, the document includes subtle branding for both the sponsor and developer of the product. It also includes an Internet address for one to seek additional resources, guidance, and information.



Note to self:

Must fix this problem!

In order to improve mobility, growing communities must measure, document and report mobility changes. These 6 steps outline the framework designed to help accomplish this task and plan needed improvements to fix the problem.

1. Identify the needs and opportunities in our community and set targets. We must know our public. What are their primary concerns? What's the best way to communicate with them and others? And we must know our community. Which congestion-reduction strategies will work best here? How are transportation projects planned and built in our community? We must determine the best method for measuring mobility and, most importantly, identify a funding source because the monitoring will be on-going.

2. Next, create a monitoring plan. Make sure key locations are covered and that key timeframes are considered (for example, there may be certain days, weeks or seasons during the year that impact mobility). Figure out ***how much*** data is needed and ***how often*** the monitoring will occur.

3. Monitor the system we've put in place. This is the on-going work that involves collecting all the information we need for a substantive report.

4. Now, analyze the data. Compute the mobility performance measures and compare performance to our community targets. This is where we'll start to see the fruits of our labor. Make note of recurring and new trends revealed by the data. And, make sure the performance measures are capturing known congestion.

5. We're ready to package and distribute the results! Write the content and create graphics so the information is packaged and communicated as effectively as possible. Develop mobility improvement strategies based on the data collected. Produce press releases and work with the media to publicize our findings.

6. Finally, move forward with improvements and keep the steps in motion. Monitoring congestion in our community is not a one-time event. As our community grows and changes, and as improvements are made, our monitoring and data collection must continue in order to provide current and useful information. We must always be seeking ways to improve our monitoring system.

Texas Transportation Institute

For more information, visit: mobility.tamu.edu/resources

Figure 3-1. SMSCs Mobility Monitoring One-Page Framework.

3.4 FRAMEWORK STEPS

3.4.1 Identify the Needs and Opportunities

This first step is a very important one. It begins with understanding the context of the community—including what the community cares about—putting into context the purpose of the mobility monitoring program.

First the public's cares and concerns—the community's values—should be documented. In doing this, determining the priority of the transportation system and mobility in the community is important. This can also be accomplished by reviewing how transportation is viewed in local plans. Comprehensive plans are good planning tools to guide the community in the direction of growth and economic development through controlled measures; transportation network/system improvements are part of that process.

The primary users are also identified. Begin working with the audience in mind and know what their needs are and how best to communicate to them. It may be best to find methods to connect to the users using performance measures with which they can easily identify.

Determine the ultimate outcomes from the monitoring program. Begin with an idea or concept of what the press release will say at the end of the monitoring. By doing this, the monitoring process is sure to evaluate the parts of the system that are of greatest concern using measurements that support community targets.

Next, professionals will identify the mobility performance measures for their community and determine target levels of performance. The performance measures selected should be ones that all audiences will be able to understand. The target levels should be tied to community goals and be reasonable to the community.

Before the monitoring begins, technical professionals should identify agreeable congestion reduction strategies. This becomes the professionals' toolbox. Some congestion reduction strategies are less applicable to small or medium-sized communities, such as high-occupancy vehicle lanes, where other less costly but very effective strategies are more appropriate, such as signal progression, minor geometric changes, or access management.

Finally, identifying the initial and a continued funding source for on-going monitoring is key to this process. Without funding there is no process. Ensuring that the monitoring program results reach the right audiences relating to community targets and produce measurable results from congestion mitigation strategies is important to secure continued funding. Also, communities should look for partners to share the cost of the monitoring. Synergy should be sought.

3.4.2 Make the Monitoring Plan

The next step in the process is to create the actual monitoring plan. In this step, one determines the best method(s) for monitoring mobility in the community. The decision to collect certain data to support performance measures is made. Given the financial and staffing available for the monitoring effort, the technical professional must determine at this point what methods are most appropriate.

As the plan is developed, some quality assurance is performed so that key locations where monitoring should be performed are verified that they are indeed in the plan. These locations may be roadways, known bottlenecks, or can include one or more signalized intersections. Locations where modes conflict may also be included.

Next, the plan should identify that key timeframes are covered. Mobility monitoring should include some off-peak period data from which comparisons can be made to peak-period travel conditions. Ensuring that days of the week, seasons, special events, and other considerations are covered within the plan will strengthen the monitoring program and provide credible results to the primary users.

The final element to this step is identifying the monitoring frequency. This is a function of available resources balanced with extent of the monitoring effort. Routine monitoring is recommended, however the monitoring frequency can be variable to some degree. Long periods between monitoring will lessen the community's ability to be very proactive in mitigating worsening mobility conditions because there is simply a lack of information to develop strong trends from which to draw educated conclusions.

3.4.3 Monitor the System

This third step is putting the monitoring plan into action. Two primary items are included in this step.

First, the community will measure their initial mobility status or their mobility changes if previous monitoring was completed. This requires the community to collect field data. The guidebook describes different data collection methods available to measure mobility (*1*).

Second, communities are encouraged to perform a videolog of the physical environment to document conditions at the time of data collection. A videolog is a narrated video taken from the front windshield of a vehicle traveling along the measured streets. The videolog is an invaluable resource to capture a snapshot of driveway or intersection spacings, lane configurations, location of pedestrian crossings, and other geometric conditions of the roadway.

3.4.4 Analyze the Data

Actions in this step are the analyses of the data collected in the previous step. Data analysis elements include computing mobility performance measures, comparing calculated performance measures to community targets, ensuring known congestion is captured, and comparing mobility changes to past monitoring efforts, if completed.

Technical professionals will use the field data to calculate simple traffic statistics—such as average daily traffic, peak direction, peak hour factor, and others—and also more complex calculations such as travel rate index and vehicle delay. Commercially available software, such as spreadsheets, can be used to calculate these measures. Spreadsheets can also act as a database for storing past mobility monitoring efforts.

After performance measures are calculated, they are compared to community targets previously set in Step 1. The comparison is used to grade mobility conditions and identify problem areas, with a now known magnitude, or areas that are worsening but not yet critical. The latter condition is important to a proactive approach for managing community mobility.

Quality control is also conducted in this step. One sure quality control technique is to ensure performance measures are capturing known congestion, or simply conducting a "reasonableness check." From the analysis, one verifies where congestion occurs, its intensity, and duration. If the results are counter to local knowledge of mobility conditions, managers should evaluate the data collection process for problems and also verify that the collected data is not in error, damaged, or corrupted.

A final task in this step is to compare mobility changes (how has mobility changed [duration, intensity, extent] since the previous monitoring cycle). Ultimately, this iterative process is to be used to identify changes in mobility so that a proactive approach can be taken to maintain mobility to community thresholds.

3.4.5 Package the Results

After the data is analyzed, the fifth step centers on preparing the results to be shared with technical and non-technical audiences. Preparing results includes both written and graphical documentation of the process and the results.

Creating reader-friendly documents is encouraged. This requires writing in a plain English style so that all readers can understand—public, elected officials, technical professionals. This can be a challenging task for technical professionals, but the potential impacts of a readable document are great. The readers become more engaged in the results, the process, and can better communicate thoughts with technical professionals.

In documenting the results, efforts should be taken to develop effective graphics to display performance. Tables of data can appear or be intimidating to readers, but the same data can be presented to readers through graphical methods that can more easily convey trends and relationships. Professionals are encouraged to develop graphical techniques to relay this complex information to their constituents.

Communicating the state of the community's mobility should also include possible mobility improvement strategies and an action plan. Technical professionals should develop their own toolbox of available improvement strategies. The strategies that will be included in the toolbox would be those strategies that are both financially and politically acceptable.

Finally, distributing the results is critically important to garner continued support. One method that can be used is a press release of the findings. The guidebook provides guidance for writing the press release (*1*).

3.4.6 Continue the Monitoring

The final step is simply to continue the monitoring effort. The guidebook discusses the benefits of performing monitoring on regular basis (*1*). For instance, it argues that trends can be evaluated through regular monitoring. It asks the reader what they want their subsequent monitoring effort's press release to say.

Finally within this step, continuous improvement to the mobility monitoring process is encouraged. The process application should be evaluated during implementation and post-implementation to identify any improvements that can be made. The framework acknowledges that some changes may be required by new elected or professional leadership in the community.

CHAPTER 4
CASE STUDIES AND COLLECTED DATA

4.1 INTRODUCTION

This chapter describes what case studies were selected to apply the framework described in Chapter 3. Brief descriptions of the initial meetings with transportation professionals from each community are also described in this chapter. Finally, each source of mobility monitoring data is described in this chapter along with descriptions of the characteristics of each corridor.

4.2 SELECTION OF PILOT CASE STUDY LOCATIONS FOR FRAMEWORK APPLICATION

Researchers applied the framework developed and described in Chapter 3 to two case studies. The pilot studies provided two opportunities to implement the framework by:

- Determining the typical needs/uses of a mobility monitoring effort for an SMSC.
- Identifying the subsequently appropriate performance measures.
- Collecting appropriate data (e.g., travel time runs, traffic counts, etc. to satisfy local mobility goals/concerns) on selected corridors.
- Performing subsequent analysis.
- Developing methods to best communicate the results to different users.

Researchers selected two case study locations because there was a desire to apply the framework in a small-sized community (<50,000 with no metropolitan planning organization [MPO] present), and another in a medium-sized community (>100,000 and <250,000 with MPO presence). This allowed researchers to identify framework lessons learned at different ends of the population scale. The pilot studies provided the foundation for on-going mobility monitoring in the TxDOT district/community evaluated.

4.2.1 Case Study Locations

In the project proposal, the project team recommended the Bryan-College Station community (population approximately 160,000) as the medium-sized community with an MPO presence because of several "economies of scale," including:

- The Bryan-College Station area is experiencing many of the typical "growing pains" of a medium-sized community that is beginning to experience spot congestion, but not yet engulfed by it, as residential and commercial developments continually outpace infrastructure allocations.
- The research team is thoroughly familiar with the area, trip patterns, growth areas, and congested segments.
- TTI and the research team have long-standing working relationships with all of the transportation agencies in the community (e.g., Bryan-College Station MPO, County of Brazos, City of College Station, City of Bryan, Texas A&M University, Texas Department of Transportation, and The Brazos Transit District).

- Data collection and reduction costs will be reduced by access to students to allow for a relatively low-cost testing of the framework.
- The project director had familiarity with the area as it is in his TxDOT district; and
- Framework application results are expected to be transferable to other medium-sized communities in Texas.

The proposal also suggested the application and demonstration of the framework in a community without MPO representation. This was possible, due in part, because of the “economies of scale” in performing the data collection in the Bryan-College Station community. Huntsville, Texas, (population approximately 35,000) was suggested as a possible location because there were numerous on-system roadways entering the community. Other reasons for selecting the Huntsville, Texas, corridor included:

- The Huntsville region does not currently have MPO representation, but there is a possibility they could exceed the 50,000 population threshold at the next census.
- Data collection and reduction costs will be reduced because of the relatively close proximity of Huntsville to College Station and those performing the data collection.
- The project director had familiarity with the area as it is in his TxDOT district.
- Framework application results are expected to be transferable to other small-sized communities in Texas.

Task 3 (Selection of Pilot Study Locations to Test Framework) was initially intended to develop formal selection criteria for the two pilot locations to test the framework. However, the Project Monitoring Committee (PMC) selected the two pilot study locations during the project kickoff meeting held September 7, 2006. The decision was based upon the discussion at this meeting, and facilitated by reasons provided by the research team in the project proposal (including those bulleted above).

4.2.2 Obtaining Input from Local Transportation Professionals

Researchers met with local transportation professionals in the Bryan-College Station (B-CS) community as well as in Huntsville. The purposes of the meeting were to:

- Introduce the project.
- Provide an overview of the framework.
- Discuss how congestion is defined in the local community.
- Discuss congested locations for possible monitoring.

4.2.2.1 Bryan-College Station, Texas, Initial Meeting

Attendees in the B-CS meeting included:

- TxDOT Bryan District Director of Transportation Planning and Development,
- MPO transportation planner,
- Texas A&M University Parking representative,
- College Station Independent School District representative,

- Bryan Independent School District representatives,
- City of College Station transportation planner and engineer,
- City of Bryan transportation planner and engineer, and
- Brazos Valley Council of Governments representative.

The B-CS group immediately indicated that it is the perception/expectations that drive what is considered congestion. Using an example of a smaller nearby community, it was noted that what would be considered congestion to them would not be considered congestion in B-CS.

The group discussed what could constitute congestion for drivers, including sitting through more than one red signal, or not being able to travel at the speed limit.

The group then discussed the fact that the community does not have any current monitoring/threshold per se for congestion. In College Station, it was noted that while there is no technical definition of congestion identified, level-of-service (LOS) is used in the Unified Development Ordinance (UDO) related to traffic impact analyses (TIAs). City of Bryan noted that they do not have such a requirement, and generally look at increased traffic volumes.

The discussion then turned to the importance of measures that include travel time because that is what is most understood by, and of interest to, individual drivers. There was interest in collecting travel time information along key corridors. Travel time and speed-based measures were identified and discussed. The travel rate index (ratio of the travel rate [minutes per mile] in the peak period to the off-peak period) was selected as a measure. The discussion then turned to identifying corridors for mobility monitoring.

4.2.2.2 Huntsville, Texas, Initial Meeting

Attendees in the Huntsville meeting included:

- TxDOT Bryan District Director of Transportation Planning and Development,
- City of Huntsville Public Works Director/city engineer,
- City of Huntsville street superintendent, and
- TxDOT Huntsville area office representatives.

The initial meeting with the Huntsville transportation professionals was similar in content to the meeting with the B-CS transportation professionals. The group also identified sitting through more than one signal as an indication of congestion for drivers. The importance of travel time measures was identified and discussed. Travel time and speed-based measures were of most interest, and the travel rate index was one of the measures selected to pursue. As with the B-CS meeting, the discussion then turned to identifying corridors for possible mobility monitoring.

4.2.3 Data Collection Plans

Based upon the meetings in both B-CS and Huntsville, the research team identified the following data collection efforts, which are described in detail in each of the subsequent sections:

- survey of small to medium-sized communities,
- traffic counts,
- travel time runs,
- stopped delay studies, and
- videologs.

4.2.3.1 Survey of Small to Medium-Sized Communities

It became clear in the initial meeting with the Huntsville transportation professionals that there was a need to better understand congestion definitions, monitoring activities, and when/where/why congestion occurs in SMSCs. Researchers proposed to the Project Monitoring Committee that a survey be implemented to gather information on these needs. Though this survey was not originally in the proposal of the project, and represented an additional work effort, the research team believed it would shed valuable light on the fundamental mobility-related questions and issues in SMSCs.

The research team developed a web-based survey that included branches in the coding based on survey response. A copy of the written format is provided in Appendix A. The research team received approval from the Texas Municipal League (TML) to distribute (by e-mail) a link to the survey to select TML members. The research team identified both several municipal positions and a short list of SMSCs outside of MPOs. The survey was open between March 28 and April 13, 2007.

Figures 4-1 to 4-3 illustrate selected screenshots of the web-based survey.

4.2.3.2 Traffic Counts

In SMSCs, simple traffic volume changes can be a good indication of mobility changes. Traffic counts at selected locations along each travel time corridor provide a baseline of the amount of traffic. Total delay along a corridor can be estimated by multiplying the number of vehicles by the difference in actual travel time and free-flow travel time.

Fifty-five count locations were identified in the B-CS area, and 10 were identified in Huntsville. Researchers studied 12 corridors in B-CS and 2 in Huntsville.

4.2.3.3 Travel Time Runs

Table 4-1 presents the B-CS corridors identified as the most critical for providing baseline mobility monitoring information. Table 4-2 presents the same information for the two Huntsville corridors. Tables 4-1 and 4-2 provide characteristics of each corridor including termini, possible turnaround locations, study length, and the number of vehicles used for the travel time data collection.

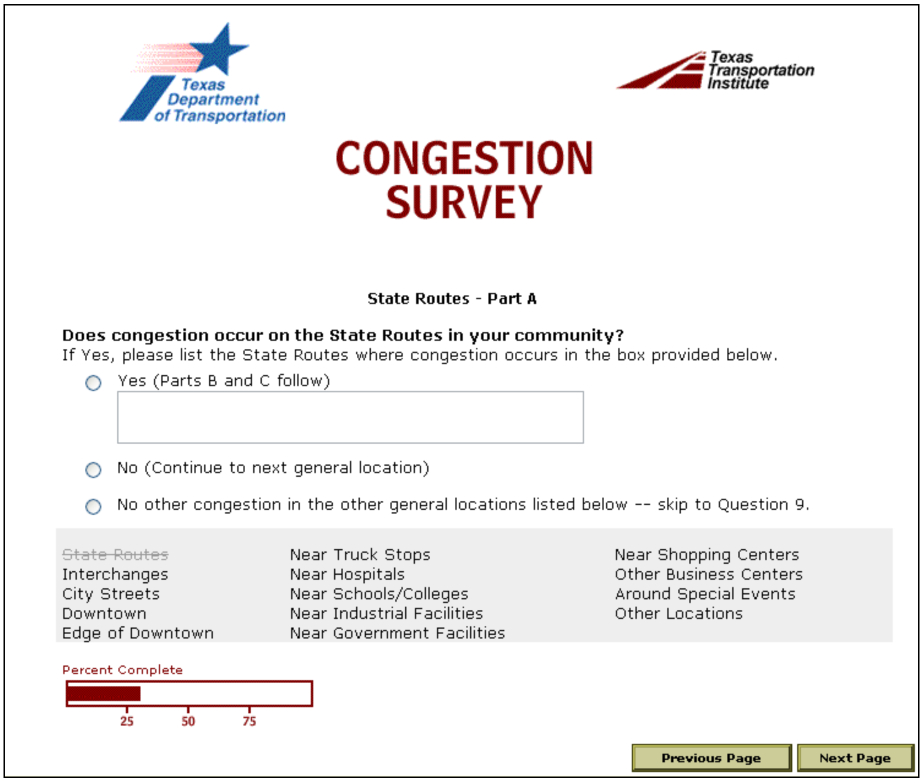


Figure 4-1. Screenshot of Web-based Survey Showing Question on Whether Congestion Occurs in the Community.

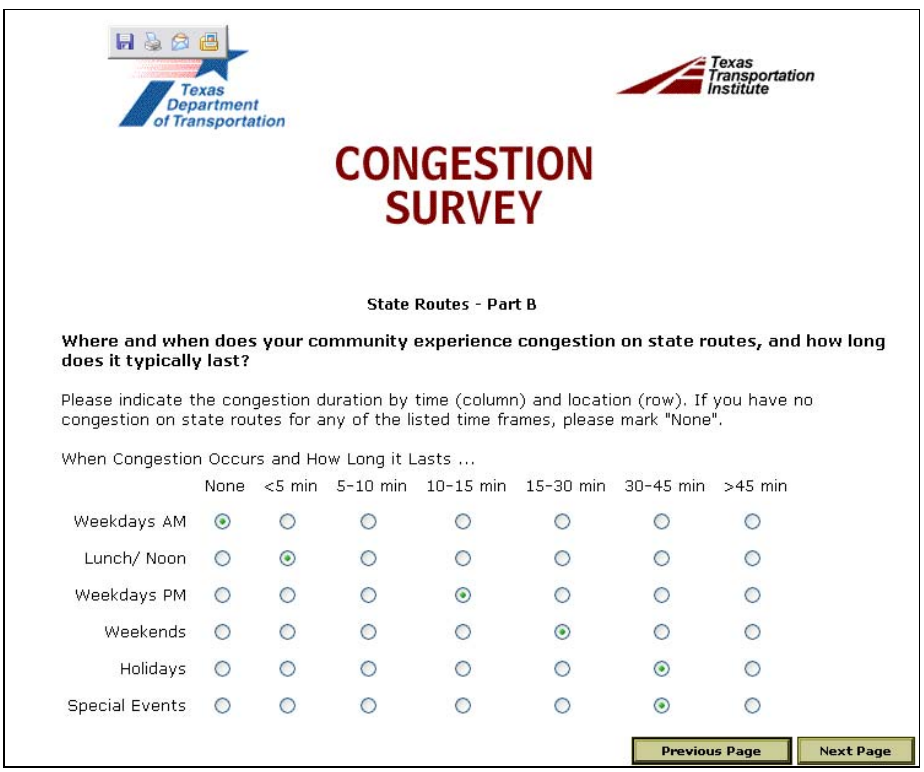


Figure 4-2. Screenshot of Web-based Survey Showing Question on Where and When Congestion Occurs in the Community.

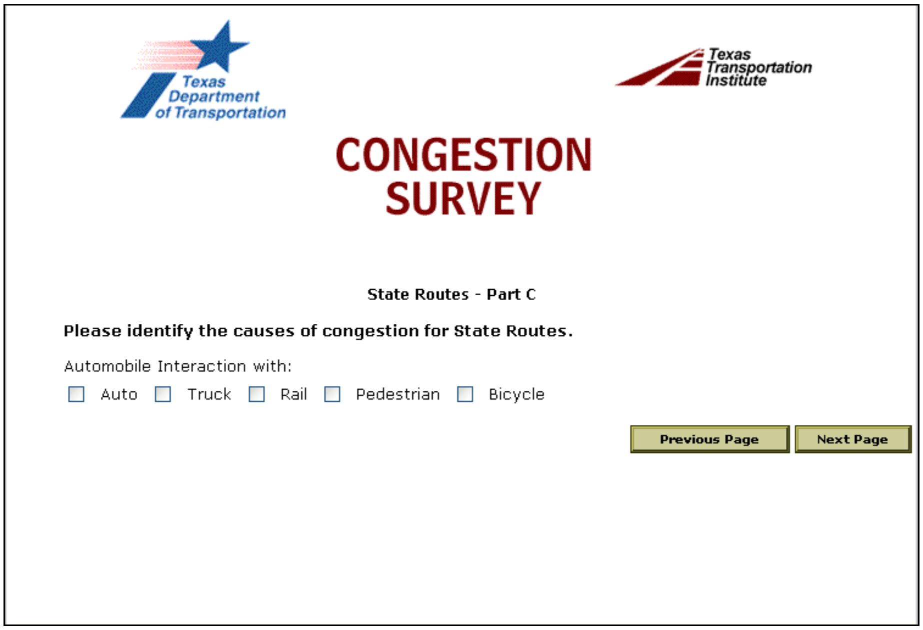


Figure 4-3. Screenshot of Web-based Survey Showing Question on the Causes of Congestion for the State Routes Location.

Travel time runs were performed along each corridor during the morning peak period (7:00-8:30 a.m.), off-peak (8:30-10:00 a.m.), and afternoon peak (4:00-6:00 p.m.). Travel time runs were performed for one day on each corridor. Tuesdays through Thursdays were used for data collection to avoid any abnormal traffic pattern changes close to the weekends. The relatively longer timeframes for the peak and off-peak periods than what currently represents fully congested time periods are useful because, with mobility monitoring year after year, the analyst can see how much longer the peak period is growing. Global positioning system (GPS) equipment, along with a laptop computer, was used to collect the data.

For most of the corridors, five data collection vehicles were sufficient to obtain four runs per time period and peak direction of interest, which yielded a 90 percent confidence level for segments with three to six signals per mile (*11*). Typically, three vehicles started at the end of the corridor in the peak direction, and two vehicles started in the off-peak direction. Prior to travel time data collection, the drivers were shown the corridor, turnaround areas, and the GPS equipment so they understood how to collect data along the corridor. Researchers developed data collection forms that the drivers used before or after each run. The forms allowed the drivers to document the run number and relevant observations from the run. The form is shown in Figure 4-4.

The travel time run drivers were instructed to drive using the "floating car method" where they attempt to safely pass as many vehicles as the test vehicle (*11*). This method attempts to replicate average operating conditions. As part of the training to all the drivers, researchers prepared equipment lists and driver instructions for using the equipment and for performing the "floating car method."

Table 4-1. Travel Time Run Characteristics of B-CS Corridors.

Facility	North/East Terminus	South/West Terminus	North/East Turnaround	South/West Turnaround	Length[1]	No. of Vehicles
FM 158 Boonville Road	Harvey	SH 21	Shepler's	Brazos County Detention Center (on Sandy Point)	7.3	5
FM 1179 Villa Maria/Briarcrest	Steep Hollow	FM 2818	Planters Loop	Kingdom Hall Jehovah's Witness Driveway	7.7	5
Villa Maria	William Joel Bryan	FM 2818	Wood Trail Apartments	Kingdom Hall Jehovah's Witness Driveway	4.0	4
29th Street	Crosswalk west of Parker (west of railroad tracks)	University	St. Anthony's Catholic Church	Rosa's Café	4.5	5
Texas Avenue (Bus. SH 6)	SH 6	Deacon	RV Center	Masonic Library and Museum	14.8	5
FM 2818	SH 21/San Jacinto	SH 6	Brazos County Detention Center (on Sandy Point)	Williams' Dentist Offices'	11.6	3
FM 60 University Drive	Boonville	Jones	Bell's Welding	Brazos County Precinct 4 Fire Department	8.3	5
SH 30 Harvey Road	Boonville	Texas Avenue	Central Baptist Church	Hobby Lobby	4.1	5
Southwest Parkway	SH 6	Wellborn	Sherman Court residential cul-de-sac	CC Creations	3.1	5
Longmire Drive	FM 2818	Barron Road	Tractor Supply Company	Spring Brook on north side of Barron Road	3.0	3
Rock Prairie	Greens Prairie	Wellborn	Pebble Creek Golf Course Employee Lot	Wellborn Road Veterinary Medical Center	5.0	5
FM 2154 Wellborn Road	Villa Maria	Barron	Bryan Municipal Golf Course	Americas Country Store	8.2	5

[1]Length includes assumed turnaround area at terminus of the corridor.

Table 4-2. Travel Time Run Characteristics of Huntsville Corridors.

Facility	North/East Terminus	South/West Terminus	North/East Turnaround	South/West Turnaround	Length[1]	No. of Vehicles
SH 30 / US 190	SH 19 Overpass	FM 1791	Shell Gas Station	Walker County Fairgrounds	6.5	4
SH 75 (Sam Houston Avenue)	11th Street (SH 30)	SH 19 Overpass	First United Methodist Church	Tri-County Services Building	3.0	4

[1]Length includes assumed turnaround area at terminus of the corridor.

The travel time run data were then analyzed with software that segmented out the second-by-second GPS data for analysis of average travel time conditions for each segment. The off-peak period travel time runs allowed for calculation of the travel rate index.

4.2.3.4 Stopped Delay Study

The travel time runs described above provided travel time information between key checkpoints (e.g., intersections) for congestion monitoring. However, monitoring congestion between these points does not necessarily provide the door-to-door travel time of trips (e.g., commuting) that might be of particular interest. Because trips typically include “summing” up the travel times along several links and intersections in addition to turns, there is a need to include traffic control delay at turning movements, too.

The project team wanted to demonstrate how corridor travel time runs can be combined with a stopped delay study to develop a trip travel time estimate along a corridor of interest. Therefore, the research team performed a stopped delay study at the intersection of SH 6 and University Drive (College Station, Texas). The northbound left turn from SH 6 to University Drive (morning) and the eastbound right turn from University Drive to SH 6 (afternoon) are known to be peak turning movements. Performing a stopped delay study for these turning movements demonstrated how seconds per vehicle could be estimated for the turning maneuver. In practice, such a turning movement estimate can be added to the link travel time estimates to estimate total trip travel time. Table 4-3 summarizes the characteristics of the stopped delay study.

Driver: ______________________________

Vehicle: _____________________________

Date: ________________________ Time Period (circle one): 7:00-10:00 am 4:00-6:00 pm

EASTBOUND University Drive Travel Time Data Collection Form
(Note: your run numbers will be all odd numbers in one direction, and even numbers in the other direction)

Intersection/Section Limit	**Time = Run# =**	**Time = Run# =**
Did you hit spacebar at checkpoint?		
Discovery Dr.		
Agronomy Rd. / Olsen Blvd.		
College Main / Houston		
Tauber St. / Asbury St.		
Ireland St. / Nagle St.		
Spence St.		
South College Ave. / Bizzell St.		
Avenue D / Polo Road		
Texas Ave.		
Tarrow West		
Tarrow East		
Spring Loop / Lincoln Ave.		
Forest Dr.		
Glenhaven Dr.		
West Frontage Rd.		
East Frontage Rd.		
Boonville Rd. / FM 158		
Did you hit spacebar at checkpoint?		
Other Comments? ***Bus Info?***	*Peak or Off Peak?*	*Peak or Off Peak?*

Place a "Q" and draw a line downward indicating the location in the corridor where a queue began and ended that you experienced in the run.
Place an "I" for incident if/where an incident was experienced, and if/where there might have been a lane blocked.
Place a "B" and draw a line downward indicating where a bus was located and how far you followed it.

Figure 4-4. Travel Time Run Data Collection Form.

Table 4-3. Characteristics of Intersection Turning Movement Delay Study.

Intersection	Turning Movement	Time Period
SH 6 at University Drive	NB Left from SH 6 to WB University (2 left-turning lanes)	Morning (7:00 a.m. to 9:00 a.m.)
SH 6 at University Drive	EB Right from University to SB SH 6 (1 right-turning lane)	Afternoon (4:00 p.m. to 6:00 p.m.)

Data collection for the stopped delay study was performed using the form shown in Figure 4-5. The stopped delay study was performed with two persons watching each lane of turning traffic. One person would constantly watch the stream of traffic and keep a "real-time" count of the number of stopped vehicles. Stopped vehicles were defined as those having their wheels locked. The other person served as a timer/recorder, and after each 15-second time period, they would call "time" and the counter would give them their stopped vehicle count. This was recorded for each 15-second time period for each two-hour period. There was also an individual at the intersection counting the total 5-minute traffic volume going through the intersection making the turning maneuver. The number of stopped vehicles, multiplied by the time interval (15 seconds), divided by the total number of vehicles going through the intersection provided an estimate of the stopped delay in seconds/vehicle.

4.2.3.5 Videologs

A very useful part of a mobility monitoring effort is creating a videolog of the physical environment (e.g., overpasses, pedestrian bridges, buildings, work zones, speed limits). This is a narrated video taken out of the front windshield of the vehicle. Key developments or undeveloped properties along the side of the road can also be included in the log. The video is best recorded with two individuals so that the passenger can narrate and record the video. The video camera can be mounted to the vehicle's dashboard.

Researchers performed videologs of all 14 corridors used in the study. The videolog served as a valuable reference when clarifying roadway geometry, work zones, speed limits, cross-sections, etc., during the analysis.

Intersection________________________ Time__________________ To__________________________
Date__________________ Day_________________________
Weather____
Observer(s)____
Street__________________________ ________Bound Traffic Traffic Lane____________________

	Number of Stopped Vehicles; V_s			
Min \ Sec	15	30	45	
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
Totals				

$\Sigma V_s =$ ______

$$\text{Stopped Delay} = \frac{\Sigma V_s \times I}{V} = \text{\_\_\_\_\_\_ sec/veh}$$

Volume, $V =$ ______

Figure 4-5. Stopped Delay Data Collection Form (Adapted from Reference *24*).

4.2.3.6 Data Collection Dates

Data collection was performed from Monday, March 19, 2007, to April 26, 2007. Table 4-4 summarizes the data collection schedule for all of the corridors. Note that typically only one day of travel time runs was performed per site. Note that FM 2818 was collected a second time due to construction. Typically, the traffic counters were put out early in the week and collected later in the week along the corridors where travel time data were collected.

Table 4-4. Bryan-College Station and Huntsville Data Collection Schedule.

Day of Week				
Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
3/19/07 Counters down at all three sites	*3/20/07* Villa Maria/Briarcrest	*3/21/07* Villa Maria	*3/22/07* FM 2818 (Re-collected on 4/26 because of construction)	*3/23/07* Pull up all counters from all three sites
3/26/07 Counters down at all three sites	*3/27/07* Texas Avenue	*3/28/07* University Drive	*3/29/07* Rock Prairie	*3/30/07* Pull up all counters from all three sites
4/2/07 Counters down at all three sites	*4/3/07* Wellborn Road	*4/4/07* Harvey Road	*4/5/07* Southwest Parkway	*4/6/07* Pull up all counters from all three sites
4/9/07 Counters down at all three sites	*4/10/07* 29th Street	*4/11/07* FM 158	*4/12/07* Longmire Drive	*4/13/07* Pull up all counters from all three sites
4/16/07 Counters down at both sites	*4/17/07* 11th Street (Huntsville)	*4/18/07* Sam Houston Avenue (Huntsville)	*4/19/07* Pull up counters from both sites	*4/20/07*
4/23/07	*4/24/07* University Drive Stopped Delay Study	*4/25/07*	*4/26/07* FM 2818 (Re-collected from 3/22)	*4/27/07*

4.3 CONCLUDING REMARKS

This chapter documents the case studies and data sources collected as part of this project. Prior to a discussion of the data reduction in the next chapter, there are several important key points to highlight from this chapter. These points include:

- Researchers identified two case study locations for data collection—one with an MPO present (Bryan-College Station, Texas) and one without an MPO present (Huntsville, Texas).
- Researchers performed successful meetings with transportation professionals in each community to identify possible corridors for mobility monitoring.
- Researchers collected traffic count data, travel time data, and videologs along each case study corridor.
- Researchers performed a stopped delay study in College Station, Texas.
- Researchers performed a survey of congestion issues to SMSCs.

The next chapter describes the data reduction of each of these data sources.

CHAPTER 5
DATA REDUCTION, ANALYSES, AND FINDINGS

5.1 INTRODUCTION

This chapter describes the data reduction, analyses, and findings for all the data collected as a result of this project. These data include:

- survey of small to medium-sized communities,
- traffic count data from the B-CS and Huntsville corridors,
- travel time run data from the B-CS and Huntsville corridors, and
- stopped delay study data from study performed in College Station, Texas.

5.2 SURVEY OF SMALL TO MEDIUM-SIZED COMMUNITIES

5.2.1 Survey Respondents

The congestion survey gathered 26 total responses. Seven of the respondents held elected office and two cities had repeat respondents. Figure 5-1 displays the distribution of respondents by title.

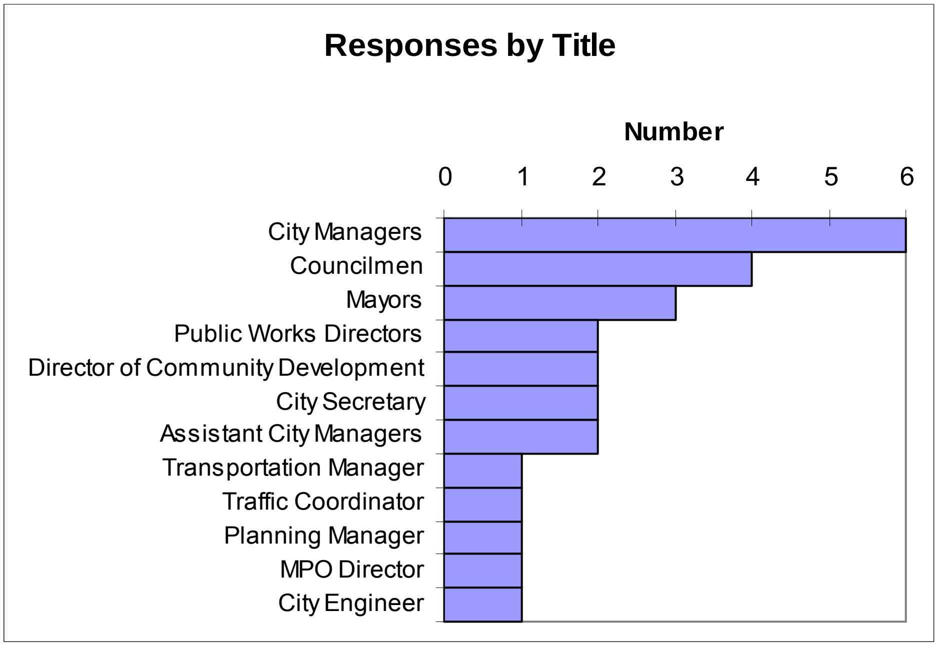


Figure 5-1. Survey Respondents by Title.

5.2.2 Definitions of Congestion

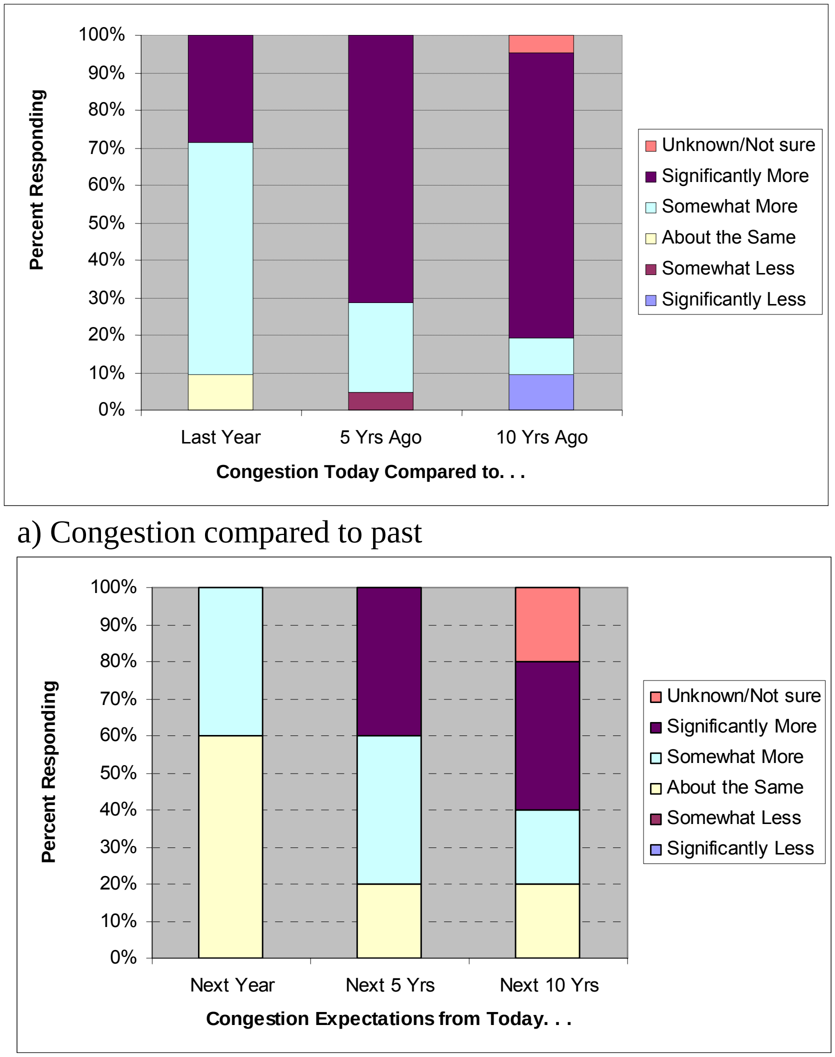
The respondents were first asked to provide a narrative statement for how local drivers define "congestion" in their community. The most common response (n=13) was delay at signalized intersections commonly one to two cycle lengths. The second most common response (n=7) was queuing, with several respondents specifically calling out queues related to stop-controlled intersections commonly greater than five vehicles. One respondent related queuing problems to heavy traffic volumes. Related to queuing and heavy volumes, five respondents noted problems with right and left turns. Two respondents directly related to rate of travel citing travel time and travel speed definitions.

The respondents were then asked what the technical definition of congestion was in their community, with the ability to state 'none.' The most common definition (n=15) was drivers waiting through some number of signal cycles. The median response was 2 signal cycles of delay. Some respondents clarified the time of day (peak period) or movement (any and through only). The second most common definition (n=7) was based on travel speed less than the posted speed limit. The median response was 25 percent less than the posted speed limit. The third most common definition (n=6) was travel time longer than the off-peak period. The median response was 40 percent longer than the off-peak period.

5.2.3 Congestion Conditions

Questions were then asked about their existing congestion conditions. Twenty respondents (83 percent) responded that their community experiences congestion. Nineteen respondents (95 percent) consider the existing congestion a problem. At this point in the survey, those responding that their community does not experience congestion were directed to an alternate survey branch that posed the same questions as the congestion branch, but in the context of anticipated congestion.

Figure 5-2 displays how respondents viewed the current congestion to past conditions (those responding that their community experiences congestion today) or their future conditions to today (those that did not indicate congestion was present in their community). In Figure 5-2a respondents (n=21) indicate that congestion is somewhat more to significantly more congested today compared to last year, five years ago, and 10 years ago, with marked intensity tended to significantly more congestion as time is referenced further back. Those indicating anticipated congestion (n=5) expect conditions to worsen in the next five to 10 years; nearly half expect congestion to be about the same or somewhat more in the next year.



a) Congestion compared to past

b) Anticipated congestion

Figure 5-2. Existing and Anticipated Congestion Severity Compared to Specific Reference Points.

5.2.4 Where Congestion Occurs and Where It Doesn't

Respondents were then asked over a series of questions about where congestion is considered a problem today or in the future. Figure 5-3 shows response total for each of the predefined areas asked in order from left to right as they progressed through the survey. The top five problem locations include:

1) State Routes
2) Near Schools/Colleges
3) City Streets
T4) Interchanges
T4) Downtown
T4) Near Shopping Centers
5) Around Special Events

The bottom five problem locations were:

1) Near Industrial Facilities
2) Hospitals
3) Near Other Business Centers
T4) Other Locations
T4) Edge of Downtown
T5) Near Government Facilities
T5) Truck Stops

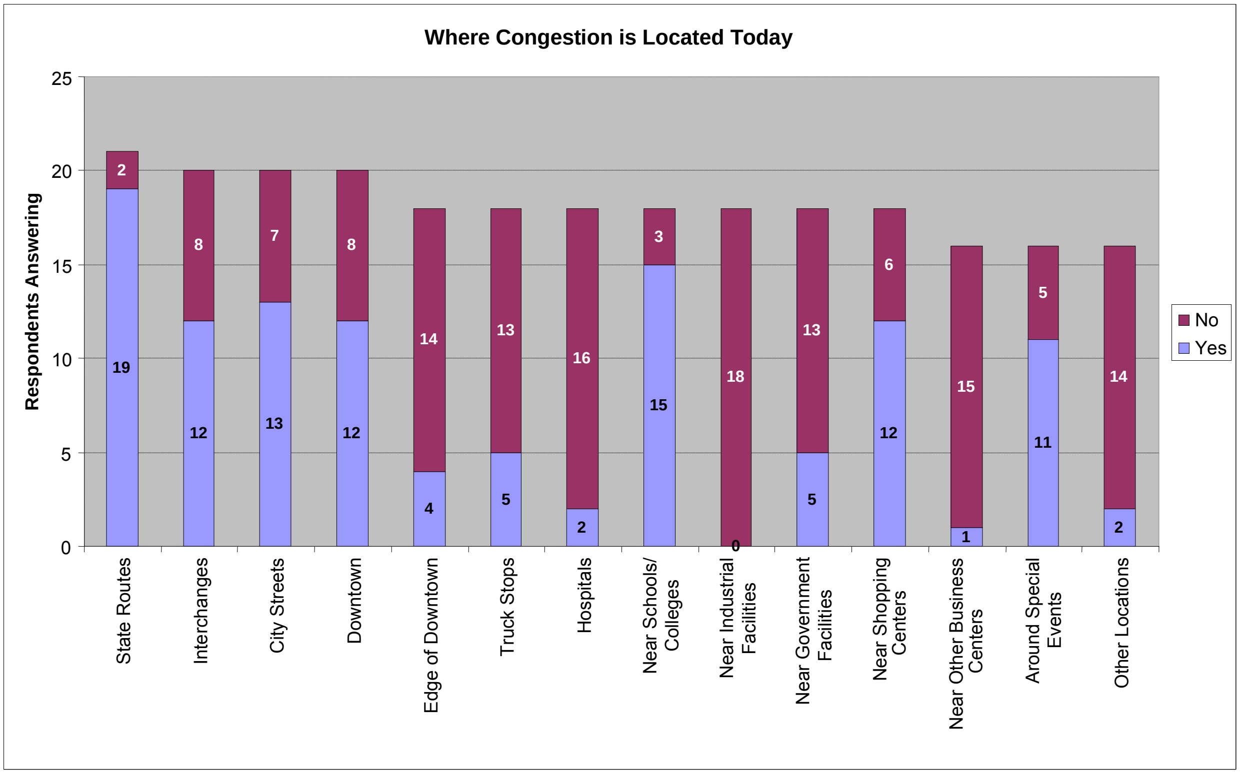


Figure 5-3. Areas Currently Experiencing Congestion.

Congestion along state routes was expected to be a high rank because SMSCs typically develop and grow around or along these transportation arteries. These communities must work in cooperation with local TxDOT districts to resolve congestion issues, and secure future funding for congestion relief. A high ranking for Near Schools/Colleges is not surprising, given that these activity centers have sharp peaking characteristics and high conflict potential as autos, buses, pedestrians, and bicyclists ingress and egress from school property.

Interestingly, the few that anticipated congestion chose a mix of top and bottom congestion areas in existing communities, shown in Figure 5-4. The most commonly anticipated area is along state routes, which is consistent with where communities are currently identifying the congestion problems, and from where likely future development and traffic demand will come.

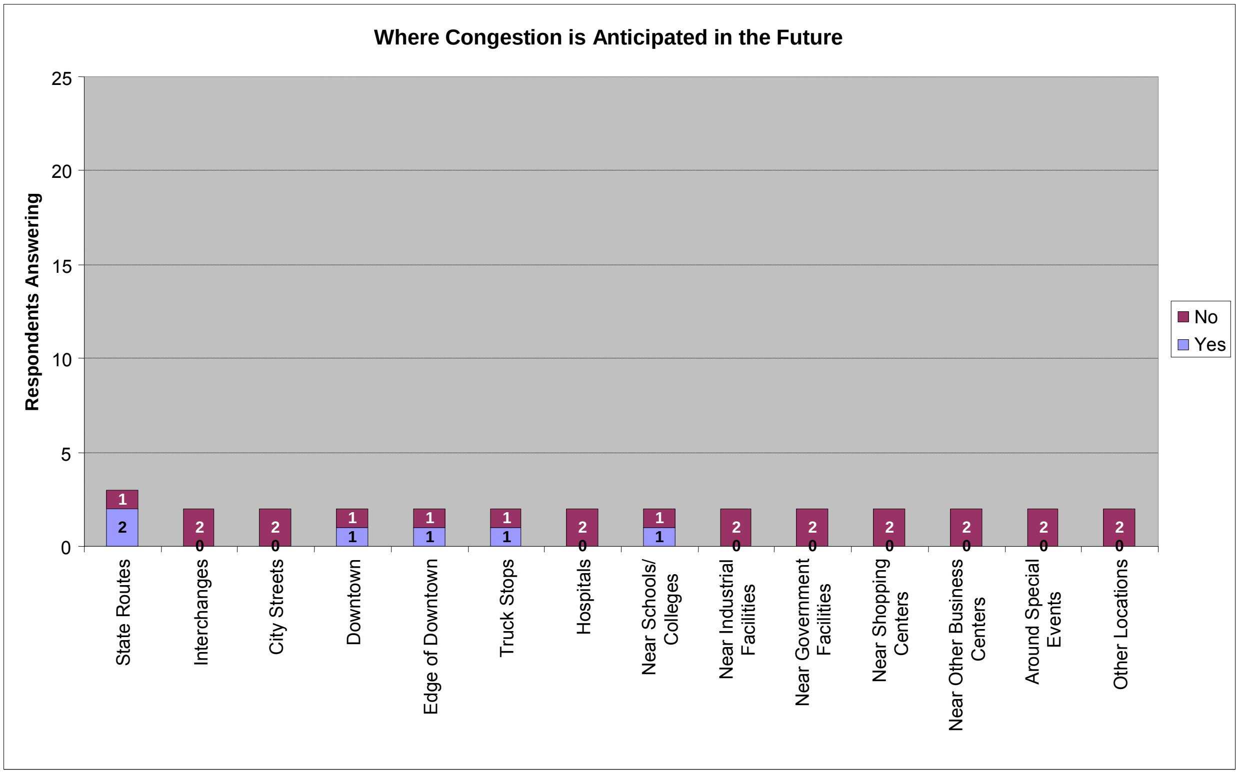


Figure 5-4. Areas Where Congestion is Anticipated.

5.2.5 Observations on Noted Congestion

In evaluating each of the 14 areas presented in the previous section, respondents were also asked in the survey to rate how long congestion occurred (none, less than 5 minutes, 5-10 minutes, 10-15 minutes, 15-30 minutes, 30-45 minutes, and greater than 45 minutes) by time periods (weekday morning peak, lunch/noon, weekday afternoon peak, weekends, holidays, and special events). They also indicated which modes were responsible for the congestion (where auto vs. auto, truck, rail, pedestrian, or bicycle).

For state routes, 12 of 19 respondents indicated that congestion lasted 30 minutes or more in either peak period. Weekends were generally free of congestion (n=7); however, around special events congestion exceeded 45 minutes (n=7) and holidays were split between congestion-free (n=5) and congestion exceeding 45 minutes (n=5). The predominant modes interacting to cause congestion was auto with auto (n=16), truck (n=13), and rail (n=5).

Congestion associated Near Schools/Colleges was less intense than other areas. Of the 15 respondents indicating this as a problem, the most common weekday morning peak period congestion was 5-10 minutes (n=4) with response tendencies up to 45 minutes of congested length. The lunch hour was generally less congested with responses (n=12) indicating less than 10 minutes. The afternoon peak period congestion was indicated slightly worse than the morning period where congestion lasted 10-15 minutes (n=4) though the range included 5 minutes to 45 minutes of congested time. The weekends and holidays are congestion free (n=12 for each general period); however, congestion related to special events at the schools ranges from 10 to 30 minutes (n=7). The predominant modes interacting to cause congestion was auto with auto (n=13), truck (n=9), pedestrians (n=8), and bicycle (n=5). The interaction between auto and pedestrian was the highest, tied with Special Events. The interaction between auto and bicycle was the highest of all areas. Respondents identified elementary to high schools as problem areas; no mention was made of colleges specifically.

Respondents (n=13) indicated that congestion on City Streets is greater than 45 minutes in either peak period (n=4 for both morning and afternoon periods). Congestion during the lunch hour is between 5 and 15 minutes (n=3 for each of the two time periods). Weekends and holidays are generally free of congestion; however, travel during special events can cause congestion greater than 45 minutes. The predominant modes interacting to cause congestion were auto with auto (n=11) and truck (n=10), followed by auto with rail (n=3) and auto with pedestrian (n=2). Respondents noted congestion on the city streets occurs at intersections with state routes and around elementary schools.

Twelve respondents indicated Interchanges as locations where congestion occurs. Respondents indicated congestion at interchanges was greater than 45 minutes for the weekday morning peak period (n=7), lunch/noon (n=5), and weekday afternoon peak period (n=9). The predominant modes interacting to cause congestion was auto with auto (n=9) and truck (n=9).

Congestion within the Downtown is widely varied. Twelve respondents provided an almost even response for length of congestion for each time period in the morning and afternoon peak periods, however a slight shift was seen to longer congested periods in the afternoon peak period. Congestion over the noon hour lasts 5-10 minutes (n=3). Weekends (n=4) and holidays (n=5) are generally congestion free. During Special Events, congestion is 15-30 minutes (n=4). The predominant modes interacting to cause congestion was auto with auto (n=9), truck (n=8), rail (n=3), pedestrians (n=6), and bicycle (n=1). The interaction between auto and pedestrian was third highest, behind Special Events and Near Schools/Colleges.

Respondent comments for Around Special Events indicate that the predominant modes interacting to cause congestion was auto with auto (n=10), truck (n=8), pedestrians (n=8), and bicycle (n=4). The interaction between auto and pedestrian was the highest, tied with Near Schools/Colleges. The interaction between auto and bicycle was the second highest for all areas. Congestion duration was commonly indicated at greater than 45 minutes regardless of time of day, weekend, or holiday. Special events singled out by respondents included parade routes, football games, park activities, and downtown/town square festivals.

5.2.6 Current Congestion Monitoring Efforts

Only six respondents indicated they conducted congestion monitoring. The common methods are traffic volume counts and turning movement counts. When asked how frequent monitoring is made, Upon Receiving Complaints from Public (n=4) was most common followed by Annually and for Comprehensive Plan Updates (n=2 for each). Four respondents had no performance measure; two respondents indicated using level of service. These answers seem disconnected from early questions that sought to obtain technical definitions of congestion in their communities. Previously delay, travel time, and travel speed were noted as technical definitions for community congestion; but none of the areas that indicate congestion monitoring appear to be collecting data to support those performance measures.

5.3 TRAFFIC COUNT DATA

5.3.1 Computing Operational Characteristics at Each Count Location

Researchers collected traffic data at 55 count locations in B-CS along the 12 corridors, and at 10 count locations in Huntsville along the two study corridors. The count locations were generally between the significant cross streets. Typically between one and three days of axle count data using pneumatic tubes were collected. The average daily traffic (ADT) for each location was computed. The ADT, by definition, is the amount of traffic in both directions. Total ADT is a useful statistic to assess relative level of demand on surface streets. Figure 5-5 and Figure 5-6 show maps of the count locations in B-CS and Huntsville, respectively. The figures spatially present ADT values throughout each region. One can quickly see that ADT values are higher in central locations, and lower further away from the central locations. It should be noted that the ADT values in Figure 5-5 and Figure 5-6 are not seasonally adjusted, and simply reflect the ADT based upon the one to three days of data collected.

Researchers also computed many other operational characteristics including the *K*-factor, directional factor *D*, and Peak Hour Factor (PHF). The *K*-factor represents the amount of daily traffic (ADT) that occurs during the peak hour of the day. For example, if the traffic volume in the peak hour is 3,600 vehicles and the ADT is 42,000 vehicles, the *K*-factor is 0.09—or, 9 percent of the daily volume occurs in the highest peak hour.

The directional factor (*D*) is the ratio of the highest directional volume to the total bi-directional volume within the peak hour. For example, if there are 2,160 vehicles in the eastbound direction and 1,440 vehicles in the westbound direction, the directional factor is 0.60 EB, meaning that 60 percent of the bi-directional traffic is traveling in the eastbound direction in the peak hour.

When 15-minute volumes are collected as they were in this study, the peak-hour factor (PHF) is calculated as the ratio of the highest 15-minute volume in the highest hourly volume. For example, if there are 3,600 vehicles in the hour, and 1,100 vehicles is the highest 15-minute period, the PHF is computed as 3,600 / (4 x 1,100) or 0.82.

Researchers created graphics as shown in Figure 5-7 for each count location in B-CS and Huntsville. The graphic shows how the 15-minute volume fluctuates throughout the "working day" (7:00 a.m. to 7:00 p.m.) A line is shown for both directions of traffic. The operational characteristics are shown to the right of the graphic, including ADT, directional daily totals, *K*-factor, directional factor *D*, and PHF. The "working day capacity" is explained in the next section of this report (5.3.2).

Graphics such as Figure 5-7 were initially used by researchers to identify suspect data. Graphing the 15-minute volume throughout the day can quickly identify where traffic counts are missing or suspicious. Days with suspiciously low, or missing, volume counts were re-counted.

Figure 5-5. Average Daily Traffic Values (1,000s) Based Upon Traffic Counts in B-CS.

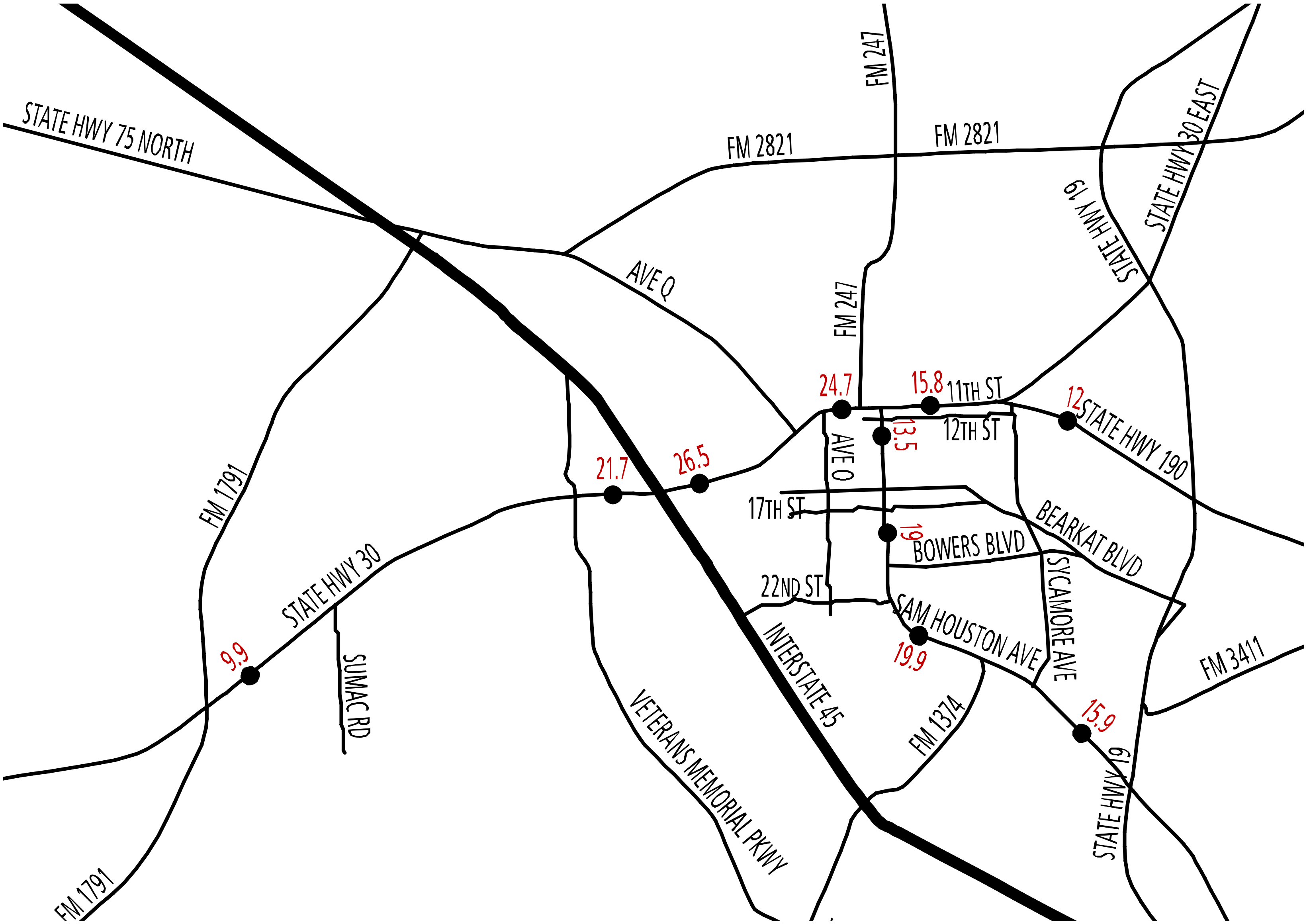


Figure 5-6. Average Daily Traffic Values (1,000s) Based Upon Traffic Counts in Huntsville.

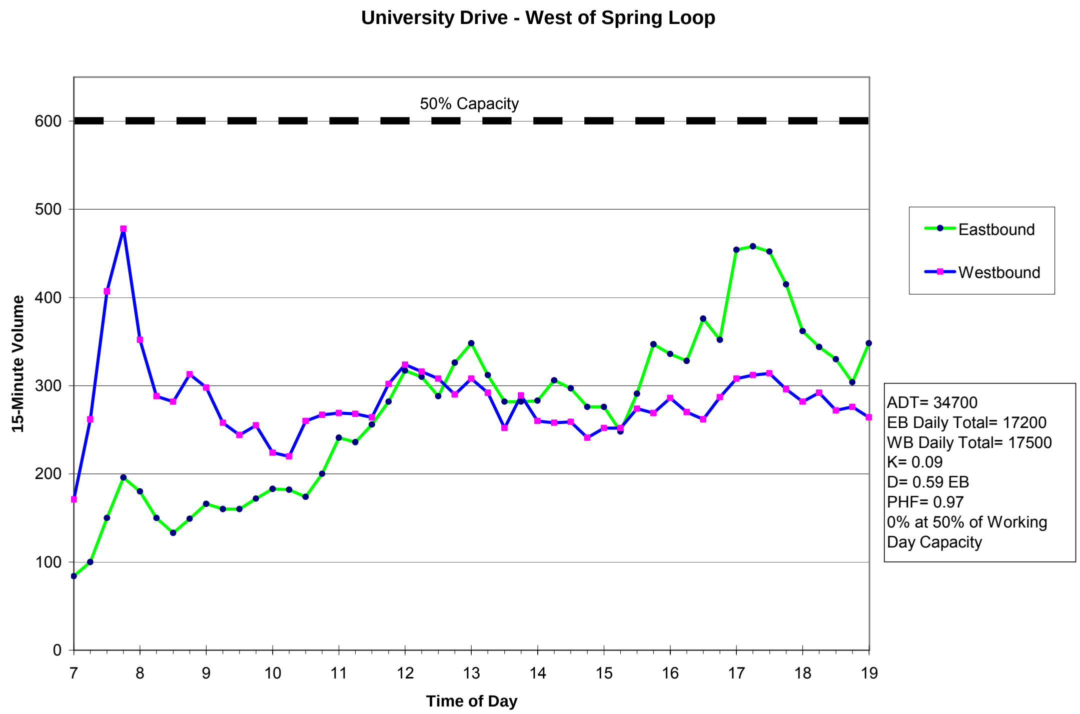


Figure 5-7. Sample Count Location Graphic Showing Directional Volume by Time-of-Day and Operational Characteristics.

After graphics such as that shown in Figure 5-7 were created for all sites in B-CS and Huntsville, the research team mapped the data. Figure 5-8 and Figure 5-9 present *K*-factors and PHFs at each count location in B-CS and Huntsville, respectively. Note that the *K*-factor is shown "above" the roadway line at the count location and the PHF is shown "below" the roadway line at the count location. As expected, one can observe that the *K*-factor values are generally greater than 9 percent outside of the central area of each community. Likewise, PHF values are higher in the central area of each community in comparison to outside the central area of each community.

Researchers then investigated the graphic for each count location of the form shown in Figure 5-7, and identified the predominant direction of travel in the morning (7:00 to 9:00 a.m.) and afternoon (4:00 to 6:00 p.m.) peak periods. For the morning and afternoon peak period, the data were mapped to show the predominant directions of travel. An arrow in both directions indicates that the travel was split closely in each direction. Figure 5-10 and Figure 5-11 show these maps for the B-CS community in the morning and afternoon, respectively. Figure 5-12 and Figure 5-13 show similar maps for the two Huntsville corridors in the morning and afternoon, respectively. One can quickly notice how traffic tends to move toward the urbanized area in the morning and away from the urbanized area in the afternoon.

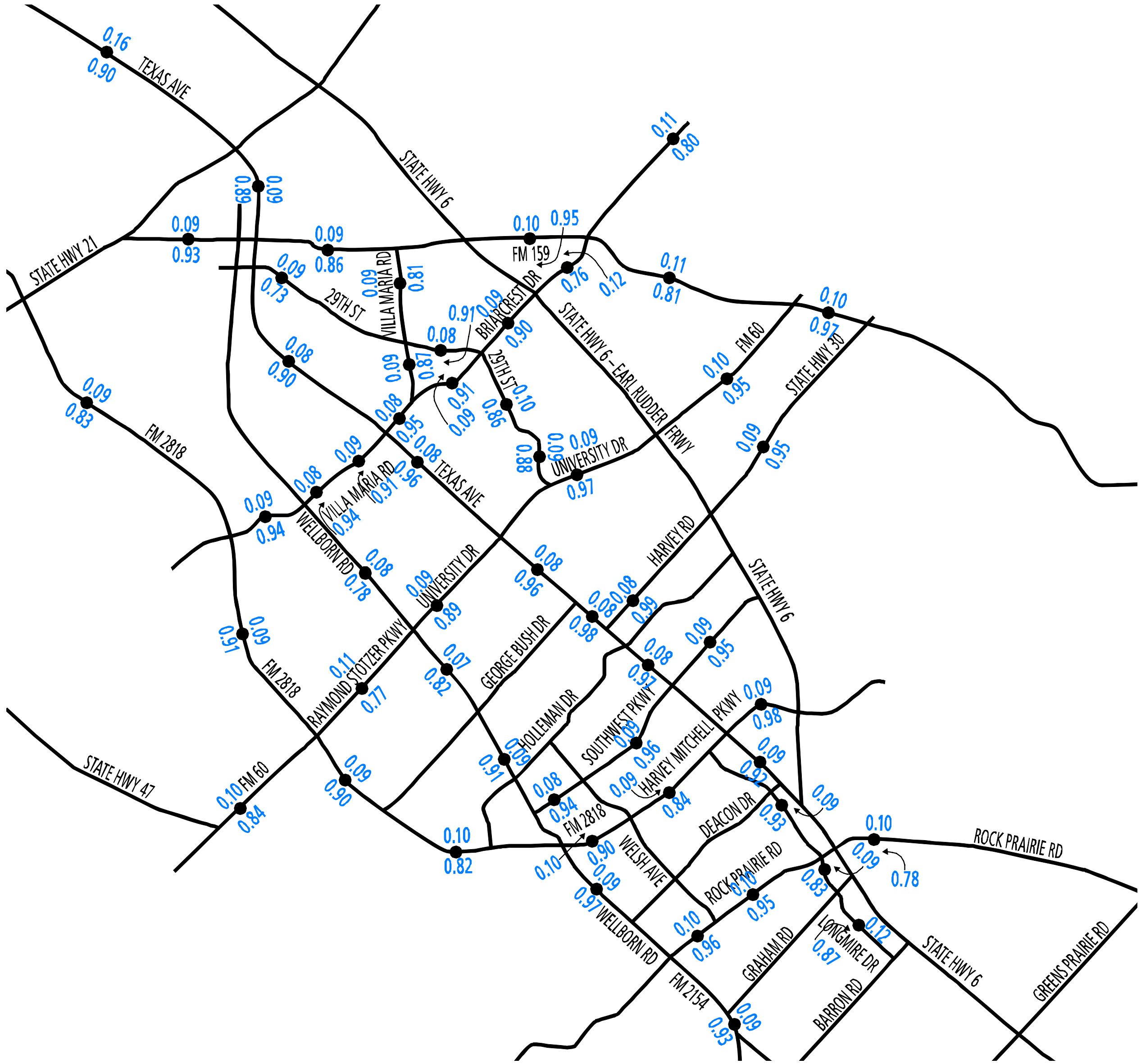


Figure 5-8. ***K*-factors and PHFs for Each Count Location in B-CS.**

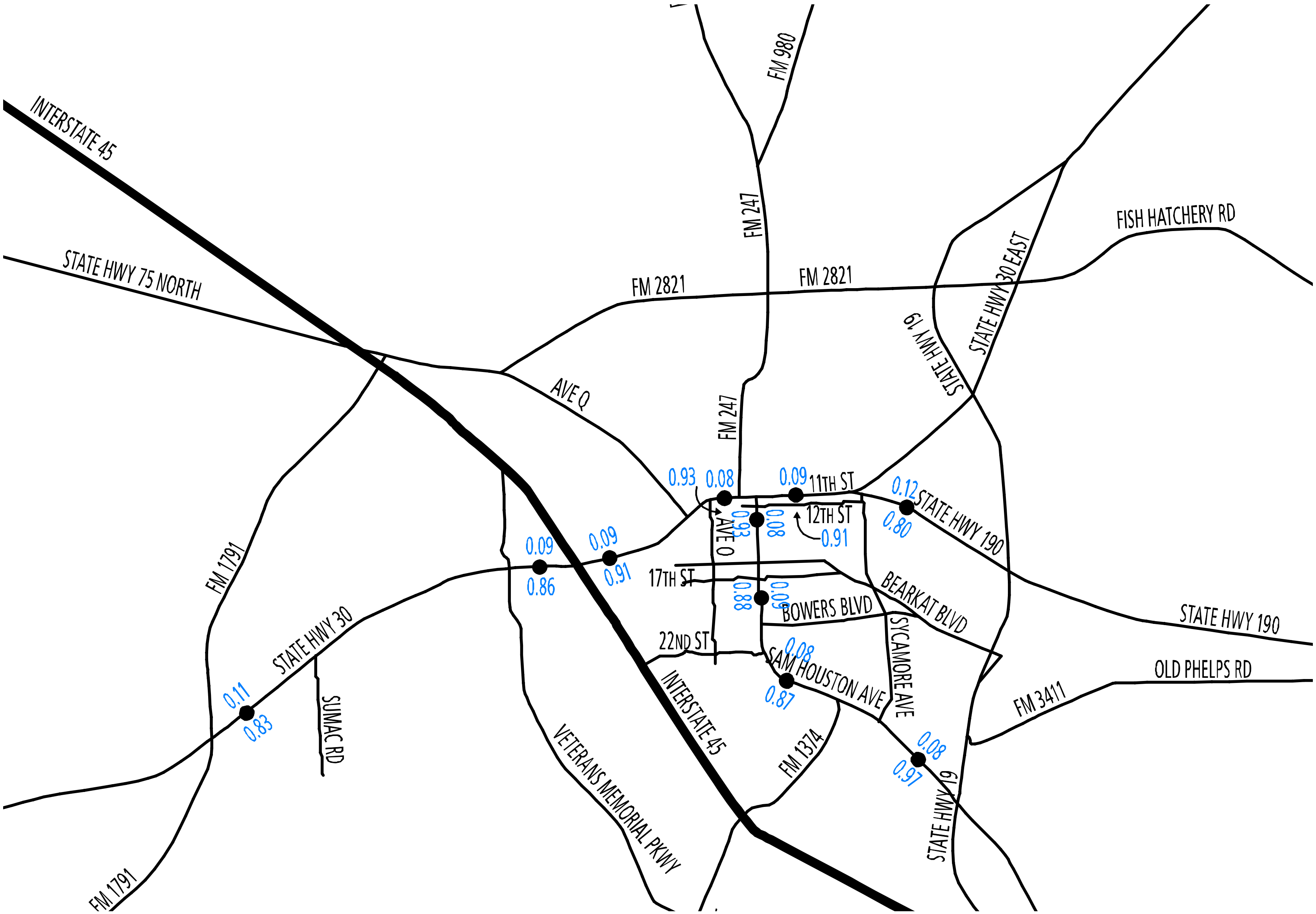


Figure 5-9. *K*-factors and PHFs for Each Count Location in Huntsville.

Figure 5-10. Morning Traffic Flow in B-CS.

Figure 5-11. Afternoon Traffic Flow in B-CS.

Figure 5-12. Morning Traffic Flow in Huntsville.

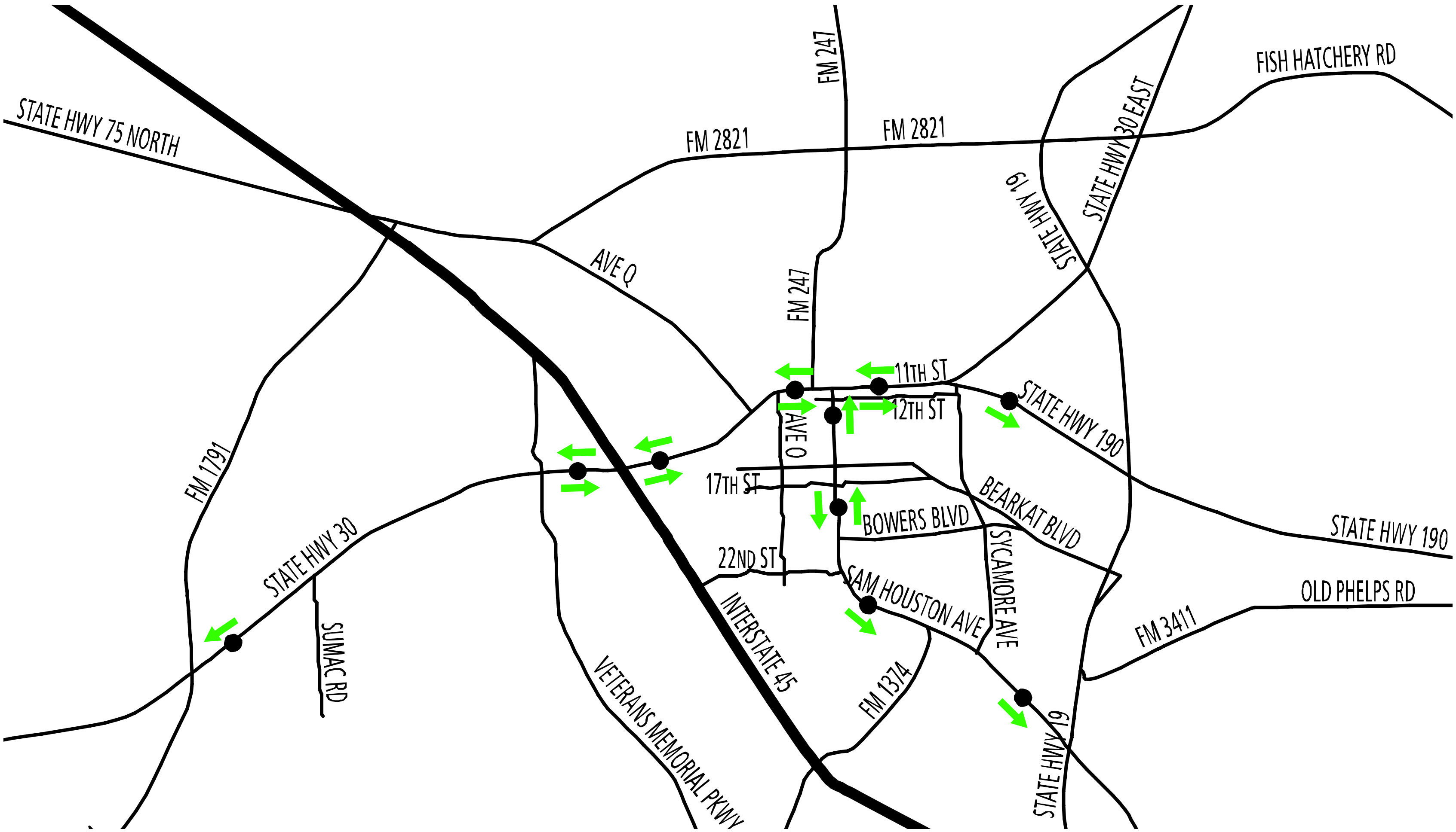


Figure 5-13. Afternoon Traffic Flow in Huntsville.

5.3.2 Volume Threshold Application

Without some sort of threshold on the count location graphics such as those shown in Figure 5-7, there is a question about whether the data are "good" or "bad" because there is no indication of whether the volumes are "high" or "low." Researchers investigated the use of an appropriate threshold. Thresholds can be applied against the volume data to graphically show how traffic volumes relate to the available roadway capacity. A 50 percent capacity threshold may be an appropriate initial threshold for SMSCs. The percent of time during the day above this threshold can be reported and compared to past or future measurements.

The roadway capacity can be estimated using Table 5-1. The physical characteristics, land use, and signal density affect hourly lane capacity measured in vehicles per hour per lane (vphpl). The estimate is a subjective assessment. More detailed roadway capacity estimates may be calculated using *Highway Capacity Procedures* (25). However, it is important to note that for on-going mobility monitoring, it is the year-to-year change in values, and identifying where and when these changes occur, which is of primary importance. The actual value of the measure, while important, is secondary to the year-to-year changes. Therefore, setting a preliminary threshold is important to get the monitoring started. As improved information becomes available, the analyst can always go back and update the capacity estimates.

Table 5-1. Estimated Hourly Lane Capacity Values.

General Physical Characteristics		**Estimated Hourly Lane Capacity (vphpl)**
Land Use	**Signal Density**	
Rural	Limited	2,000
Fringe	Moderately Spaced	1,800
Urban	Closely Spaced	1,600

As an example, the estimated capacity on an urban section of roadway with closely spaced signals for 15-minute volume data is calculated with Equation 5-1. Equation 5-2 shows the calculation with the values substituted into Equation 5-1.

$$\begin{matrix}\text{Estimated Roadway}\\ \text{Capacity Threshold}\end{matrix} = \text{Lane Capacity} \times \begin{matrix}\text{Number}\\ \text{of Lanes}\end{matrix} \times \begin{matrix}\text{Interval}\\ \text{Adjustment}\end{matrix} \times \begin{matrix}\text{Threshold}\\ \text{Factor}\end{matrix} \qquad \text{(Equation 5-1)}$$

$$\begin{matrix}\text{600 vehicles}\\ \text{per 15-minutes}\end{matrix} = \text{1,600 vphpl} \times \begin{matrix}\text{3 lanes,}\\ \text{Eastbound}\end{matrix} \times \frac{\text{1 hour}}{4(\text{15-min periods})} \times \text{1/2 capacity} \qquad \text{(Equation 5-2)}$$

By assigning each corridor to a general land use and signal density, capacity estimates were identified for each segment of the roadway. The "50% Capacity" threshold and the "X% at 50% of Working Day Capacity" were then calculated and placed on each bi-directional volume graphic as shown in Figure 5-7.

5.3.3 Availability of Volume Data

The operational characteristics described above are all useful for on-going mobility monitoring in any community. The data collected, reduced, and analyzed here are expected to be useful to provide a baseline for mobility monitoring in B-CS and Huntsville. Because a primary output of this project is to provide baseline data for mobility monitoring, the bi-directional volume graphics for each count location are on the compact disc (CD) attached to this report.

These data sets are anticipated to be of use to practitioners and researchers interested in performing mobility monitoring in SMSCs as well.

Appendix B contains graphics like Figure 5-7 showing the bi-directional volume data and operational characteristics for all count locations in B-CS and Huntsville.

5.4 TRAVEL TIME RUN DATA

Travel time data were collected along all 12 corridors in B-CS and both corridors in Huntsville. The field data reduction forms shown previously in Figure 4-1 were invaluable in reducing the travel time run data. On some of the runs, clock times needed to be adjusted if the GPS units did not have the correct time. The GPS units always had accurate minutes and seconds, but in a few cases, the hour on the clock would be off on the GPS unit. This can occur when the GPS unit is getting configured to a new environment (i.e., when it is new after it has been shipped). The data reduction forms also allowed a way to quickly identify which run numbers could not be used if the driver missed the first checkpoint. If drivers missed hitting the spacebar on the laptop at the first checkpoint, the data file was rendered useless because the first reference point would be off. After missing the first checkpoint, or accidentally hitting the spacebar prematurely, drivers were instructed to turn around and go back to the starting point to start over.

5.4.1 Travel Time Run Data Reduction and Summary Statistics

Table 5-2 provides summary statistics of the travel time runs in B-CS and Huntsville. Note that the morning period is three hours and the afternoon period is two hours. Researchers performed nearly 1,200 travel time runs. On average, there were between 15 and 29 runs in each direction during the peak periods. Note that the “morning period” shown in Table 5-2 actually includes one hour of off-peak runs (9:00 a.m. to 10:00 a.m.).

5.4.2 Travel Time Run Data Reduction

The travel time run data were analyzed with software that will segment the second-by-second GPS data into link speed and travel time data. Researchers performed analysis of average travel time and speed conditions for each segment. Segments were defined along each corridor primarily using signalized/major intersections. The off-peak travel time runs allowed calculation of the travel rate index (peak travel time divided by the off-peak travel time).

Appendix C contains the internal guide that was created to guide team members in converting the logged GPS data into segment travel time and speed data using the PC-Travel® and MapPoint® programs. PC-Travel® was used because the research team members had some experience using the software.

Table 5-2. Summary Travel Time Run Statistics.

Travel Time Summary Statistic	Morning Period (7:00 – 10:00 a.m.)	Afternoon Period (4:00 – 6:00 p.m.)
Bryan – College Station Corridors		
Total Number of Runs	603	360
Average Number of Runs (per direction)	25	15
Minimum Number of Runs (per direction)	11 (FM 2818)	8 (FM 2818)
Maximum Number of Runs (per direction)	42 (Harvey Road)	25 (Southwest Parkway)
Huntsville Corridors		
Total Number of Runs	115	78
Average Number of Runs (per direction)	29	20
Minimum Number of Runs (per direction)	23 (SH 30 / SH 190)	15 (SH 30 / SH 190)
Maximum Number of Runs (per direction)	35 (SH 75)	25 (SH 75)

The analysis in PC-Travel® requires the collection of a "node run." During this run, the researchers would drive slowly down the corridor and record where all the nodes (e.g., signalized/major intersections) were located. This run was uploaded into the computer, and using mapping software (MapPoint®), researchers could verify by visual inspection that the nodes appeared accurately on the map. The procedures in Appendix C provide detail about how the study groups were created for each analysis (e.g., morning runs along University Drive in the eastbound direction).

5.4.3 Travel Rate Index Computation and Graphical Illustrations

After reducing the travel time data for each link (i.e., between nodes), researchers could compute the travel rate index for each link. The travel rate index is a measure of rate of travel compared to a free-flow travel rate and does not include travel time data where nonrecurring congestion, such as congestion due to traffic incidents, is present. See Table 2-1 for the travel rate index equation. There is no consistent, single definition for the free-flow travel rate. Free-flow travel rate can be defined through use of posted speed limits or a statistical percentile of measurements (*3*). The travel rate index is calculated most frequently over the length of a corridor in the travel direction of interest. As shown in Table 2-1, it can be weighted by link traffic volume to obtain a value over a corridor. It can also be computed for links along the corridor (i.e., between nodes).

A travel rate index of 1.0 means the rate of travel measured is the same as the free-flow condition. Each increase of 0.1 is equivalent to a 10 percent increase in travel rate over the free-flow condition. A travel rate index of 1.5 means that travel takes 50 percent longer than travel in the free-flow condition.

5.4.3.1 Free-flow Travel Rate Calculation

Free-flow travel rate must first be estimated to estimate the travel rate index. The free-flow condition is calculated by summing the 15th percentile off-peak travel time for each link along the corridor. Estimating the free-flow condition in this manner eliminates one or two (typically) of the fastest recorded times, mitigating any "speed racer" effect, and synthesized better traffic flow conditions from all measurements, mitigating the effect of some congested links on the total run's travel time.

The travel rate index for each run is the ratio of that run's total travel time to the 15th percentile total travel time. Because the corridor length is the same for each run and the 15th percentile travel time, it is not necessary to use corridor length in the calculation. The researchers recommend maintaining the travel rate index to one or two decimal places. Additional decimal places are not appropriate because they infer greater accuracy in the data than is typically present.

For link travel rate indices, each checkpoint's time is set as a ratio to the link's 15th percentile travel time. The median and maximum link travel rate indices are recommended for reporting relative mobility on each link. The median represents the point where 50 percent of the number of travel time runs recorded was equally greater or less than the value.

The median travel rate is an appropriate measure where half of the measurements were faster or slower than this rate. For statistical reasons, use of a median is more appropriate than an average because the travel rate index measurements are not normally distributed. Averages can easily be skewed when measurements are not normally distributed and extreme values are not removed from the dataset.

Because the 15th percentile travel time is used, it is possible to calculate a travel rate index less than 1.0. Travel rate indices should not be less than 1.0. To correct for this condition, the minimum value was set to 1.0 in the spreadsheet calculations.

Figure 5-14 is an example of a link-based travel rate index graphic for Briarcrest Drive/Villa Maria Road in the eastbound direction in the afternoon. The graphic provides several packets of information. First, along the bottom or x-axis, the reader is presented the physical aspects of the roadway—its width, relative distance between cross streets (nodes), and traffic signal density. The blue and red lines relate the travel rate indices. The thicker line conveys the worst (maximum) mobility conditions measured. The thinner line indicates the median observation, where half of the data experienced higher or lower travel rates. The y-axis is relatively larger than the data within the chart. The scale was lengthened to provide a level comparison for data in other time periods, and other roadways, which approached an index level of 16.0.

Graphics like Figure 5-14 were created for all corridors by direction and time period. They are included in Appendix D.

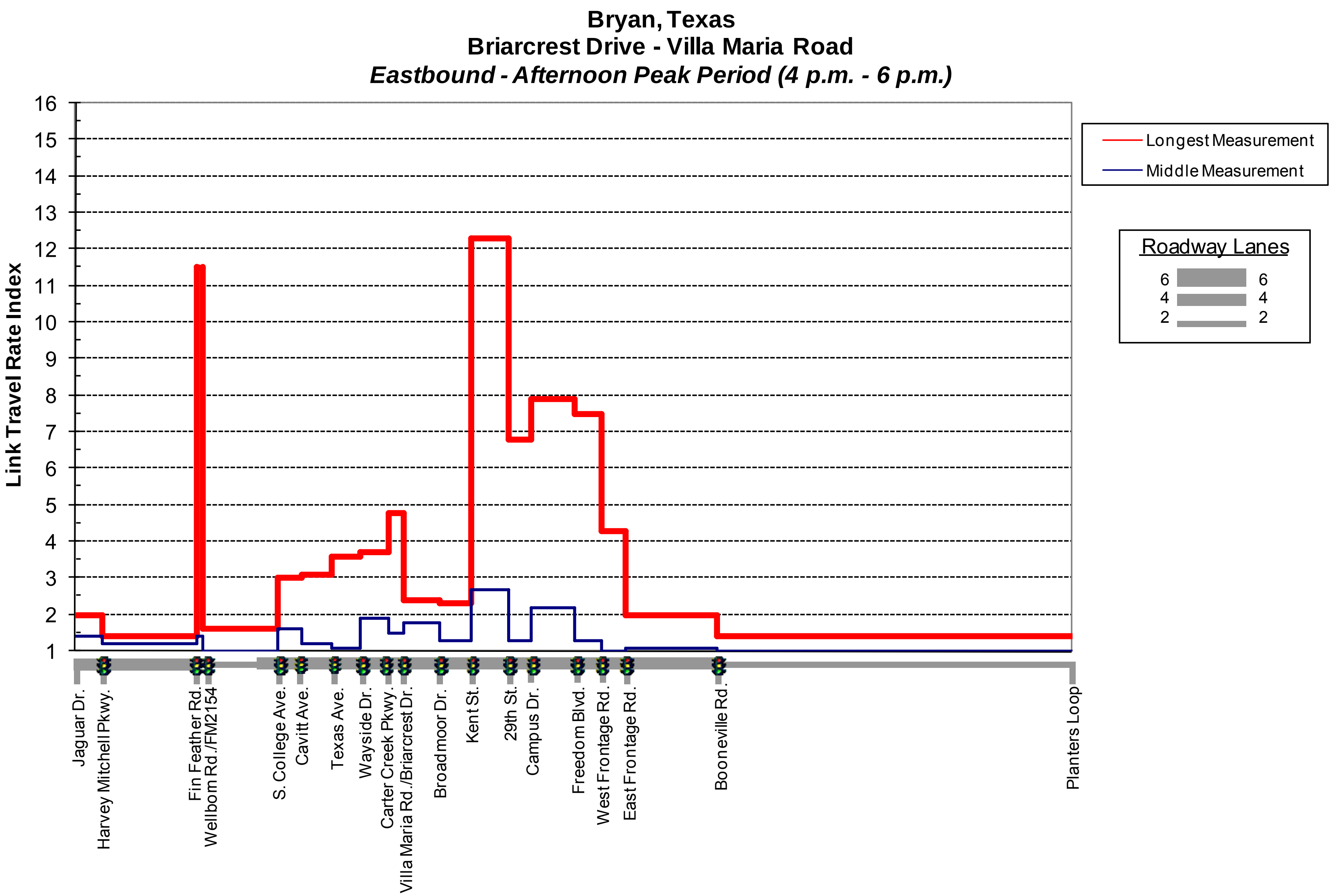


Figure 5-14. Travel Rate Index Graphic.

5.4.4 Average Speed and Cumulative Average Travel Time Graphics

Figure 5-15 presents another common method for presenting average link speed and travel time data along the same x-axis as used in Figure 5-14 for a corridor. The thicker line presents average speed between links. The thinner line with symbols indicates the average cumulative travel time through the corridor. Similar to Figure 5-14, the x-axis presents the number of lanes, cross-street locations, and signal locations. Figure 5-15 is also for Briarcrest Drive/Villa Maria Road in the eastbound direction in the afternoon.

It is interesting to note the "spike" in the travel rate index between Finfeather Road and Wellborn Road. This spike is due to construction that was on-going at this location, and the roadway was down to one lane in each direction when the travel time data were collected.

5.4.5 Availability of Travel Time Data

The travel rate index, travel time, and speed data described above are all useful for on-going mobility monitoring in any community. The data collected, reduced, and analyzed here are expected to be useful to provide a baseline for mobility monitoring in B-CS and Huntsville. Because a primary output of this project is to provide baseline data for mobility monitoring, the travel rate index and average speed/cumulative average travel time graphs are included in Appendix D and the data are on the compact disc (CD) attached to this report.

These data sets are anticipated to be of use to practitioners and researchers interested in performing mobility monitoring in SMSCs as well.

Appendix D contains graphics like Figure 5-14 and Figure 5-15 for all the corridors studied in B-CS and Huntsville.

5.5 STOPPED DELAY STUDY DATA

The stopped delay study data collection was previously described in section 4.2.3.4. The data were reduced through spreadsheet analysis. Figure 5-16 shows the 5-minute interval stopped delay data for northbound SH 6 to westbound University Drive in both left-turning lanes from 7:00 a.m. to 9:00 a.m. The ending 5-minute time is shown on the x-axis. The computed stopped delay is along the y-axis. Because the university is a primary trip generator, the stopped delay "spikes" to 102 seconds at 8:00 a.m.

Researchers also placed thresholds on the computed stopped delay values. Along the right side of the graphic, a horizontal dashed line is shown at the cycle length (100 seconds). Other thresholds of time are shown for illustration. This graphic shows that for motorists arriving at this turning maneuver between 7:56 a.m. and 8:05 a.m., they can expect to wait for two cycles. The graphic shows another small upward trend in stopped delay from 8:36 a.m. to 8:45 a.m., presumably matching the typical 9:00 a.m. business opening.

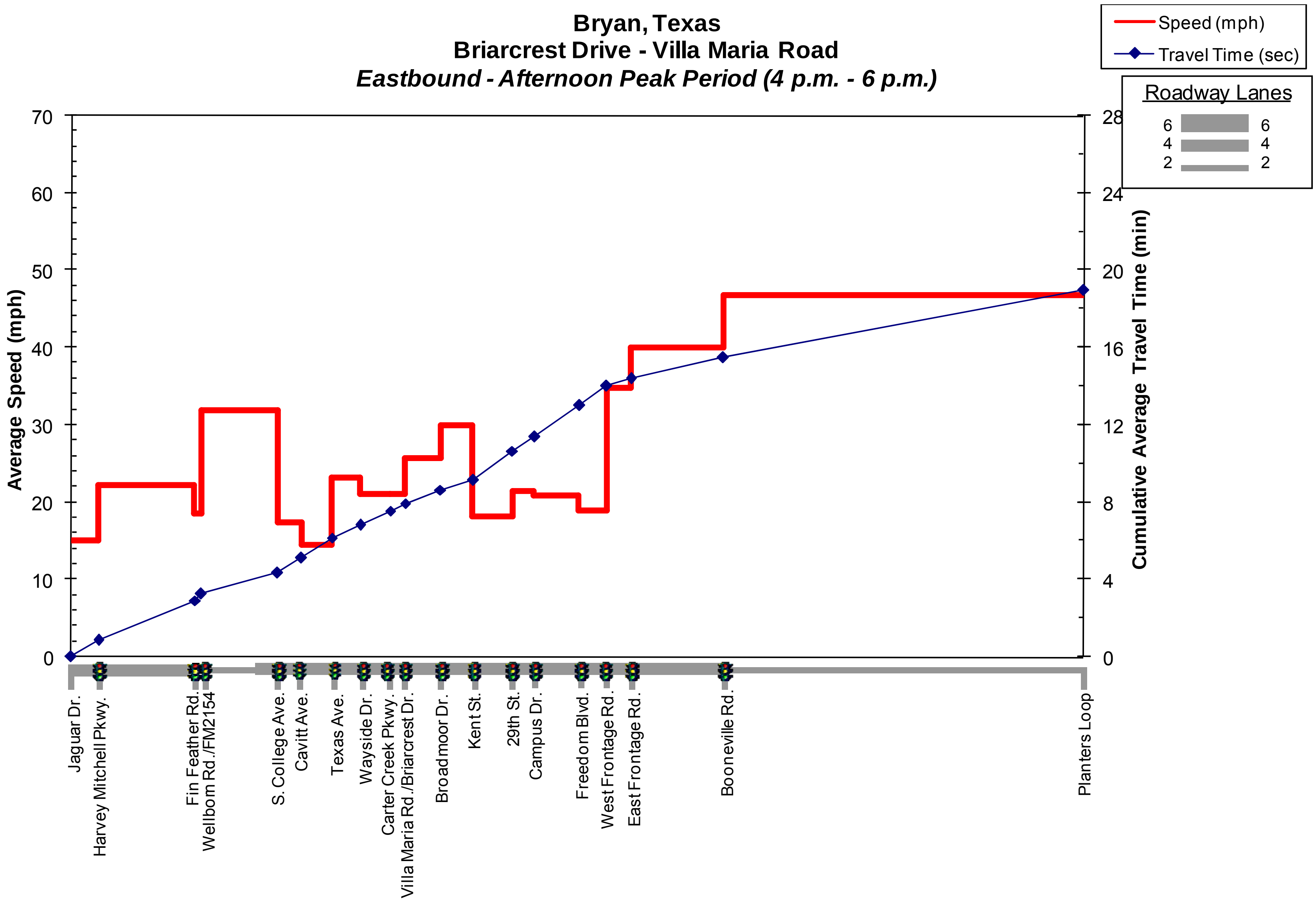


Figure 5-15. Average Speed and Cumulative Average Travel Time Graphics.

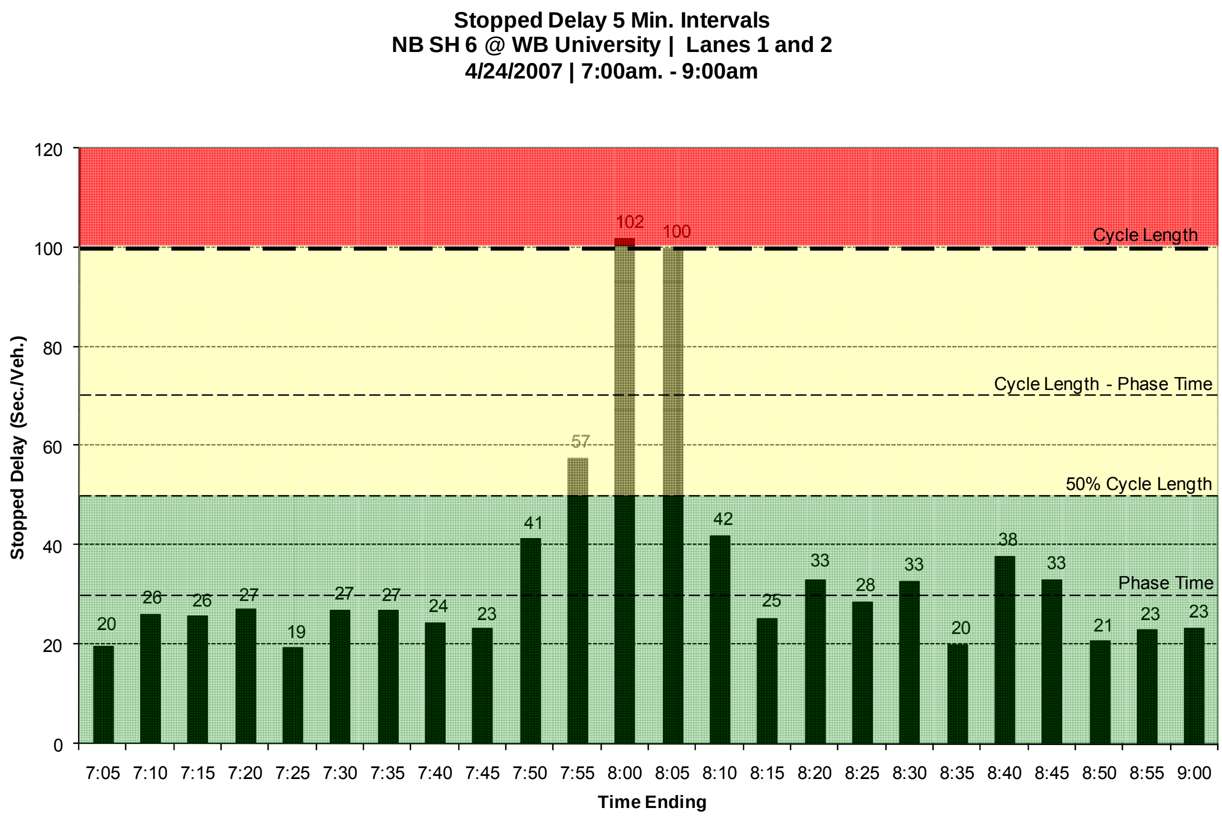


Figure 5-16. Stopped Delay Study Results by 5-Minute Intervals.

Graphics like Figure 5-16 provide useful information for at least two purposes: 1) operations of the turning movements at the signal, and 2) turning-movement travel time information that can be "added" to link travel time data along University Drive and SH 6 to provide a corridor travel time estimate.

As indicated previously, researchers also performed a stopped delay study along University Drive in the afternoon turning right onto southbound SH 6 (see Table 4-3). Due to sight distance limitations, researchers were not able to see over a hill and could not see the extent of queuing that was occurring upstream. The recommendation is that travel time runs could be performed for some turning movements when manual stopped delay computations cannot be collected.

5.6 CONCLUDING REMARKS

This chapter described the data reduction, analyses, and findings of the applications of the framework described in Chapter 3 to the two case study applications—one in B-CS and one in Huntsville.

The following bullets highlight the key points from this chapter:

- Nearly 1,200 travel time runs were performed, which were plenty of runs to ensure statistically valid travel time results for the baseline mobility monitoring efforts in B-CS and Huntsville.

- Changes in typical traffic operation characteristics (ADT, PHF, *K*-factors, directional distribution factors *D*) can be good measures of congestion changes in smaller communities, and illustrating these values spatially on a map can assist in presenting and understanding these changes.
- "X% of the working day capacity" was introduced as a reasonable threshold at count locations, and it can be adjusted in subsequent monitoring efforts as more data become available.
- Travel time based performance measures were the focus because they are easier to communicate to all audiences, and they apply to the individual traveler.
- Visual methods such as Figure 5-7 provide an efficient way to visually inspect count data for quality as well as providing a visually appealing way to present the volume data by time of day along with the important operational characteristics at the count location.
- Graphics such as Figure 5-14 and Figure 5-15 provide a much more appealing and understandable way to present travel rate indices, speed, and travel time information that is far more understandable than simple tables.
- Stopped delay studies can be used to provide travel time information through intersections along trips where travel time is of interest, though caution must be taken to ensure there is adequate sight distance to see all stopped vehicles on the approach of interest.

CHAPTER 6
COMMUNICATING MOBILITY MONITORING RESULTS

6.1 INTRODUCTION

Step 5 of the framework described in Chapter 3 is "Package and Distribute the Results." The objective of that step is to present the results of the mobility monitoring program in a manner that speaks to several audiences—technical, elected officials, and the general public.

It takes a great deal of time, and trial and error, to develop a meaningful graphic that conveys just the right amount of information in a manner that is easy to understand. Researchers developed many examples of effectively presenting and displaying mobility monitoring results in this research project. Because of the importance of this topic, several examples of graphics are presented in this chapter. These graphics are starting points, and are not meant to be the one-and-only graphic for conveying information to stakeholders. Many of the tips and graphics that follow are also described in the *Guidebook for Mobility Monitoring in Small to Medium-Sized Communities: A How-To Guide* (*1*), while some examples have already been shown in Chapter 5.

6.2 MAPS

Use map-type graphics when possible. Stakeholders relate easily to their physical environments. Choose an appropriate scale where the area and its context are large enough to orient the reader, while balanced against the need to show enough detail.

Consider the needs of the viewer when preparing maps. Consider what they want to see, and what visual information needs to be provided to orient them. Avoid extraneous information on the map. Include only the information that is meaningful to the purpose of the data.

6.3 TABLES

Data tables serve a valuable purpose. Tables should be able to stand alone, be concise, and use simple but clear labels and titles. Graphic aids like lines, shading, or spacing should be used to separate data groups. The graphic aids should be used both horizontally and vertically in the table. Separating data groups helps the reader understand where data categories change.

Use consistent table formats in documents with a font that differs from document text. The best fonts for document text are those that have serifs (the embellishments to the letters that lead the eyes to the next letter or word). Examples are Times New Roman or Garamond. Data tables are best displayed in a san serif font (a font that has no embellishments). Examples are Arial or Helvetica. Use a leading zero for data between zero and one (0.97 vs. .97). Use decimal alignment in columns that clearly convey magnitudes to the reader.

Finally, use only the appropriate number of significant digits in the data. Currently available tools are capable of reporting calculated data results out to many decimal places. However, calculated results are only as precise as your least accurate input parameter. Reporting with more significant digits than the least accurate data input is a mis-statement of the data.

6.4 DENSITY PLOTS

The density plots shown in Figures 6-1 through 6-3 provide readers with a sense of congestion intensity through the corridor (spatially) and through time (temporally). Figure 6-1 is a basic representation. This density plot compresses all of the data together so that each observation (ending cross-street run time) is weighted equally in terms of plot area. Time is read from left to right in accordance with natural reading tendencies. Likewise, movement through the corridor is conveyed as the reader scans down the graphic. Note that the direction of travel is also indicated to confirm the reader's sense of movement through the corridor. Increasing congestion, or higher travel rate index values, can be color-coded through the use of either more intense color saturation or more intense color choice (of course, a simple grayscale also is adequate, but not as eye-catching). In this example, decreased mobility can be seen to become more common through time over the afternoon peak period and geographically from mid-way through to the end of the corridor.

A second density plot, shown in Figure 6-2, provides the reader with more information by adding blank rows for times (in this case at 5-minute intervals) where data were not collected. This graphic switches column and row headers to show movement through the corridor in a left-to-right configuration. Time is shown as an upward movement, forcing the reader to begin at the bottom of the graphic and work up through the visual data.

Finally, Figure 6-3 displays the last density plot in this progressive series. This figure builds upon the previous figure by relating the length of the individual corridor segments. This graphic succeeds in relating congestion intensity and duration over a spatial representation. For instance, travel rate index values near the center of the corridor are intense over short links.

6.5 USE OF COLOR AND SCALE

Use of color in graphics makes them more visually appealing to readers. Most technical professionals were trained to develop graphics for black-and-white reproduction. This is important when the results will be shown in grayscale format. However, many applications for mobility monitoring graphical results—workshops, presentations, brochures—are likely to use color.

The first tip is to carefully select the scale. Time-based scales can either highlight acute, short-duration events or can dampen them so that they appear less severe. Distance-based scales should be used to relate spatial concepts.

In conveying stopped delay at intersections, Figure 5-16 was previously shown with shaded horizontal bands that relate to the signal cycle length, which is a tangible quantity for the reader or driver. In color, the red band (>100 seconds/vehicle), yellow band (50% cycle length to cycle length threshold), and green band (<50% cycle length) would readily speak to a general audience. The "red band" at the top of the graphic means that the motorist must wait to be processed through the intersection on the second cycle after arrival in the queue. The reader is encouraged to review reference *1* to see this and other graphics in full color.

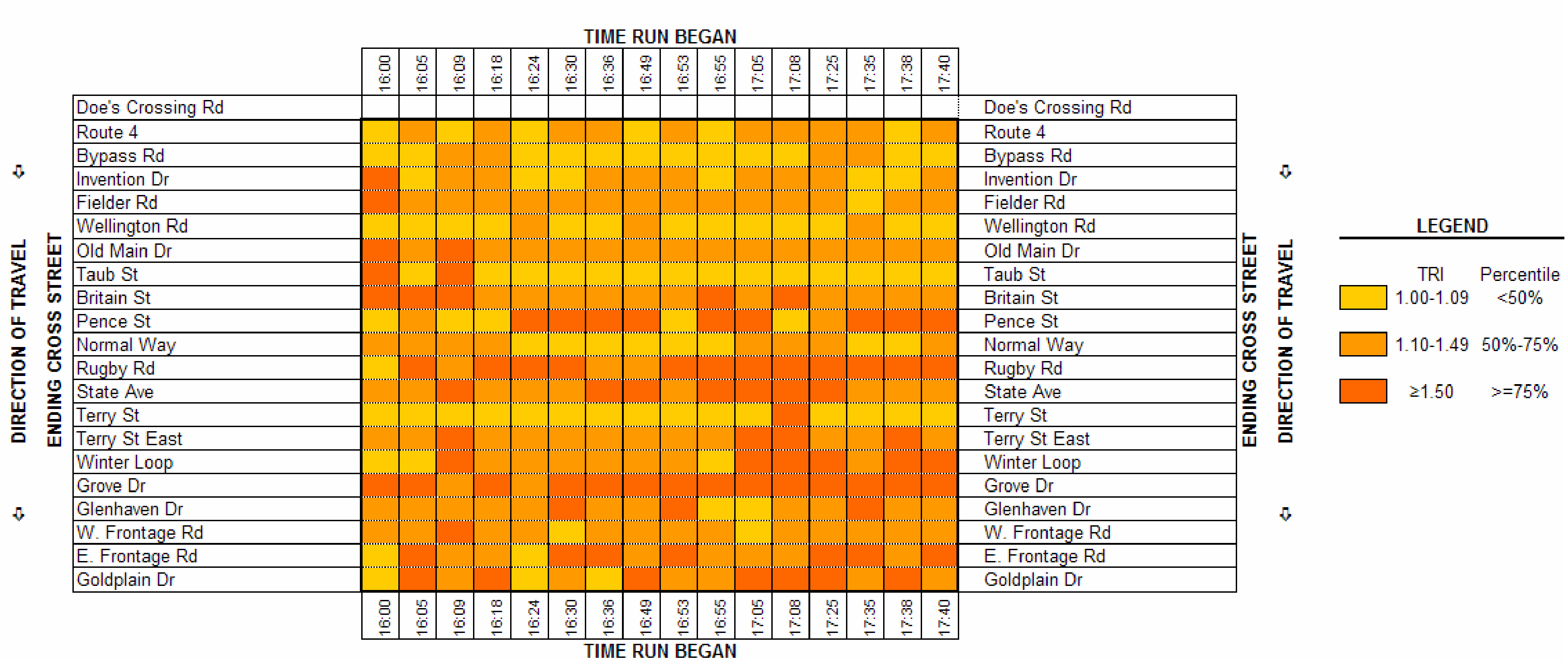


Figure 6-1. Grayscale Density Plot of Travel Rate Index Measurements (Reference *1*).

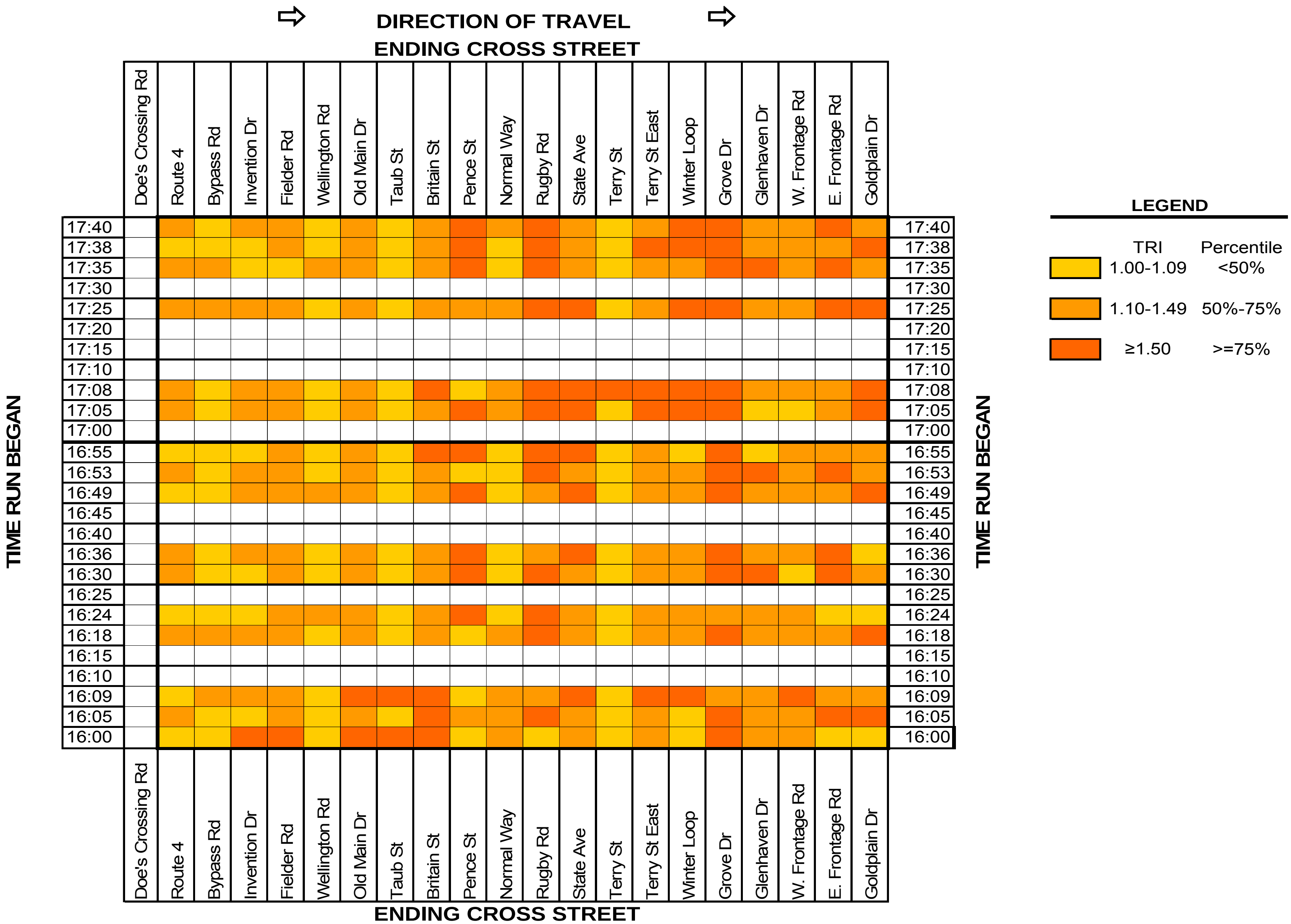


Figure 6-2. Grayscale Density Plot of Travel Rate Index Measurements Related Within the Time Period (Reference *1*).

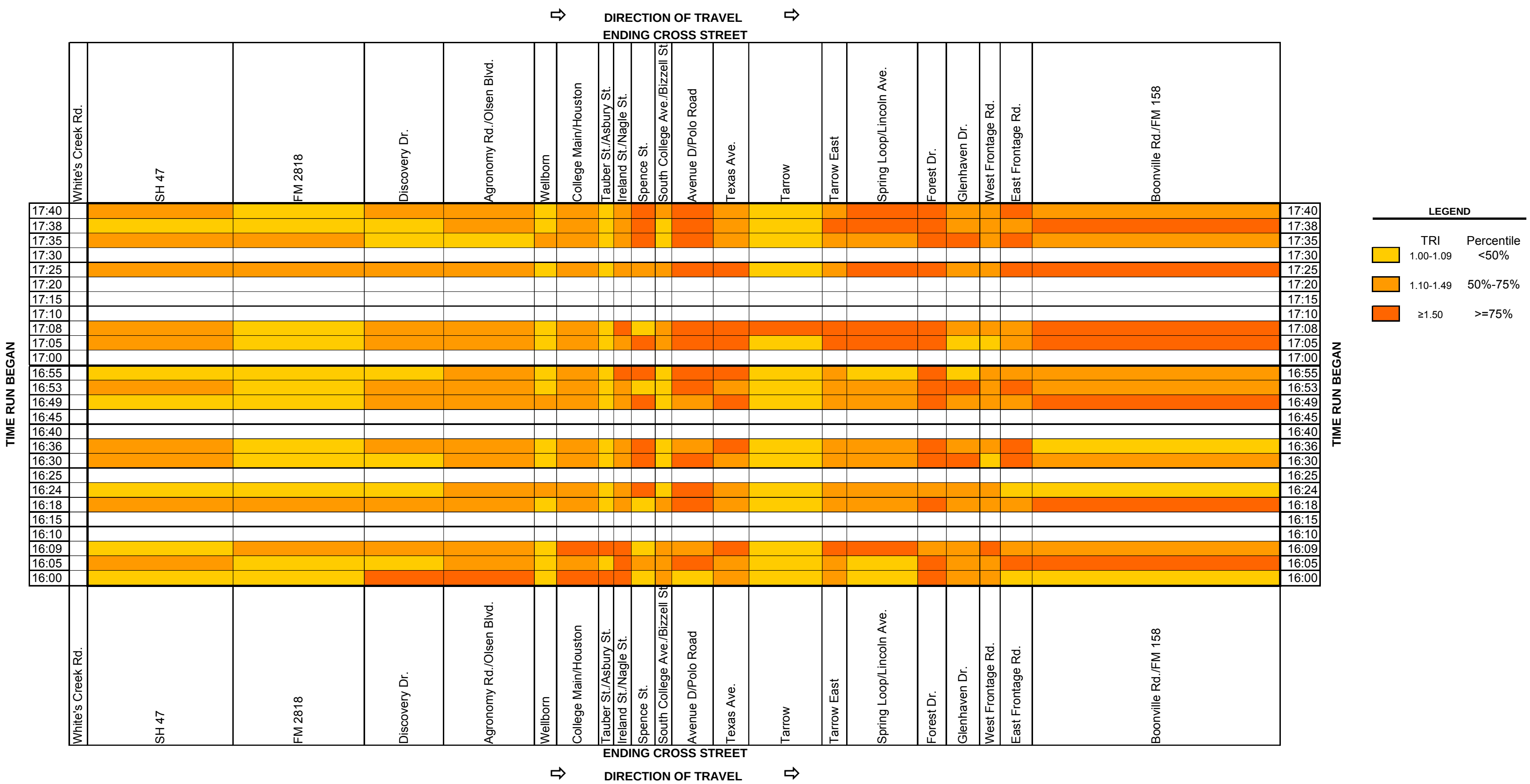


Figure 6-3. Grayscale Density Plot of Travel Rate Index Measurements Relating to Time and Roadway Length (Reference *1*).

6.6 RADAR GRAPHICS

Radar graphics are another form of graphic that directs focus to measurements that are extreme. Using local knowledge of congestion conditions, the user can verify when and where congestion is occurring, thereby validating that the data collection results are reasonable. Figure 6-4 presents such a radar graph that could be used for quality control of extreme observations or to quickly identify relatively extreme congestion conditions.

6.7 SPEED-VOLUME REPORTING TOGETHER

Figure 5-7 previously illustrated how bi-directional volume and traffic characteristics could be displayed on the same graphic. Figure 6-5 incorporates speed data together with one direction of the volume data. Because the general public better relates to speeds, this graphic helps to convey the speed-flow-density relationship to a non-technical audience. The speed data in this case are measured from the travel time runs and are shown with the volume data. An "estimated speed" line is regressed into the speed data to show the general trend. Appendix B contains graphics similar to Figure 6-5 for each count location along University Drive in College Station.

6.8 SPATIAL AND TEMPORAL VOLUME RESULTS TOGETHER

Figure 6-6 shows an example of current year daily 15-minute traffic volumes. The count locations are shown in relation to the major cross streets on the corridor. The figure also separates out volumes by direction of travel. The graphic is kept relatively simple—no repeating axis values on each graph. Keeping the graphic simple directs the reader's attention to the data and is less distracting. Note that each of the small "volume graphics" represents the data in one direction from graphics like Figure 5-7. Figure 6-6 is an extremely effective way of making spatial sense out of several directional volume count graphics along a given corridor.

Historical traffic volumes along the fictitious Alternator Avenue are displayed in Figure 6-7. This example illustrates how annual counts were available on each end of Alternator Avenue. However, for the count locations between the endpoints, count data were available only every five years. This is typical of some count locations in Texas where TxDOT does counts every five years, rather than annually. It is acceptable to show the gaps in the data, as necessary. Trends can still be identified; however, trends are more evident and stronger conclusions can be made when the data gaps are filled.

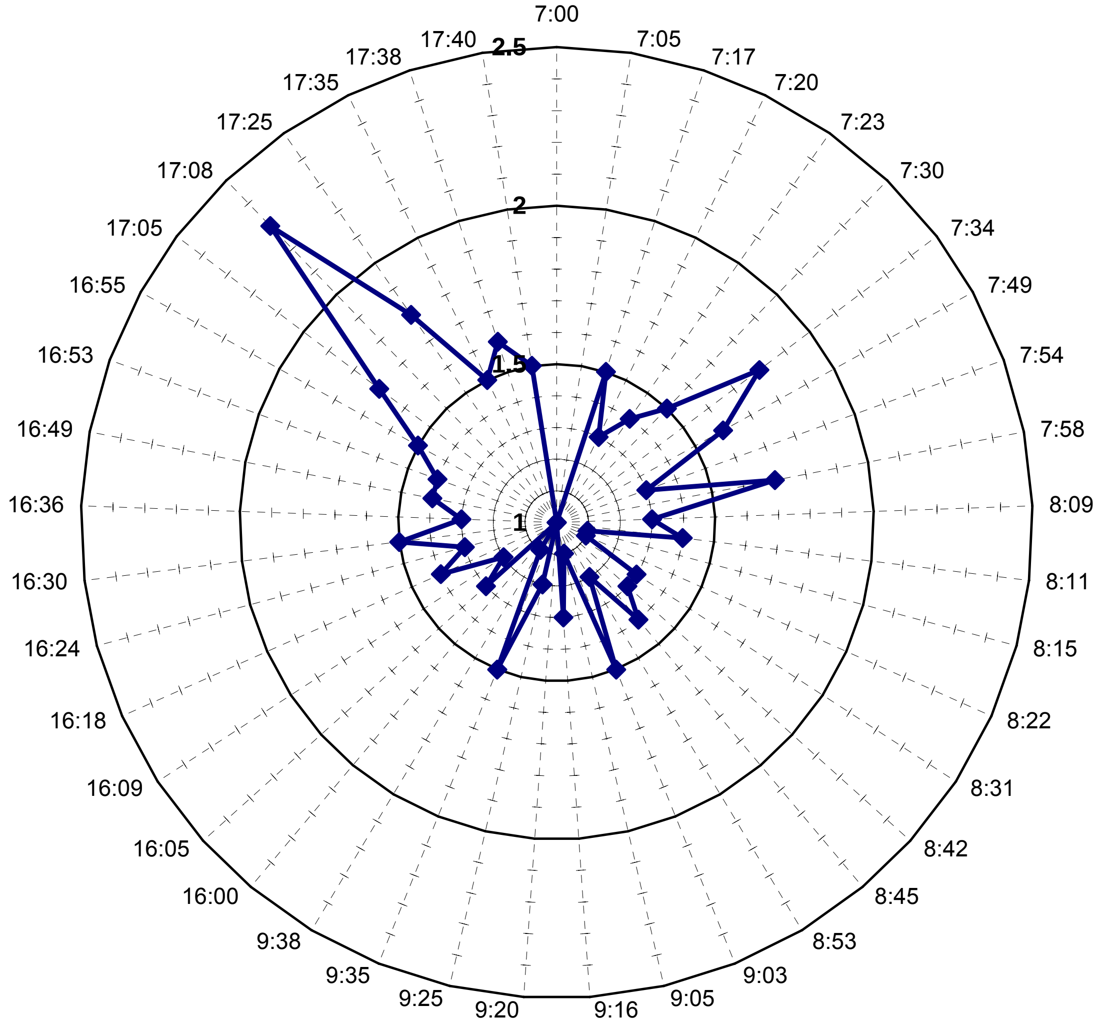


Figure 6-4. Travel Rate Index Radar Charts for Identifying Extreme Congestion (Reference *1*).

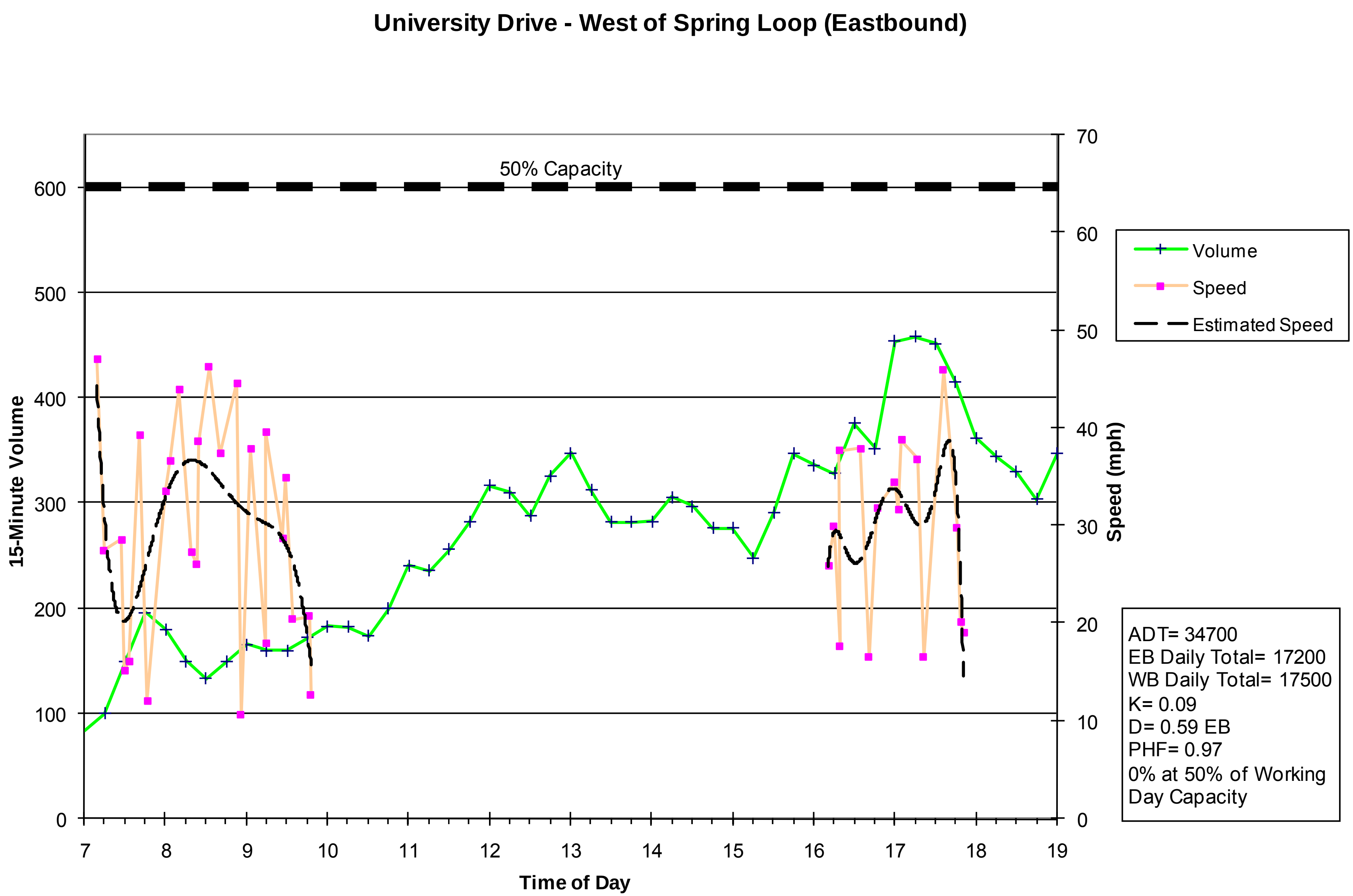


Figure 6-5. Example of Speed-Volume Reporting on Same Graphic.

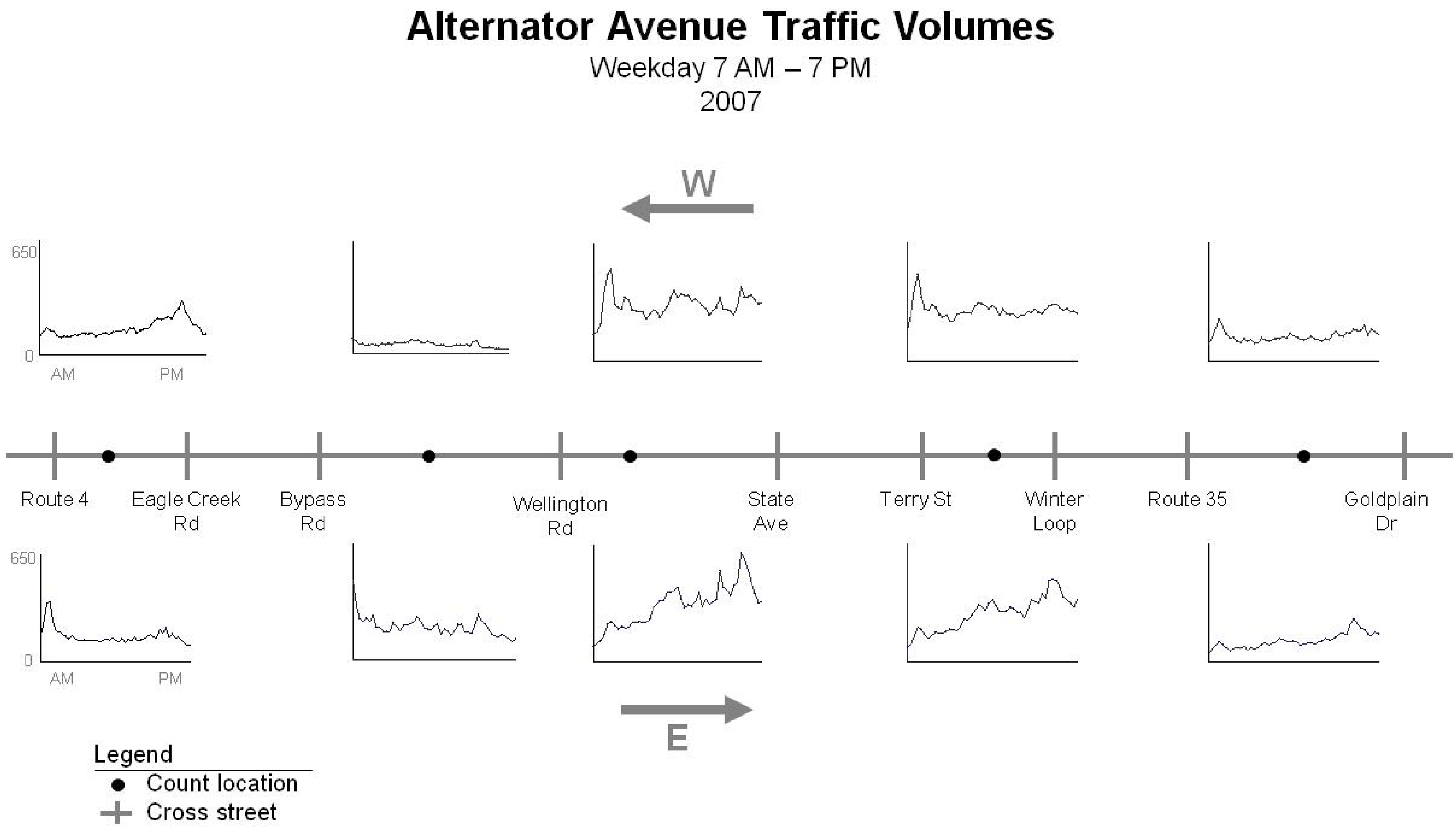


Figure 6-6. Corridor Current Daily Traffic Volumes (Reference *1*).

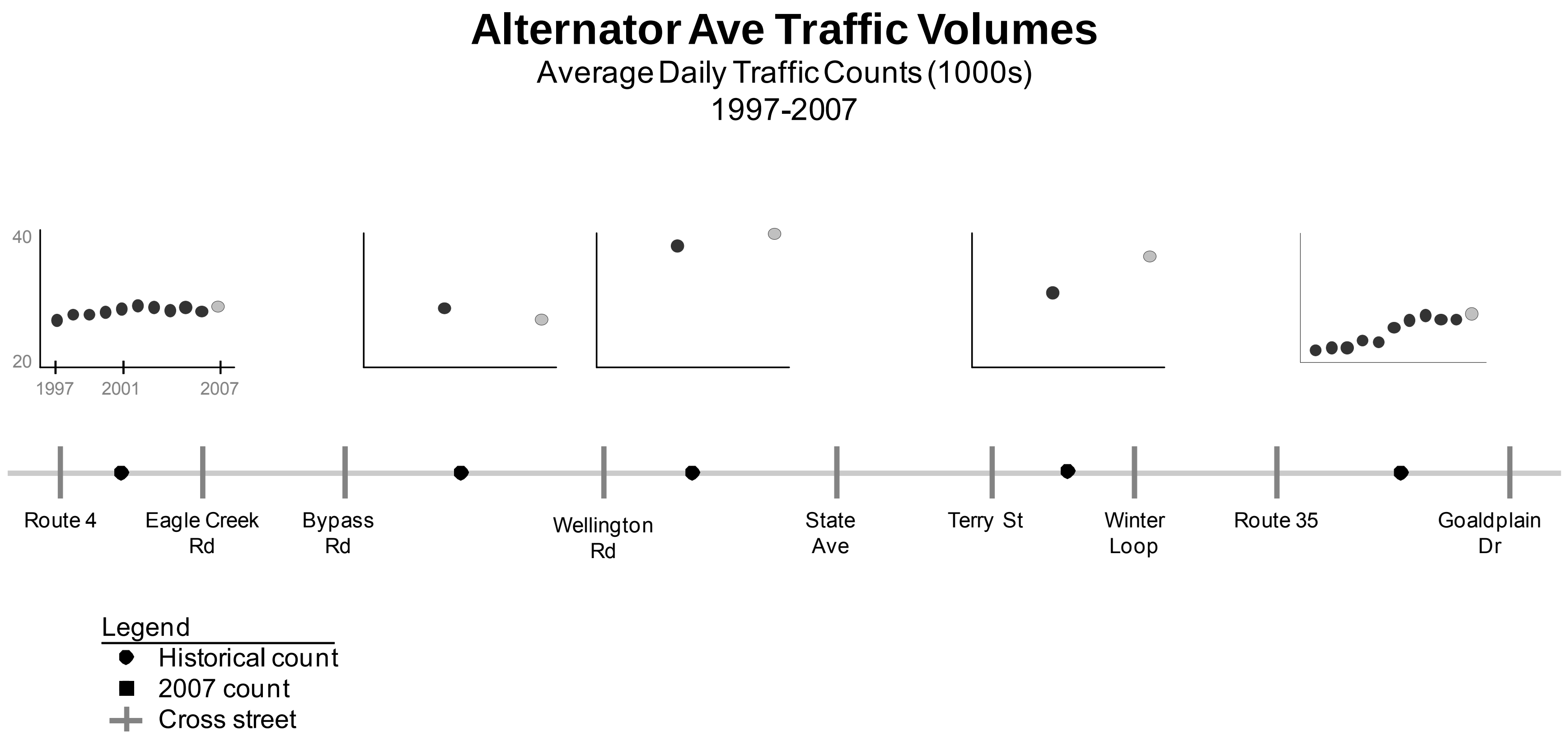


Figure 6-7. Corridor Volume Historical Trends (Reference *1*).

6.9 EXPANDED TRAVEL RATE INDEX GRAPHICAL REPRESENTATION

Figure 6-8 presents a link travel rate index graphic similar to the one previously shown in Figure 5-14. However, it expands the amount of information shown on the graphic. The summary box on the right side provides the reader with travel rate index values for a few long segments along the corridor. The x-axis also shows land use. The land uses shown include retail/housing as well as a major university and an airport. All of these additional pieces of information provide additional useful information to the reader in a visually appealing form.

6.10 CONCLUDING REMARKS

Effectively communicating mobility monitoring results to stakeholders is imperative. Effective communication allows all stakeholders to understand monitoring results, and understand how mobility affects their trips. The bullets below highlight some of the key tips described in this chapter to improve mobility monitoring communication.

- Map-type graphics should be used when possible as stakeholders relate easily to their physical environments.
- Tables serve a valuable purpose, but it is important that they be concise, use clear labels, and shade/space data groups appropriately.
- Density plots can be used to convey extent, duration, and location of congestion by time of day.
- Use of color and scale are effective tools for communicating mobility monitoring results.
- Radar graphics can direct focus to extreme measurements.
- Speed and volume data together on the same graphic can be useful to the general public, which relates better to speed measurements.
- Count location volume data can be shown temporally and spatially in effective ways such as Figure 6-6 and Figure 6-7.
- Illustrating land use on graphics (e.g., Figure 6-8) provides an effective reference for stakeholders in communicating monitoring results.

Finally, the reader is encouraged to review the *Guidebook for Mobility Monitoring in Small to Medium-Sized Communities: A How-To Guide* (*1*) for additional communication tips and color graphics of the examples presented in this chapter.

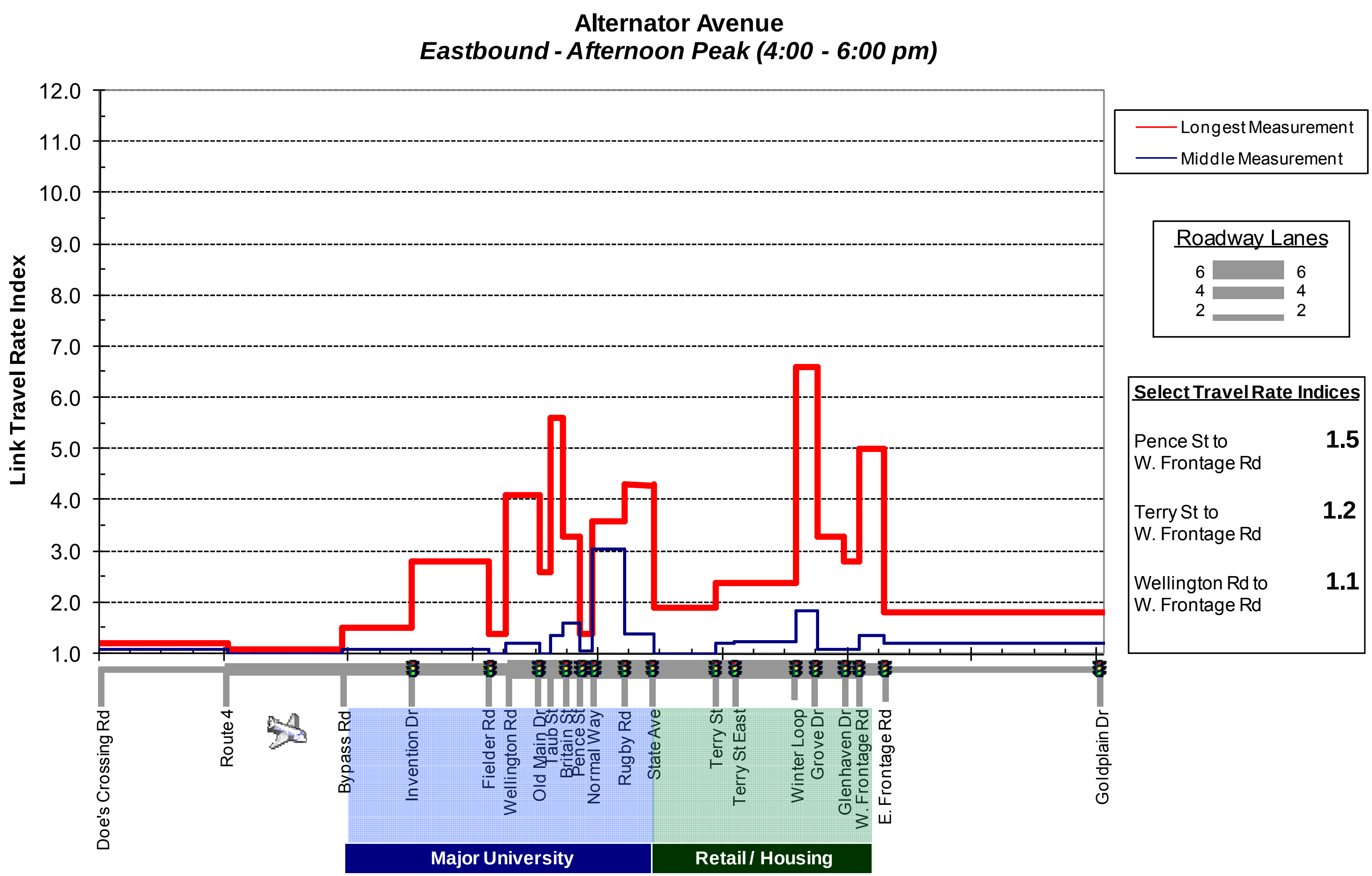


Figure 6-8. Travel Rate Index Graphical Representation with Longer Segment Statistics and Land Uses (Adapted from Reference *1*).

CHAPTER 7
IMPLEMENTATION RESOURCES

7.1 INTRODUCTION

The success of this research will be measured by the extent of application and implementation of the results. This chapter provides resources to further facilitate effective implementation of the results. Specifically, this chapter describes:

- products developed,
- preliminary lesson plans developed, and
- cost estimates for travel time data collection.

7.2 AVAILABLE RESOURCES

The *Guidebook for Mobility Monitoring in Small to Medium-Sized Communities: A How-To Guide* (*1*) was created as part of this project. The guidebook steps the user through all of the mobility monitoring framework steps discussed in Chapter 3 of this report. The user is prompted with questions and issues that are critical within each step of the framework. A made-up case study community (Fender Falls) is presented in the guidebook, and the user can see how this community addresses the key issues in each step of the mobility monitoring framework.

Several additional resources are included in the guidebook. While the guidebook is intended for a technical audience, a companion document in the guidebook (*A Guide for Monitoring Mobility in Small to Medium-Sized Communities*) provides information on mobility monitoring to a broader audience that may not be interested in the level of detail shown in the guidebook. This companion document presents the highlights of the framework for general audiences. A tri-fold pamphlet is also included to provide additional information to interested citizens. The tri-fold is entitled *Frustrated by Big City Congestion in Your Community: We're Working to Improve Your Standard of Driving.* The pocket at the end of the guidebook also includes a one-page overview of the mobility monitoring framework described in Chapter 3. This can be used for reference.

There is an interactive CD at the end of the guidebook. The CD includes two PowerPoint® presentations—one to a technical and one to a non-technical audience about how to implement mobility monitoring in SMSCs using the framework and techniques identified throughout this report and the guidebook itself. The CD includes an interactive presentation of the Fender Falls case study that allows the user to "drill" forward and backward through the steps of the framework and how they are addressed in the example case study. The CD provides links to additional resources available through the Internet, the research reports generated by this project, and electronic (PDF) versions of the guidebook, companion document, tri-fold, and one-page overview.

All of these resources are available at http://tti.tamu.edu/mobility/resources under a section entitled "Mobility Monitoring in Small to Medium-Sized Communities." Figure 7-1 shows the available products.

Figure 7-1. Available Products for Mobility Monitoring in SMSCs.

7.3 PRELIMINARY LESSON PLANS

The research team has had success with implementing research through workshops out to the TxDOT district offices. Because of this, the research team proposed the development of preliminary lesson plans. They were delivered to the PD by technical memorandum during Task 5 (Develop Guidebook, PowerPoint® Presentations, Interactive CD, Preliminary Lesson Plans, and Research Reports). Researchers believe the preliminary lesson plans will be a useful resource for TxDOT; therefore, they are included in this report as Appendix E. The preliminary lesson plans are for a one-day workshop. The lesson plans detail the workshop learning objectives, and they provide sufficient detail on the structure, instruction method, and evaluation methods for each lesson in the workshop. These details can be used at a later time to fully develop this workshop and direct its delivery style.

7.4 COSTS OF TRAVEL TIME DATA COLLECTION

This section provides travel time data collection unit costs and costs for example data collection scenarios. All costs are 2007 dollars. The following relatively low-cost test vehicle travel time data collection scenarios are included in this section:

- manual,
- distance measuring instrument (DMI),
- global positioning system (GPS) (with a laptop in the vehicle), and
- global positioning system (GPS) (with no laptop in the vehicle).

The following assumptions are made with respect to the scope of the data collection for a single route:

- 5-mile corridor,
- 5 minutes to turn around at end of corridor,
- Average running speed during two-hour peak period = 30 mph,
- Drivers are performing runs at the same time,
- 90% confidence desired: Segments with 3-6 signals per mile require six runs in each direction for each directional analysis period, and
- Assume average speed during peak is 30 mph; therefore:

$$\left(5mi \times \frac{hr}{30mi} \times \frac{60\,\text{min}}{hr}\right) + 5\,\text{min} = 15\,\text{min} \text{ to complete one directional run}$$

  - Two drivers are necessary over a two-hour peak period, which results in a total of 16 directional runs or 8 runs in each direction.

7.4.1 Manual

Manual data collection is conducted safely with a driver and recorder in each test vehicle. Stopwatches are used to record the cumulative time over the route and at each checkpoint. Data are recorded onto customized, printed sheets and entered into the computer at the office. Data entry requires labor to create the spreadsheet structure and enter recorded values. Data analysis requires more labor unless automated techniques are created and used with later monitoring cycles.

7.4.1.1 Unit Costs

Table 7-1 displays unit cost estimates for the manual travel time data collection method.

Table 7-1. Travel Time Data Collection Unit Costs: Manual Method.

Equipment/Personnel	**Unit Cost (2007 dollars)**
Hardware	
Stopwatches	$25 each
Office Computer	$1,000
Software	
Use Commercially Available Spreadsheets	$0
Personnel	
Test Vehicle Driver+Recorder	$15 to $40 per hour
Data Reduction Personnel	$15 to $30 per hour
Supervision and Management	Varies
Other Costs	
Reimbursed Vehicle Mileage[1]	$0.485 per mile
Data Collection Sheets, Clipboard, & Pen	Minimal

[1] Reimbursement for vehicle mileage at Internal Revenue Service allowable cost for personal vehicle.

7.4.1.2 Example Costs

Table 7-2 displays the example costs for the manual travel time data collection method.

Table 7-2. Travel Time Data Collection Example Costs: Manual Method.

Equipment/Personnel	**Unit Cost (2007 dollars)**
Hardware	
Stopwatches	$25 × 2 vehicles = $50
Office Computer	$1,000
Software	
Use Commercially Available Spreadsheets	$0
Personnel	
Test Vehicle Driver+Recorder	$480 (See calculations below)
Data Reduction Personnel[1]	$450 (See calculations below)
Supervision and Management[2]	$450
Other Costs	
Reimbursed Vehicle Mileage[3]	$50 (See calculations below)
Clipboard	Minimal
Data Collection Sheets	
Total Initial Cost[4]	Approx. $2,500
Subsequent Collection Cost[5] **(No Capital Cost)**	$1,400

[1] Assumes just reducing data by experienced personnel. Does not include producing graphics or analyzing the results.
[2] Includes time for manager to scope corridor, contact businesses at turnaround points, etc.
[3] Reimbursement for vehicle mileage at Internal Revenue Service allowable cost for personal vehicle.
[4] Total initial cost includes the cost to purchase all travel time data collection equipment and collect data for one peak period.
[5] Subsequent collection cost includes the cost to collect data for one peak period (without initial capital costs).

Calculations:

Test Vehicle Driver:

$$\left(\frac{\$30}{hr}\times 3\ hr\times 2\ drivers\times 2\ recorders\right)+training=\$480$$

Data Reduction Personnel:

$$\frac{\$30}{\text{hr}}\times 15\ \text{ hr} = \$450$$

Reimbursed Vehicle Mileage:

$$\frac{\$0.485}{mile}\times\left(\frac{5\ mile}{run}\times 16\ runs+30\ miles\right)=\$50$$

7.4.2 Distance Measuring Instrument

Data collection using a distance measuring instrument (DMI) is conducted safely with a driver and helper in each test vehicle. The DMI is used to record checkpoints, which then send data to a connected laptop with specialized, commercially available software. The data are then taken back to the office and processed.

7.4.2.1 Unit Costs

Table 7-3 displays unit cost estimates for the distance measuring instrument travel time data collection method.

Table 7-3. Travel Time Data Collection Unit Costs: Distance Measuring Instrument Method.

Equipment/Personnel	Unit Cost (2007 dollars)
Hardware	
Distance Measuring Instrument	$600 to $1,200
Distance Measuring Instrument Installation	$60
Laptop Computer	$500 to $700
Office Computer	$1,000
Software	
Software	$150 for 1 laptop
Personnel	
Test Vehicle Driver+Helper	$15 to $40 per hour
Data Reduction Personnel	$15 to $30 per hour
Supervision and Management	Varies
Other Costs	
Reimbursed Vehicle Mileage[1]	$0.485 per mile
Data Collection Sheets, Clipboard, & Pen	Minimal

[1] Reimbursement for vehicle mileage at Internal Revenue Service allowable cost for personal vehicle.

7.4.2.2 Example Costs

Table 7-4 displays the example costs for the distance measuring instrument travel time data collection method.

Table 7-4. Travel Time Data Collection Example Costs: Distance Measuring Instrument Method.

Equipment/Personnel	**Unit Cost (2007 dollars)**
Hardware	
Distance Measuring Instrument	\$900 x 2 vehicles = \$1,800
Distance Measuring Instrument Installation	\$60 x 2 vehicles = \$120
Laptop Computer	\$600 x 2 vehicles = \$1,200
Office Computer	\$1,000
Software	
Software (e.g., CATS)	\$150 x 2 laptops = \$300
Personnel	
Test Vehicle Driver+Helper	\$480 (See calculations below)
Data Reduction Personnel[1]	\$300 (See calculations below)
Supervision and Management[2]	\$315
Other Costs	
Reimbursed Vehicle Mileage[3]	\$50 (See calculations below)
Clipboard	Minimal
Data Collection Sheets	
Total Initial Cost[4]	Approx. \$5,600
Subsequent Collection Cost[5] **(No Capital Cost)**	\$1,200

[1] Assumes just reducing data by experienced personnel. Does not include producing graphics or analyzing the results.
[2] Includes time for manager to scope corridor, contact businesses at turnaround points, etc.
[3] Reimbursement for vehicle mileage at Internal Revenue Service allowable cost for personal vehicle.
[4] Total initial cost includes the cost to purchase all travel time data collection equipment and collect data for one peak period.
[5] Subsequent collection cost includes the cost to collect data for one peak period (without initial capital costs).

Calculations:

Test Vehicle Driver:

$$\left(\frac{\$30}{hr}\times 3\ \ hr \times 2\ \ drivers \times 2\ \ helpers\right) + training = \$480$$

Data Reduction Personnel:

$$\frac{\$30}{hr}\times 10\ \ hr = \$300$$

Reimbursed Vehicle Mileage:

$$\frac{\$0.485}{mile}\times\left(\frac{5\ \ mile}{run}\times 16\ \ runs + 30\ \ miles\right) = \$50$$

7.4.3 Global Positioning System (GPS) (with a Laptop in the Vehicle)

Global positioning system techniques are becoming increasingly popular. For this data collection method, a GPS is connected to a laptop using specialized, commercially available software. The driver has minimal interaction with the laptop, only indicating defined nodes by pressing a single key (e.g., space bar) during each run. This method does require some planning work to create a matching file containing node information (beginning, ending, and major cross streets, or driveway locations). Data are collected on the laptop and reduced at the office using another specialized, commercially available software. The office software is capable of facilitating quality control and report generation.

7.4.3.1 Unit Costs

Table 7-5 displays unit cost estimates for the GPS (with laptop) travel time data collection method.

Table 7-5. Travel Time Data Collection Unit Costs: GPS with Laptop Method.

Equipment/Personnel	Unit Cost (2007 dollars)
Hardware	
GPS Receiver	$50 to $150
Laptop Computer	$500 to $700
Power Inverter	$40 to $80
Office Computer	$1,000
Software	
GPS Data Collection Software	Approx. $700 for 1 laptop
GPS Data Reduction Software	Approx. $1,100 for 5 computers
Personnel	
Test Vehicle Driver	$15 to $40 per hour
Data Reduction Personnel	$15 to $30 per hour
Supervision and Management	Varies
Other Costs	
Reimbursed Vehicle Mileage[1]	$0.485 per mile
Data Collection Sheets, Clipboard, & Pen	Minimal

[1] Reimbursement for vehicle mileage at Internal Revenue Service allowable cost for personal vehicle.

7.4.3.2 Example Costs

Table 7-6 displays the example costs for the GPS (with laptop) travel time data collection method.

Table 7-6. Travel Time Data Collection Example Costs: GPS with Laptop Method.

Equipment/Personnel	Unit Cost (2007 dollars)
Hardware	
GPS Receiver	\$75 × 2 vehicles = \$150
Laptop Computer	\$600 × 2 vehicles = \$1,200
Power Inverter	\$50 × 2 vehicles = \$100
Office Computer	\$1,000
Software	
GPS Data Collection Software	\$700 × 2 laptops = \$1,400
GPS Data Reduction Software	\$1,100
Personnel	
Test Vehicle Driver	\$240 (See calculations below)
Data Reduction Personnel[1]	\$300 (See calculations below)
Supervision and Management[2]	\$315
Other Costs	
Reimbursed Vehicle Mileage[3]	\$60 (See calculations below)
Clipboard	Minimal
Data Collection Sheets	
Total Initial Cost[4]	Approx. \$5,900
Subsequent Collection Cost[5] **(No Capital Cost)**	\$900

[1] Assumes just reducing data by experienced personnel. Does not include producing graphics or analyzing the results.
[2] Includes time for manager to scope corridor, contact businesses at turnaround points, etc.
[3] Reimbursement for vehicle mileage at Internal Revenue Service allowable cost for personal vehicle.
[4] Total initial cost includes the cost to purchase all travel time data collection equipment and collect data for one peak period.
[5] Subsequent collection cost includes the cost to collect data for one peak period (without initial capital costs).

Calculations:

Test Vehicle Driver:

$$\left(\frac{\$30}{hr}\times 3\ hr\times 2\ drivers\right)+node\ runs+training=\$240$$

Data Reduction Personnel:

$$\frac{\$30}{hr}\times 10\ hr=\$300$$

Reimbursed Vehicle Mileage:

$$\frac{\$0.485}{mile}\times\left(\frac{5\ mile}{run}\times 16\ runs+\frac{5\ mile}{run}\times 2\ node\ runs+30\ miles\right)=\$60$$

7.4.4 Global Positioning System (GPS) (with no Laptop in the Vehicle)

A second GPS technique is to not use a connected laptop. Instead the GPS device includes a mass storage device that is taken to the office for data download. The driver has no interaction with the device during data collection. Specialized, commercially available software is used to perform quality control and report generation.

7.4.4.1 Unit Costs

Table 7-7 displays unit cost estimates for the GPS (without laptop) travel time data collection method.

Table 7-7. Travel Time Data Collection Unit Costs: GPS without Laptop Method.

Equipment/Personnel	Unit Cost (2007 dollars)
Hardware	
GPS Receiver (with storage device)	$500
Office Computer	$1,000
Software	
GPS Data Reduction Software	$2,000 for 1 license
Personnel	
Test Vehicle Driver	$15 to $40 per hour
Data Reduction Personnel	$15 to $30 per hour
Supervision and Management	Varies
Other Costs	
Reimbursed Vehicle Mileage[1]	$0.485 per mile
Data Collection Sheets, Clipboard, & Pen	Minimal

[1] Reimbursement for vehicle mileage at Internal Revenue Service allowable cost for personal vehicle.

7.4.4.2 Example Costs

Table 7-8 displays the example costs for the GPS (without laptop) travel time data collection method.

Table 7-8. Travel Time Data Collection Example Costs: GPS without Laptop Method.

Equipment/Personnel	**Unit Cost (2007 dollars)**
Hardware	
GPS Receiver (with storage device)	$500 × 2 vehicles = $1,000
Office Computer	$1,000
Software	
GPS Data Reduction Software	$2,000
Personnel	
Test Vehicle Driver	$240 (See calculations below)
Data Reduction Personnel[1]	$300 (See calculations below)
Supervision and Management[2]	$315
Other Costs	
Reimbursed Vehicle Mileage[3]	$50 (See calculations below)
Clipboard	Minimal
Data Collection Sheets	
Total Initial Cost[4]	Approx. $4,900
Subsequent Collection Cost[5] **(No Capital Cost)**	$900

[1] Assumes just reducing data by experienced personnel. Does not include producing graphics or analyzing the results.
[2] Includes time for manager to scope corridor, contact businesses at turnaround points, etc.
[3] Reimbursement for vehicle mileage at Internal Revenue Service allowable cost for personal vehicle.
[4] Total initial cost includes the cost to purchase all travel time data collection equipment and collect data for one peak period.
[5] Subsequent collection cost included the cost to collect data for one peak period (without initial capital costs).

Calculations:

Test Vehicle Driver:

$$\left(\frac{\$30}{hr} \times 3\ hr \times 2\ drivers\right) + training = \$240$$

Data Reduction Personnel:

$$\frac{\$30}{hr} \times 10\ hr = \$300$$

Reimbursed Vehicle Mileage:

$$\frac{\$0.485}{mile} \times \left(\frac{5\ mile}{run} \times 16\ runs + 30\ miles\right) = \$50$$

7.4.5 Cost Comparison

Communities will have to evaluate the costs estimated for their mobility monitoring. This section presents a cost comparison between the four methods discussed in this chapter. Costs are shown in 2007 dollars, and a 3 percent rate was used for net present value (NPV) calculations. This analysis is provided in greater detail in Appendix F. The attached CD contains an electronic file with the spreadsheet used to compute cost estimates. The spreadsheet can be used by interested readers to estimate costs of data collection efforts.

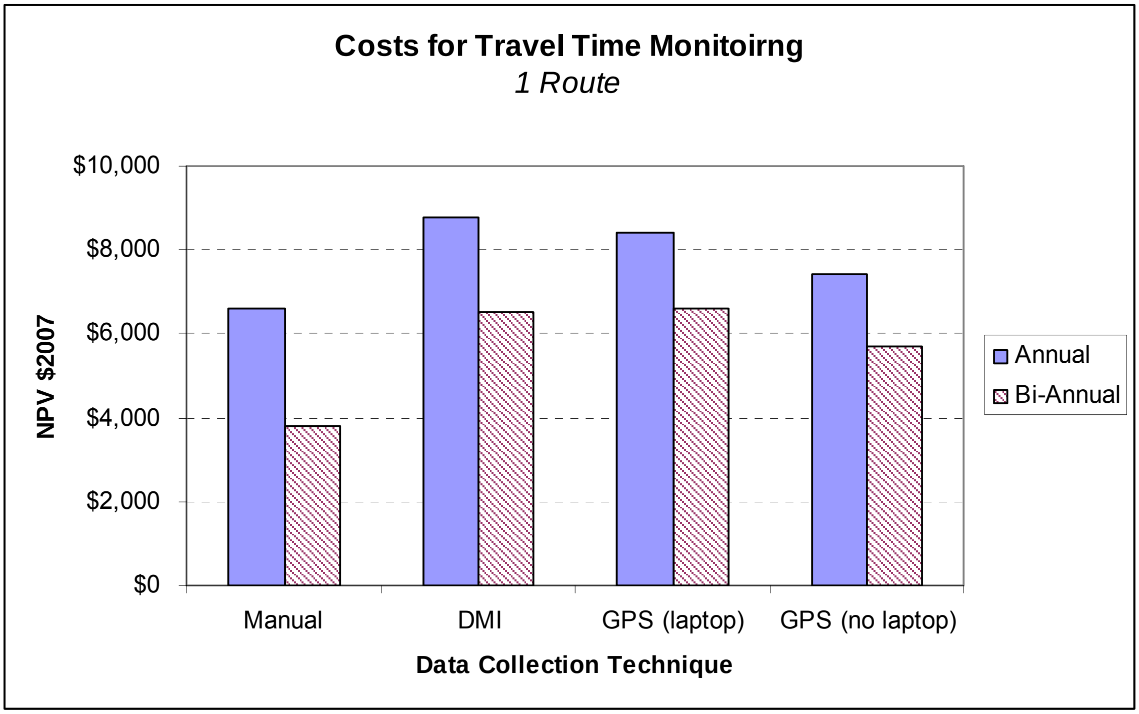
A comparison for each data collection method used annually or bi-annually is shown in Table 7-9. The table also shows how the program costs expand beyond the first route. The first route has a higher percentage of sunk costs associated with it. If more routes are monitored, the sunk cost percentage decreases.

Table 7-9. Estimated Annual and Bi-Annual Monitoring Costs by Data Collection Method.

Method	Annual Monitoring (NPV $2007)		Bi-annual Monitoring (NPV $2007)	
	1 Route	4 Routes	1 Route	4 Routes
Manual	$6,600	$23,300	$3,800	$12,200
DMI	$8,800	$22,100	$6,500	$13,200
GPS (laptop)	$8,400	$19,000	$6,600	$11,900
GPS (no laptop)	$7,400	$18,000	$5,700	$10,900

Referring to Table 7-9, as expected, the cost for a bi-annual program is less over the same four-year period as an annual program; however, the bi-annual costs are not substantially different between data collection methods (variance of $2,300). Figure 7-2 shows these results graphically for one route and annual monitoring in year one. As the monitoring program is expanded to more routes, a greater cost advantage can be taken with GPS methods, though their initial costs are higher.

To demonstrate the estimated cash flow for each data collection method for a four-year annual monitoring program of four routes, Table 7-10 and Figure 7-3 display the results. The GPS methods require the highest initial cost but then become the lowest labor cost methods in subsequent years. The manual method has the lowest initial cost, however its labor costs are roughly $2,000 greater each subsequent monitoring year.



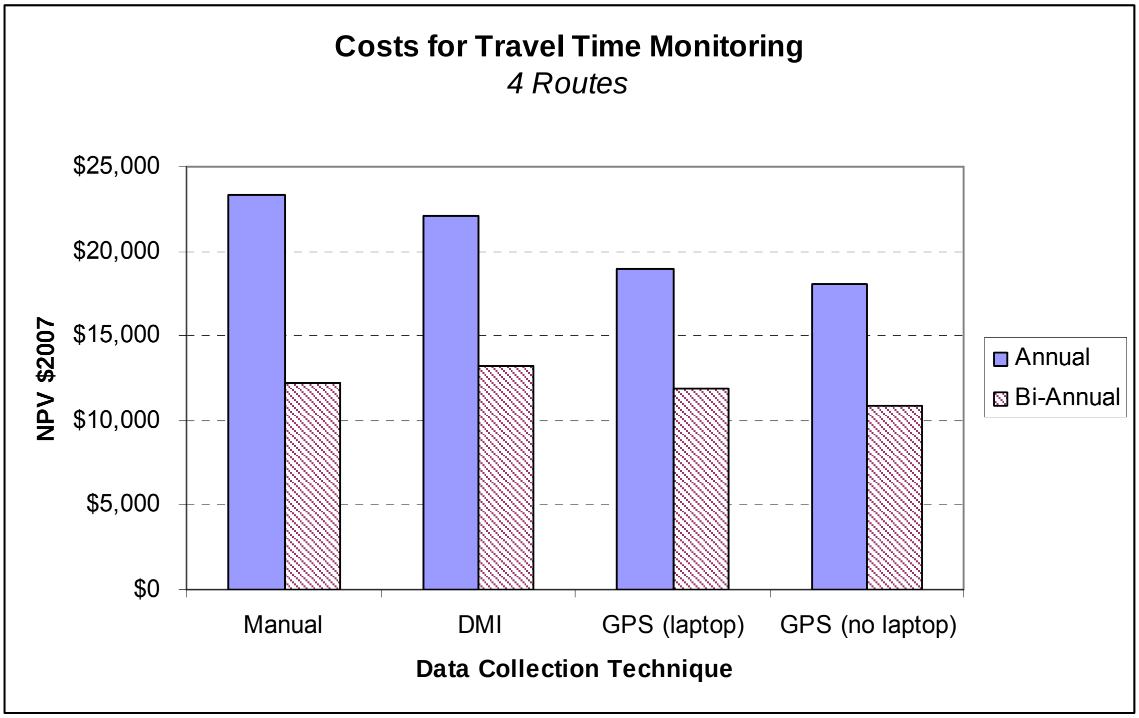


Figure 7-2. Comparison of Travel Time Monitoring Costs by Data Collection Technique and Number of Routes Monitored.

Table 7-10. Time-series Cash Flow for Travel Time Monitoring by Data Collection Technique (4 routes).

Method	Year			
	1	2	3	4
Manual	$6,786	$5,905	$6,083	$6,265
DMI	$9,016	$4,731	$4,873	$5,019
GPS (laptop)	$8,606	$3,762	$3,875	$3,992
GPS (no laptop)	$7,636	$3,742	$3,855	$3,970

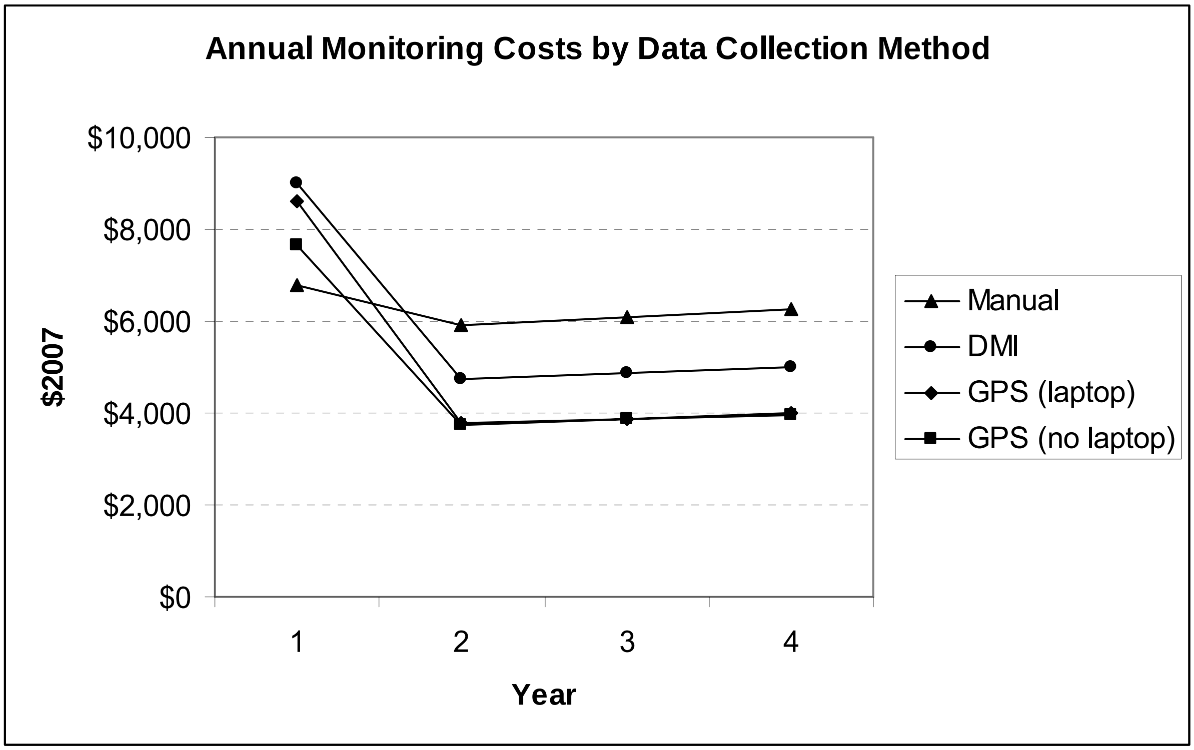


Figure 7-3. Estimated Annual Monitoring Costs by Data Collection Method for Four Routes.

CHAPTER 8
CONCLUSIONS AND DISCUSSION

8.1 INTRODUCTION

This chapter lists the key concluding points from each chapter of this report. Finally, there is a listing of further research needs identified by the research team.

8.2 LITERATURE REVIEW HIGHLIGHTS

The following bullets highlight the key observations from the literature review.

- Congestion is best defined through the eyes of the delayed—what constitutes congestion in one location may be different in another location.
- Congestion in SMSCs in Texas is growing.
- Congestion measures should be developed only after an examination of the uses and audiences to be served, the full consideration of program goals and objectives, and the nature of likely solutions.
- Travel time based congestion measures are more flexible and more useful for a broad range of uses and audiences.
- Many metropolitan planning organizations (MPOs) use travel time based congestion measures to supplement traditional measures.
- While most SMSCs may not currently have continuous data sources available, they should be aware of the importance of reliability measures and incorporating them in future mobility monitoring efforts.
- SMSCs would likely use low-cost techniques like test vehicles in the traffic stream for travel time data collection. It is likely that with continued mobility monitoring, the initial costs of GPS travel time data collection are justified. Numerous locations have successfully used GPS technology, and the initial costs of GPS are likely justified for the ease of data collection, reduction, and report preparation, especially when mobility monitoring will be performed on an on-going basis.
- Using existing staff for travel time data collection can reduce costs in SMSCs.
- Funding on-going mobility monitoring might be possible through existing or increased taxing sources or transportation-based revenue sources. Though there are legislative and practical hurdles to using these sources, they do provide possibilities. One possibility might be the use of the Texas Economic Development Sales Tax.
- Typical congestion improvements in SMSCs will include signal improvements, intersection improvements, construction of additional travel lanes, and access management.
- There are many travel time and delay estimation techniques and models available to estimate speed and traffic volumes for freeways and arterials. They still rely on direct data collection of key operational and geometric inputs. As real-time signal systems become more prevalent and cost-effective, such methods may be more promising for SMSCs.

8.3 FRAMEWORK, CASE STUDIES, AND DATA SOURCES

The following are conclusions based upon the framework, case studies, and data sources.

- Researchers developed a six-step process for monitoring mobility in SMSCs. The simple and active nature of the steps make them easier to recall and will assist implementation.
- Researchers performed data collection at two case study locations—one with an MPO present (Bryan-College Station, Texas) and one without an MPO present (Huntsville, Texas), which demonstrates the applicability of the process to a range of community sizes.
- Researchers successfully demonstrated the methods for, and importance of, collecting traffic count data, travel time data, intersection studies, and videologs.

8.4 DATA REDUCTION, ANALYSIS, AND RESULTS

The following are highlights of the data reduction, analysis, and results.

- Nearly 1,200 travel time runs were performed, which were an adequate number to ensure statistically valid travel time results for the baseline mobility monitoring efforts in B-CS and Huntsville.
- Changes in typical traffic operation characteristics (ADT, PHF, K-factors, directional distribution factors D) can be good measures of congestion changes in smaller communities, and illustrating these values spatially on a map can assist in presenting and understanding these changes.
- "X% of the working day capacity" was introduced as a reasonable threshold at count locations, and it can be adjusted in subsequent monitoring efforts as more data become available.
- Travel time based performance measures were the focus because they are easier to communicate to all audiences, and they apply to the individual traveler.
- Graphical methods such as Figure 5-7 provide an efficient way to visually inspect count data for quality, as well as provide a visually appealing way to present the volume data by time of day along with the important operational characteristics at the count location.
- Graphics such as Figure 5-14 and Figure 5-15 provide a much more appealing and understandable way to present travel rate indices, speed, and travel time information that is far more understandable than simple tables.
- Stopped delay studies can be used to provide travel time information through intersections along trips where travel time is of interest, though caution must be taken to ensure there is adequate sight distance to see all stopped vehicles on the approach of interest.

8.5 COMMUNICATING MOBILITY MONITORING RESULTS

Effectively communicating mobility monitoring results to stakeholders is imperative. Effective communication allows all stakeholders to understand monitoring results, and understand how mobility affects their trips. The bullets below highlight some of the key tips described in this chapter to improve mobility monitoring communication.

- Map-type graphics should be used when possible as stakeholders relate easily to their physical environments.

- Tables serve a valuable purpose, but it is important that they be concise, use clear labels, and shade/space data groups appropriately.
- Density plots can be used to convey extent, duration, and location of congestion by time of day.
- Use of color and scale are effective tools for communicating mobility monitoring results;
- Radar graphics can direct focus to extreme measurements.
- Speed and volume data together on the same graphic can be useful to the general public, which relates better to speed measurements.
- Count location volume data can be shown temporally and spatially in effective ways such as Figure 6-6 and Figure 6-7,
- Illustrating land use on graphics (e.g., Figure 6-8) provides an effective reference for stakeholders in communicating monitoring results.

8.6 FUTURE IMPLEMENTATION AND RESEARCH NEEDS

Researchers, with assistance from TTI Communications, developed several outreach materials, which were described in detail in section 7.2. Researchers also developed preliminary lesson plans (Appendix E) for workshops to disseminate the products to technical staff to assist them in local monitoring efforts. There is a need to fully develop these workshops, and associated educational materials, for delivery to TxDOT districts, MPOs, and city and county technical staff. TxDOT, and its partnering agencies, will benefit from proactively planning and implementing mobility solutions that result from a repeated mobility monitoring program in SMSCs that identify, measure, and track locations or routes where mobility is worsening.

Additional research needs include:

- Testing the overall mobility monitoring measures, methods, and process in more SMSCs to provide additional opportunity to refine the framework and guidance further, and to develop and share additional examples that demonstrate the benefits of a mobility monitoring program in SMSCs.
- Further evaluation of the advantages and disadvantages of different types of travel time data collection techniques. Generally for a multi-year (annual) monitoring program, GPS methods do require the highest initial cost but then become the lowest labor cost methods in subsequent years. Although the manual method has the lowest initial cost, its labor costs are roughly 50 percent greater each subsequent monitoring year over GPS methods. There is a need to build an improved knowledge base of the advantages/disadvantages of each travel time data collection technique with actual SMSC monitoring efforts.
- Guidance and training can be developed to assist SMSCs or TxDOT district staff for GPS travel time data collection. Though GPS travel time data collection systems may have some differences, the general process and concerns for data collection is similar. A one to two-hour training course could be developed to provide the SMSC practitioner with the tools to give the monitoring program some inertia.
- Further development of communication techniques to best convey the results of mobility monitoring to stakeholders—particularly non-technical audiences—is needed. While some visual techniques were presented in this report, other visual techniques that better connect to non-technical audiences may be available. There is a need to objectively assess how well

these techniques communicate with non-technical audiences. One method for accomplishing this would be to run focus groups to garner their feedback to the visual display of information.

- Identification and evaluation of potential funding options for continued mobility monitoring is needed. New, innovative funding sources might be identified to assist local governments in funding these activities that are important to the growth and economic vitality of the community.

CHAPTER 9
REFERENCES

1 Eisele, W.L. and J.A. Crawford. *Guidebook for Mobility Monitoring in Small to Medium-Sized Communities: A How-To Guide.* Sponsored by the Texas Department of Transportation. Research Report 0-5571-P1. Texas Transportation Institute. College Station, Texas. August 2007. Available: http://tti.tamu.edu/publications/catalog/.

2 Eisele, W.L. and J.A. Crawford. *Mobility Monitoring in Small to Medium-Sized Communities: Executive Summary*. Sponsored by the Texas Department of Transportation. Research Report 0-5571-S. Texas Transportation Institute. College Station, Texas. October 2007. Available: http://tti.tamu.edu/publications/catalog/.

3 Schrank, D.L., W.L. Eisele, and T.J. Lomax. *The Keys to Estimating Mobility in Urban Areas: Applying Definitions and Measures that Everyone Understands.* FHWA Pooled Fund Study SPR 3(049). Texas Transportation Institute. College Station, Texas. Second Edition, May 2005. Available: http://mobility.tamu.edu/ums/estimating_mobility/complete_report.pdf.

4 Schrank, D.L. and T.J. Lomax. *The 2005 Urban Mobility Report.* Texas Transportation Institute. College Station, Texas. May 2005. Available: http://mobility.tamu.edu/ums/report/.

5 *Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation.* Produced by Cambridge Systematics with Texas Transportation Institute. Sponsored by Federal Highway Administration, Washington, DC. September 1, 2005. Available: http://ops.fhwa.dot.gov/congestion_report/congestion_report_05.pdf.

6 Lomax, T.J., S.M. Turner, G.A. Shunk, H.S. Levinson, R.H. Pratt, P.N. Bay, G.B. Douglas. *Quantifying Congestion, Volume 1, Final Report*, NCHRP Report 398, Volume 1, Final Report. Transportation Research Board, National Research Council, Washington, D.C., 1997. Available: http://trb.org/TRB/publications/Publications.asp.

7 Lomax, T.J., S.M. Turner, G.A. Shunk, H.S. Levinson, R.H. Pratt, P.N. Bay, G.B. Douglas. *Quantifying Congestion, Volume 2, User's Guide*, NCHRP Report 398, Volume 2, User's Guide. Transportation Research Board, National Research Council, Washington, D.C., 1997. Available: http://trb.org/TRB/publications/Publications.asp.

8 *Congestion Management Systems: Innovative Practices.* Prepared for New York State Association of MPOs. Performed by ICF Consulting. August 2005. Available: www.nysmpos.org/sci/cms/NYSMPO_SCI_CMS_TASK1-REPORT.pdf.

9 *Travel Time Reliability: Making It There on Time, All the Time.* Produced by Texas Transportation Institute with Cambridge Systematics, Inc. Sponsored by Federal Highway Administration. Report FHWA-HOP-06-070. Washington, D.C., January 2006. Available: http://www.ops.fhwa.dot.gov/publications/tt_reliability/brochure/ttr_brochure.pdf.

10 Turner, S.M., R. Margiotta, and T.L. Lomax. *Monitoring Urban Freeways in 2003: Current Conditions and Trends from Archived Operations Data.* Performed by Texas Transportation Institute and Cambridge Systematics. Sponsored by Federal Highway Administration. Report FHWA-HOP-05-018. Washington, D.C., December 2004. Available: http://mobility.tamu.edu/mmp/FHWA-HOP-05-018/.

11 Turner, S.M., W.L. Eisele, R. Benz, and D. Holdener. *Travel Time Data Collection Handbook.* Prepared by Texas Transportation Institute. Sponsored by Federal Highway Administration. Report No. FHWA-PL-98-035. Washington, D.C., March 1998. Available: http://tti.tamu.edu/inside/hdv/ama/its_data/tt_book.htm.

12 Lane, J.S. "Financial Planning for the Metropolitan Planning Organization." In *Proceedings for the 7th National Conference on Transportation Planning for Small and Medium-sized Communities.* Little Rock, Arkansas, 2000.

13 Meyer, M.D. *A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility*. Institute of Transportation Engineers, Washington, D.C., 1997. Available: http://www.ite.org.

14 *Congestion Mitigation Handbook.* Chicago Area Transportation Study. September 1998. Available: http://www.catsmpo.com/prog-cms.htm.

15 *St. Louis Region CMS Congestion Mitigation Handbook*. Prepared by East-West Gateway Coordinating Council, TransCore, and Wilbur Smith and Associates, Inc., February 1998. Available: www.ewgateway.org/pdffiles/library/trans/cmshandbook.pdf.

16 Crawford, J.C., W.E. Frawley, and A.S. Cothron. *Handbook of Selected Congestion Mitigation Techniques in the United States.* Sponsored by Texas Department of Transportation. Research Report 0-1798-1. Texas Transportation Institute. College Station, Texas. October 1998. Available: http://tti.tamu.edu/publications/catalog/.

17 *Congestion Management System Report – Spring 2004.* Prepared by Carter-Burgess. Prepared for Hidalgo County Metropolitan Planning Organization. McAllen, Texas, August 2004. Available: http://www.lrgvdc.org/mpo_studies.html.

18 Schrank. D.L., T.J. Lomax, and T. Baker. *Mobility in Grand Junction.* Sponsored by the Colorado Department of Transportation. Performed by Texas Transportation Institute. College Station, Texas, June 2001. Available: http://mobility.tamu.edu/ums/grand_junction.pdf.

19 Travel Time and Speed-Based Performance Measures Study: Technical Analysis for the Travel Model Update and Revalidation Project. Prepared for City of Lincoln-Lancaster County Planning Department. Prepared by Olsson Associates and Cambridge Systematics. March 1999.

20 *Traffic Studies and Evaluations for Lincoln's Arterial Street System: Interim Report.* Prepared by Meyer, Mohaddes Associates, Inc. and The Schemmer Associates, Inc. TSA Project # 398201. January 1999.

21 Guindon, M.E., "2002 Congestion Management Report: Travel Time and Delay Study." In *Proceedings of the 9th National Conference on Transportation Planning for Small and Medium-sized Communities.* Colorado Springs, Colorado. September 2004.

22 2002-2003 MAG *Regional Travel Time and Travel Speed Study.* Prepared by Carter-Burgess, Traffic Research and Analysis, Inc., and Dr. Darcy Bullock. Prepared for Maricopa Association of Governments. April 2004. Available: http://www.mag.maricopa.gov/display.cms.

23 Dowling, R., W. Kittelson, J. Zegeer, and A. Skabardonis. *Planning Techniques to Estimate Speeds and Service Volumes for Planning Applications*, NCHRP Report 387, Transportation Research Board, National Research Council, Washington, D.C., 1997. Available: http://trb.org/TRB/publications/Publications.asp.

24 *Manual of Transportation Engineering Studies.* Institute of Transportation Engineers. Washington, D.C., 2000.

25 Highway Capacity Manual. Transportation Research Board, Washington, D.C., 2000.

APPENDIX A

Survey to Small to Medium-Sized Communities

Date ____________________ **Texas Transportation Institute** **CONFIDENTIAL**

Texas A & M University System
College Station, Texas 77843-3135

TRAFFIC CONGESTION SURVEY OF SMALL AND MEDIUM-SIZED COMMUNITIES

Purpose of Survey

The Texas Transportation Institute (TTI) is studying the traffic congestion monitoring needs for small and medium-sized communities in Texas for the Texas Department of Transportation. We are interested in understanding how (1) your community perceives and experiences traffic congestion, and (2) if and how you monitor traffic congestion in your community.

Could you take a few minutes of your time to provide thoughtful responses to these survey questions? ALL ANSWERS TO THE FOLLOWING QUESTIONS WILL BE HELD CONFIDENTIAL. Your name or city will not be used in any way that would identify you without your express permission. Your name will only be used if we would like to follow-up with your community about your responses.

Thank you very much for your time in filling out this important survey!

City: ____________________________

Name: ____ **Title:**__________________________

Phone: ____ **Email:**__________________________

1. What do local drivers define as "congestion" in your community?

____

____

____

____

2. What technical definition do you use for defining congestion in your community? (Please check all that apply and indicate your associated threshold in the box)

☐ Drivers wait for [ ] signal cycle(s) (e.g., 2 signal cycles for through vehicles)

☐ Travel time [ ] % higher than off-peak (e.g., 20% of off-peak period)

☐ Volume/Capacity Ratio [ ] (e.g., greater than 0.85)

☐ Individual vehicle delay [ ] minutes (e.g., 2 minutes)

☐ Travel speed [ ] % less than posted speed (e.g., 10% less than posted)

☐ Other ____

☐ None defined

3. Does your community experience any congestion? ☐ YES ☐ NO

No skips to Question 6

4. If you answered YES to Question 3, does your community consider any of the existing congestion a problem? (You will have a chance to provide details later in this survey).

☐ YES ☐ NO

5. Please indicate on each row how overall congestion in your community has changed.

Congestion in my community today compared to…	Significantly Less	Somewhat Less	About The Same	Somewhat Worse	Significantly Worse	Unknown/ Not Sure
Last Year	☐	☐	☐	☐	☐	☐
5 Yrs Ago	☐	☐	☐	☐	☐	☐
10 Yrs Ago	☐	☐	☐	☐	☐	☐

QUESTION 6
SPLIT – Q3=YES
The next section of the survey seeks to identify where the congestion occurs in your community. For each of the general locations listed below, you will be presented with questions concerning when and where the congestion takes place in your community.

SPLIT – Q3=NO
Though you indicated in Question 3 you do not have existing congestion, the next section of this survey seeks to identify where you **anticipate** seeing the first signs of congestion in your community. For each of the general locations listed below, you will be presented with questions concerning when and where you anticipate congestion will take place in the future.

Typical Part 1 format for each general location
Do you anticipate congestion occurring on the state routes in your community?
If Yes, please list the state routes where you anticipate future congestion in the box provided below.

Typical Part 2 format for each general location
What part of the day or week would you anticipate future congestion on state routes.

Typical Part 3 format for each general location
Please identify the probable causes of future congestion for state routes.

Automobile Interaction with:

6. Where does the congestion occur in your community? (Check all that apply and please provide additional information)

	General Location	Specific Roads, Intersections, Adjacent Properties, Events, Etc.
☐	State Routes	
☐	Interchanges	
☐	City Streets	
☐	Downtown	
☐	Edge of Downtown	
☐	Near Truck Stops	
☐	Near Hospitals	
☐	Near Schools/Colleges	
☐	Near Industrial Facilities	
☐	Near Government Facilities	
☐	Near Shopping Centers	
☐	Other Business Centers	
☐	Around Special Events	
☐	Other____________________	
☐	Other____________________	
☐	Other____________________	
☐	Other____________________	

7. Where and when does your community experience congestion, and how long does it typically last? Please indicate the congestion duration by time (column) and location (row). If you have no congestion, please mark 'none.'

	When Congestion Occurs and How Long It Lasts…					
	Weekdays AM	**Lunch/ Noon**	**Weekdays PM**	**Weekends**	**Holidays**	**Special Events**[1]
General Locations Indicated from Question 6	☐ None ☐ <5 min ☐ 5-10 min ☐ 10-15 min ☐ 15-30 min ☐ 30-45 min ☐ >45 min	☐ None ☐ <5 min ☐ 5-10 min ☐ 10-15 min ☐ 15-30 min ☐ 30-45 min ☐ >45 min	☐ None ☐ <5 min ☐ 5-10 min ☐ 10-15 min ☐ 15-30 min ☐ 30-45 min ☐ >45 min	☐ None ☐ <5 min ☐ 5-10 min ☐ 10-15 min ☐ 15-30 min ☐ 30-45 min ☐ >45 min	☐ None ☐ <5 min ☐ 5-10 min ☐ 10-15 min ☐ 15-30 min ☐ 30-45 min ☐ >45 min	☐ None ☐ <5 min ☐ 5-10 min ☐ 10-15 min ☐ 15-30 min ☐ 30-45 min ☐ >45 min

[1] This column is not viewed when special event is included as a source.

8. Identify the cause(s) of congestion for each general location.

	Automobile Interaction with					
	Auto	**Truck**	**Rail**	**Pedestrian**	**Bicycle**	**Bus**
General Locations Indicated from Question 6	☐	☐	☐	☐	☐	☐

9. Do you currently monitor traffic to detect or measure congestion in your community?

<table>
<tr><td colspan="2">☐
No</td></tr>
<tr><td rowspan="6">☐
Yes</td><td>How Often . . .</td></tr>
<tr><td>☐ Annually

☐ For Long-Range Metropolitan Transportation Plan Update
__(developed by the metropolitan planning organization)

☐ For Comprehensive Plan Update (developed by the municipality)

☐ Upon Receiving Complaints from the Public

☐ Other ________________________________</td></tr>
<tr><td>Monitoring Methods . . .</td></tr>
<tr><td>☐ Traffic Volume Counts

☐ Turning Movement Counts

☐ Travel Time Runs

☐ Other ________________________________
____
____

☐ Other ________________________________
____
________________________________</td></tr>
<tr><td>Performance Measures Used (please list) . . .</td></tr>
<tr><td></td></tr>
</table>

10. If you are aware of successful congestion monitoring efforts in any small to medium-sized communities (less than 250,000 population) in Texas or elsewhere in the country, please share the name(s) of those locations.

____

____

____

____

END OF SURVEY

Thank you very much for your time in completing this important survey!!

APPENDIX B

Bi-directional Volume Graphs Including Operational Characteristics for Each Count Location
(Note: Electronic Files in Attached CD)

The Microsoft Excel files located in the directory "Appendix B" of the CD at the end of this report contain the data used to create the graphics in Appendix B.

Each roadway has a different Excel file. Each Excel workbook contains separate worksheets of volume data for the following time periods: Morning Peak, Morning Off-Peak, Afternoon Peak, and All Day. Additional worksheets contain each of the figures shown in Appendix B.

Note that the "University-speed & vol.xls" file is slightly different. It has separate worksheets to perform calculations to show volume and speed on the same figure. These figures are shown in Appendix B for University Drive only.

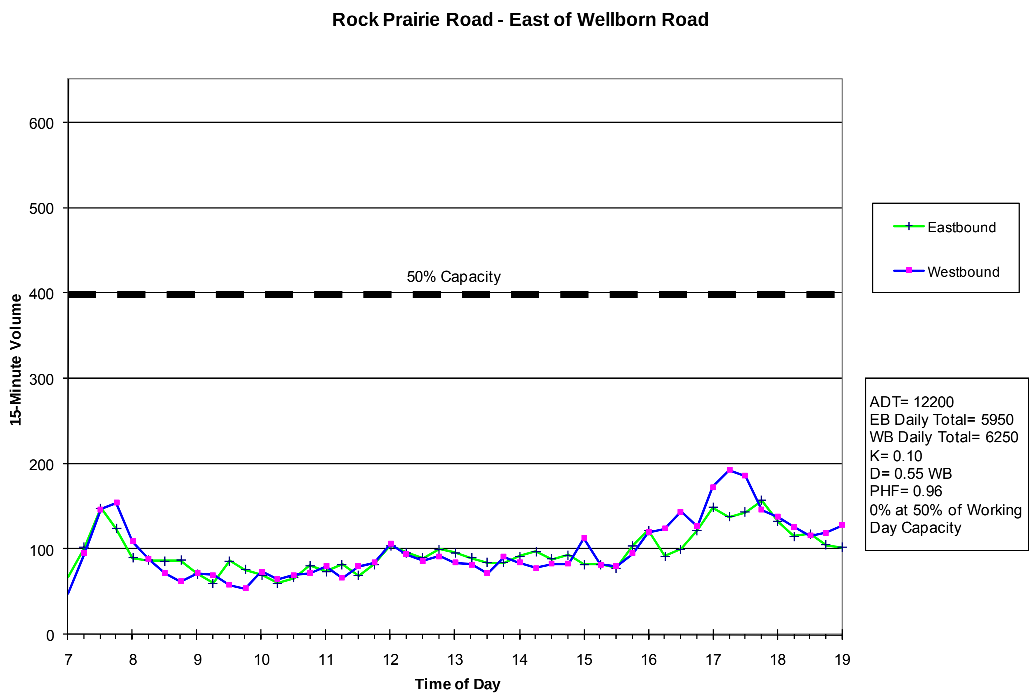


Figure B-1. Rock Prairie Road - East of Wellborn Road, Volume and Capacity Characteristics.

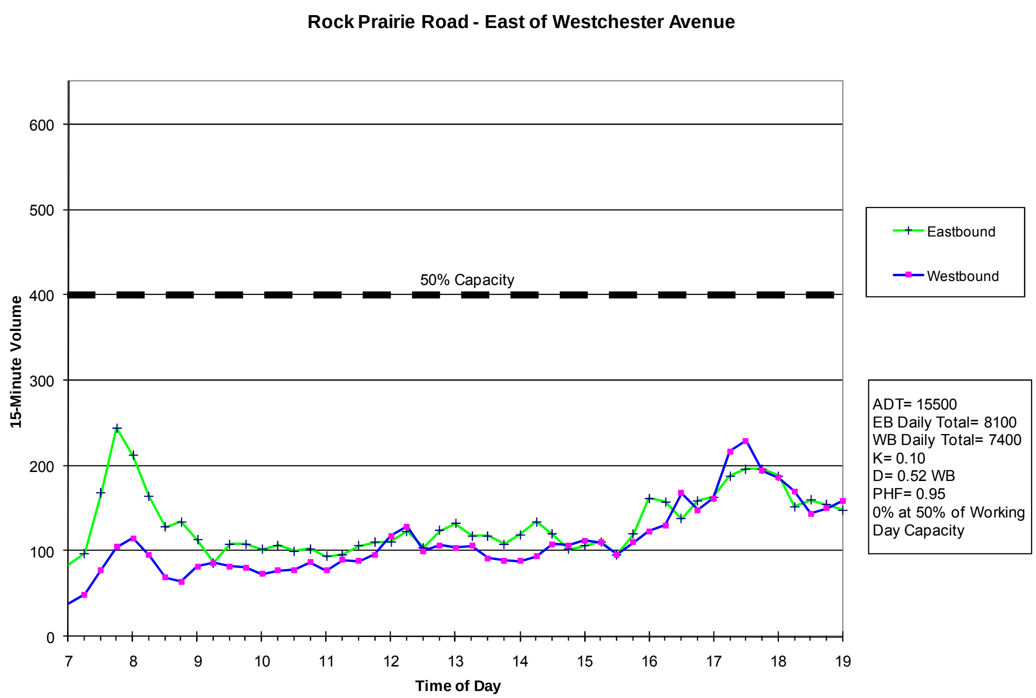


Figure B-2. Rock Prairie Road - East of Westchester Avenue, Volume and Capacity Characteristics.

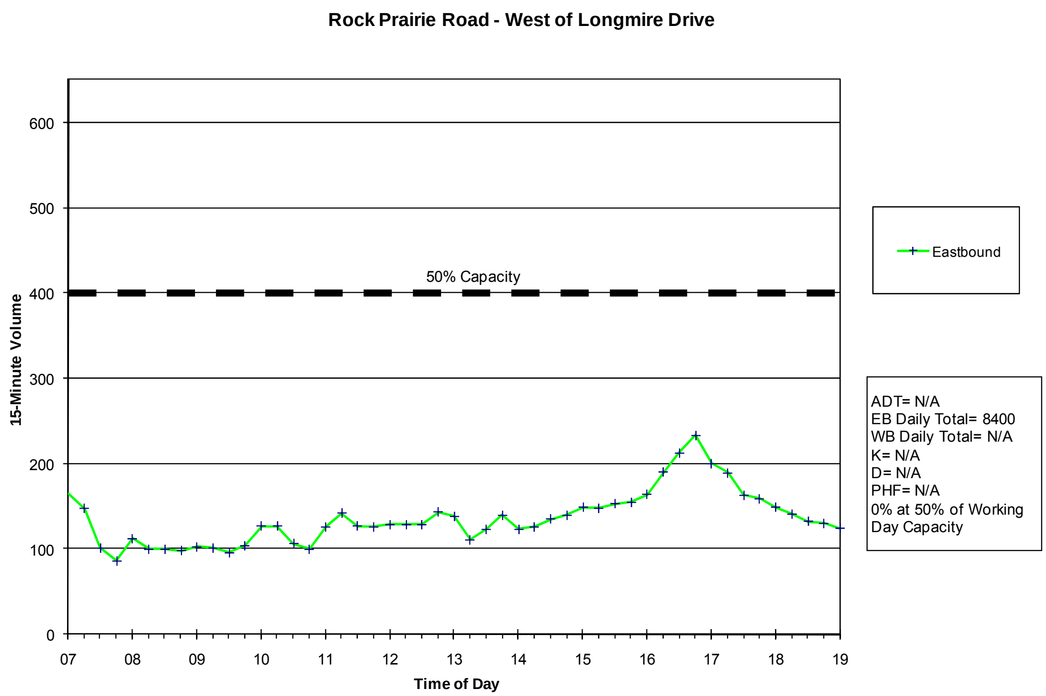


Figure B-3. Rock Prairie Road - West of Longmire Drive, Volume and Capacity Characteristics.

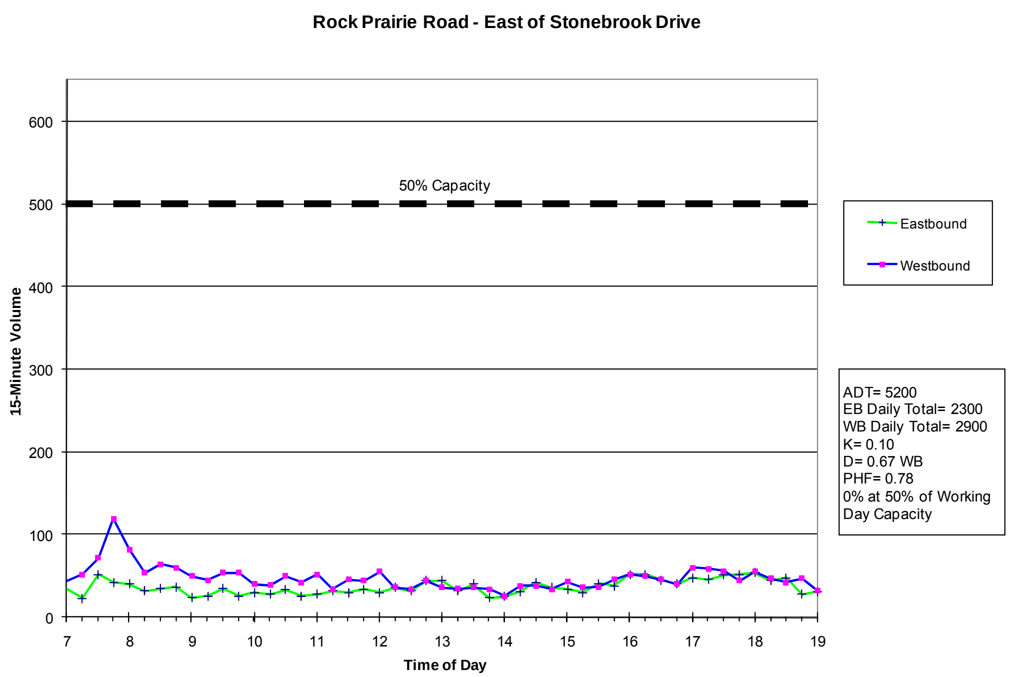


Figure B-4. Rock Prairie Road - East of Stonebrook Drive, Volume and Capacity Characteristics.

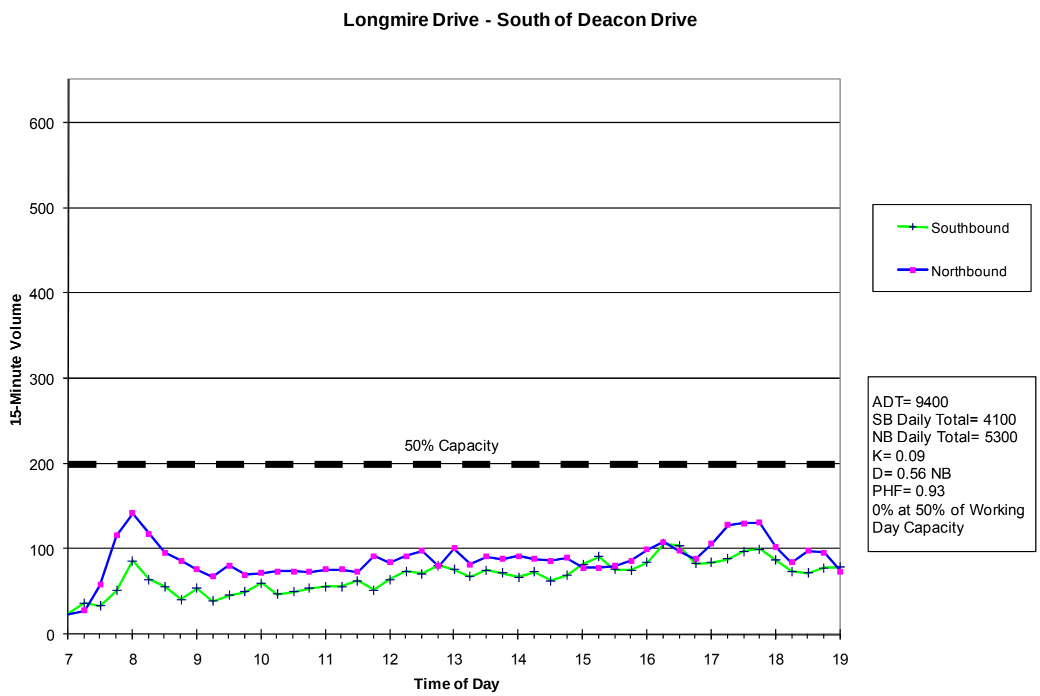


Figure B-5. Longmire Drive - South of Deacon Drive, Volume and Capacity Characteristics.

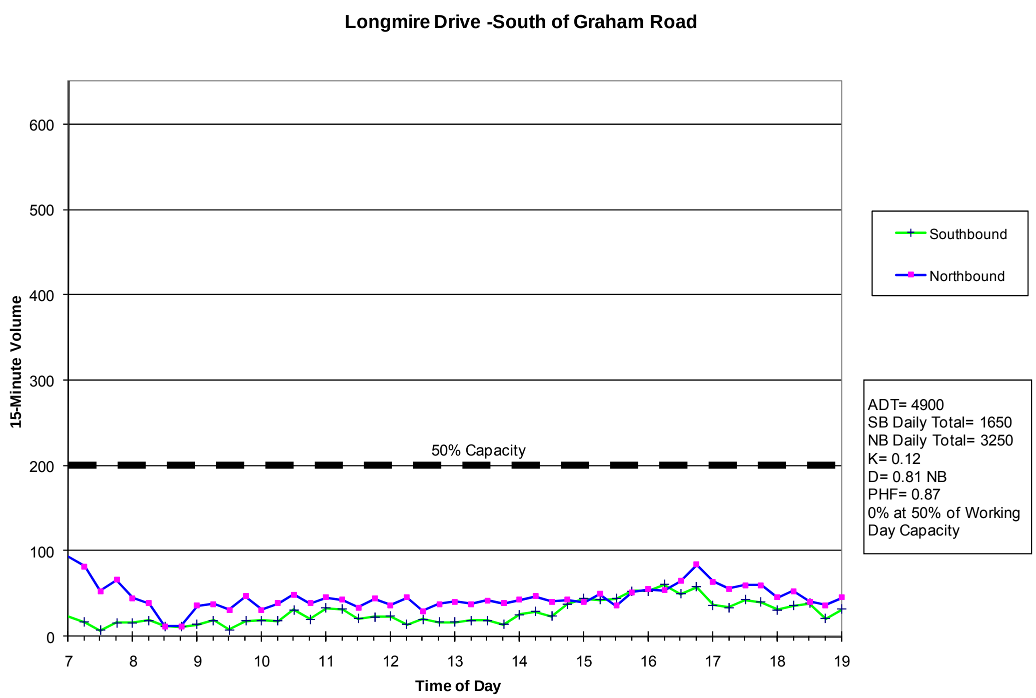


Figure B-6. Longmire Drive - South of Graham Road, Volume and Capacity Characteristics.

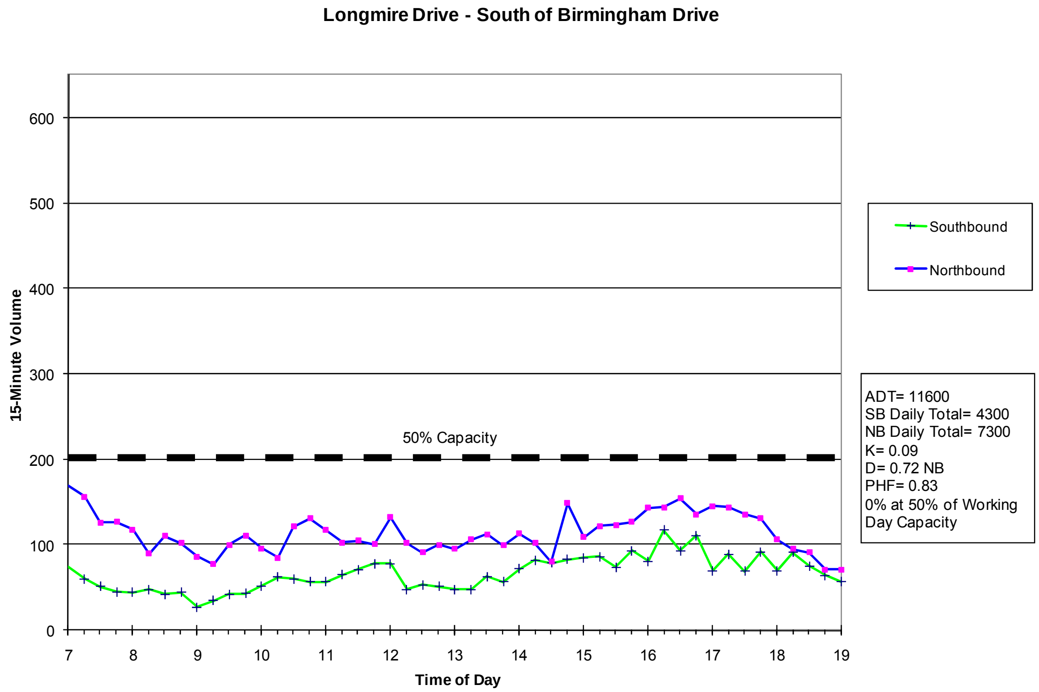


Figure B-7. Longmire Drive - South of Birmingham Drive, Volume and Capacity Characteristics.

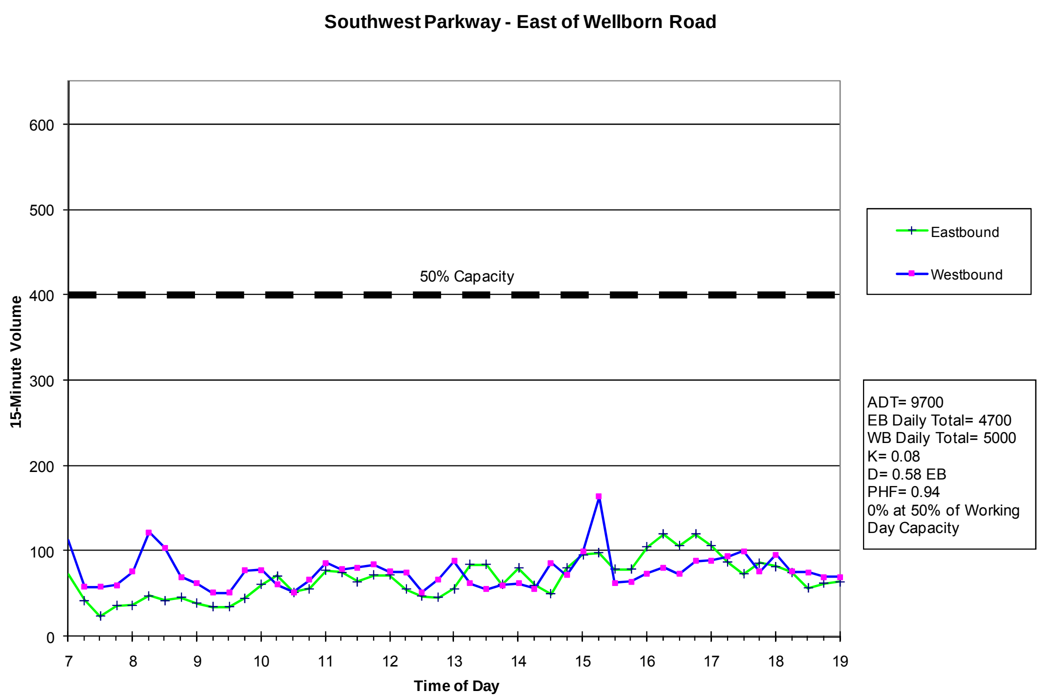


Figure B-8. Southwest Parkway - East of Wellborn Road, Volume and Capacity Characteristics.

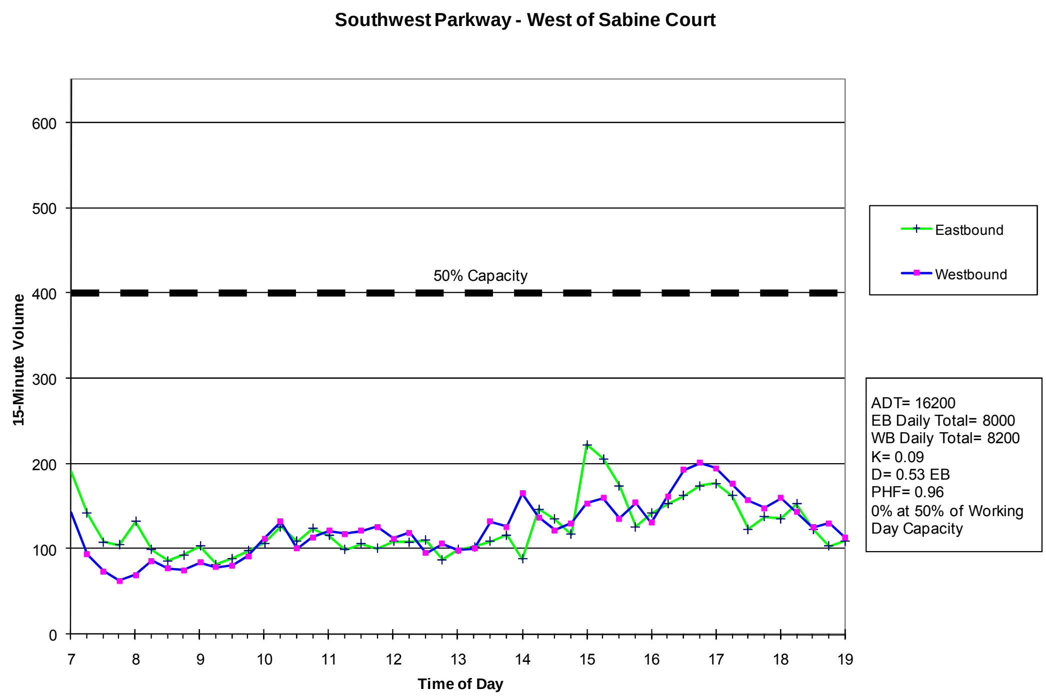


Figure B-9. Southwest Parkway - West of Sabine Court, Volume and Capacity Characteristics.

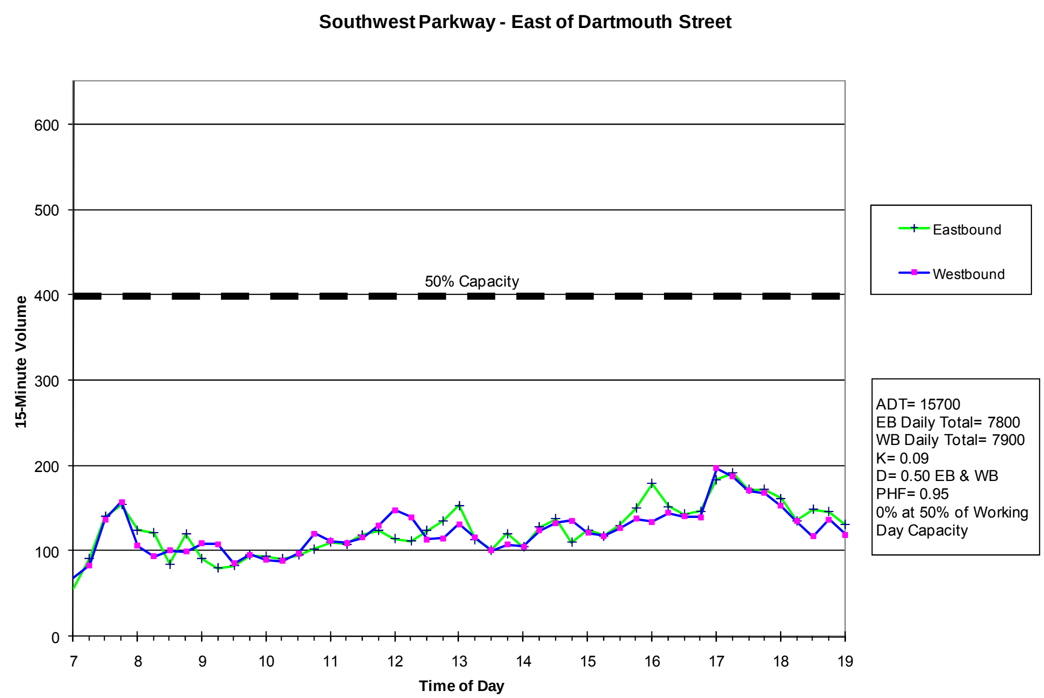


Figure B-10. Southwest Parkway - East of Dartmouth Street, Volume and Capacity Characteristics.

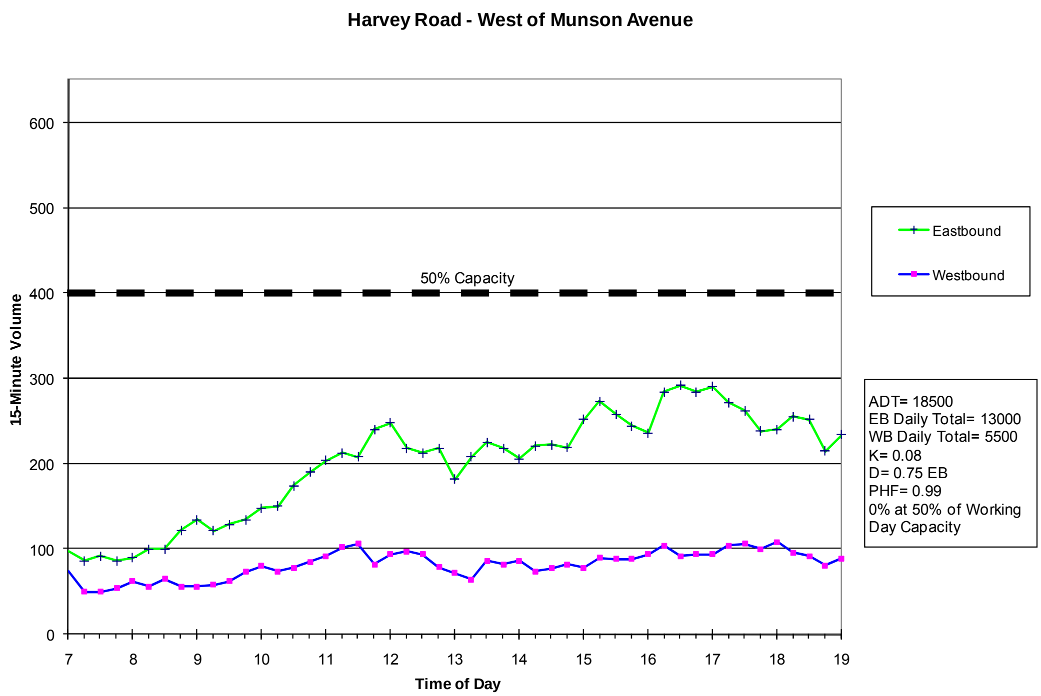


Figure B-11. Harvey Road - West of Munson Avenue, Volume and Capacity Characteristics.

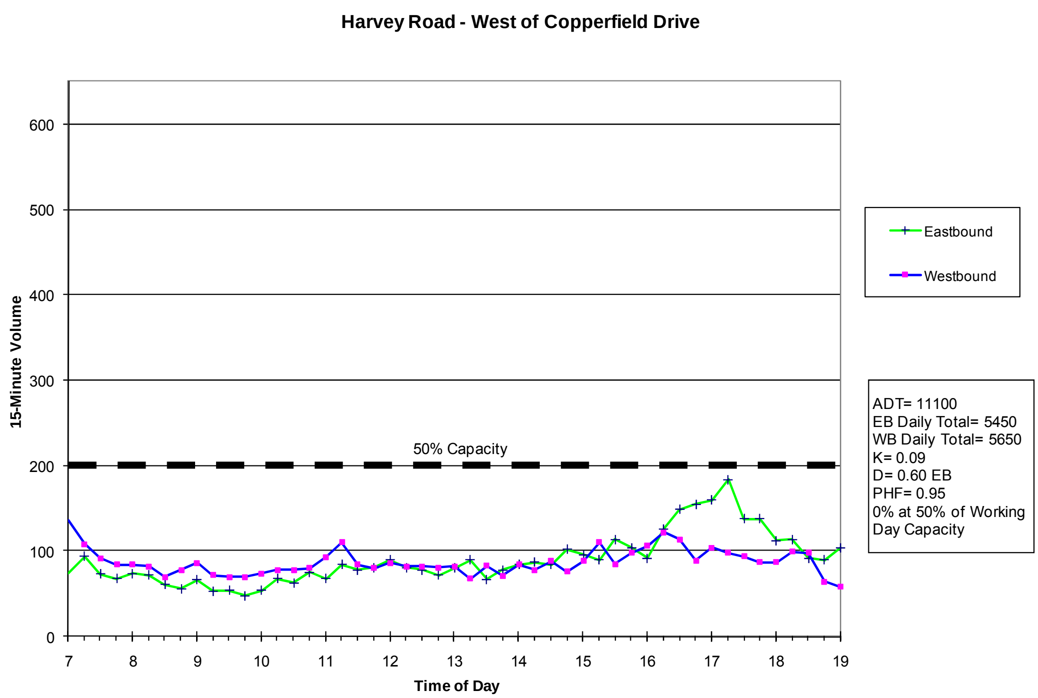


Figure B-12. Harvey Road - West of Copperfield Drive, Volume and Capacity Characteristics.

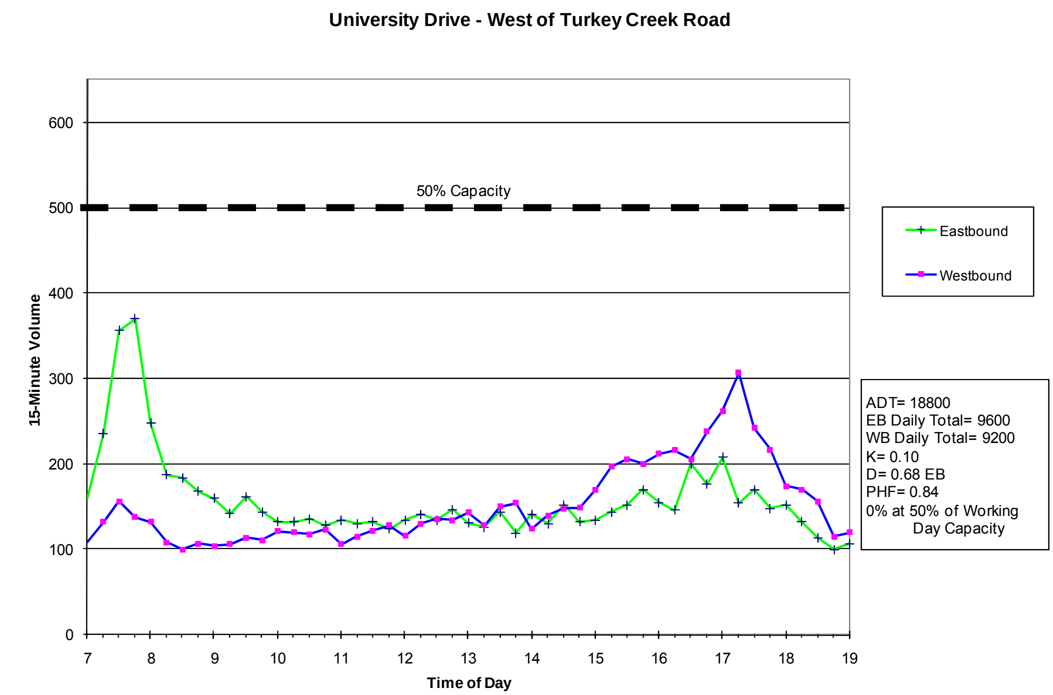


Figure B-13. University Drive - West of Turkey Creek Road, Volume and Capacity Characteristics.

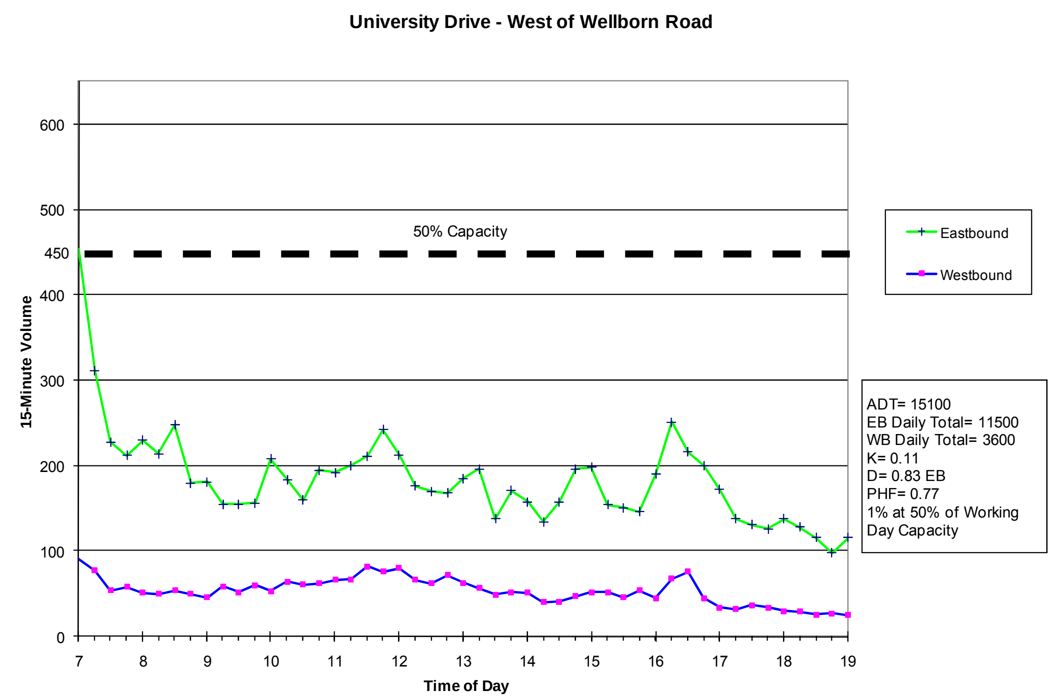


Figure B-14. University Drive - West of Wellborn Road, Volume and Capacity Characteristics.

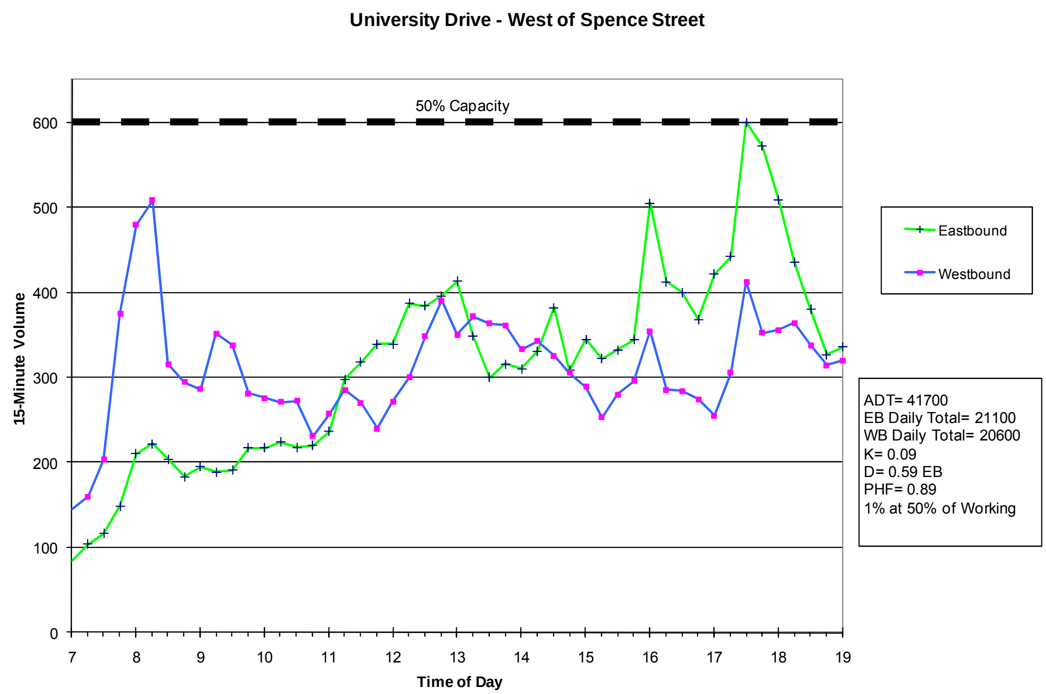


Figure B-15. University Drive - West of Spence Street, Volume and Capacity Characteristics.

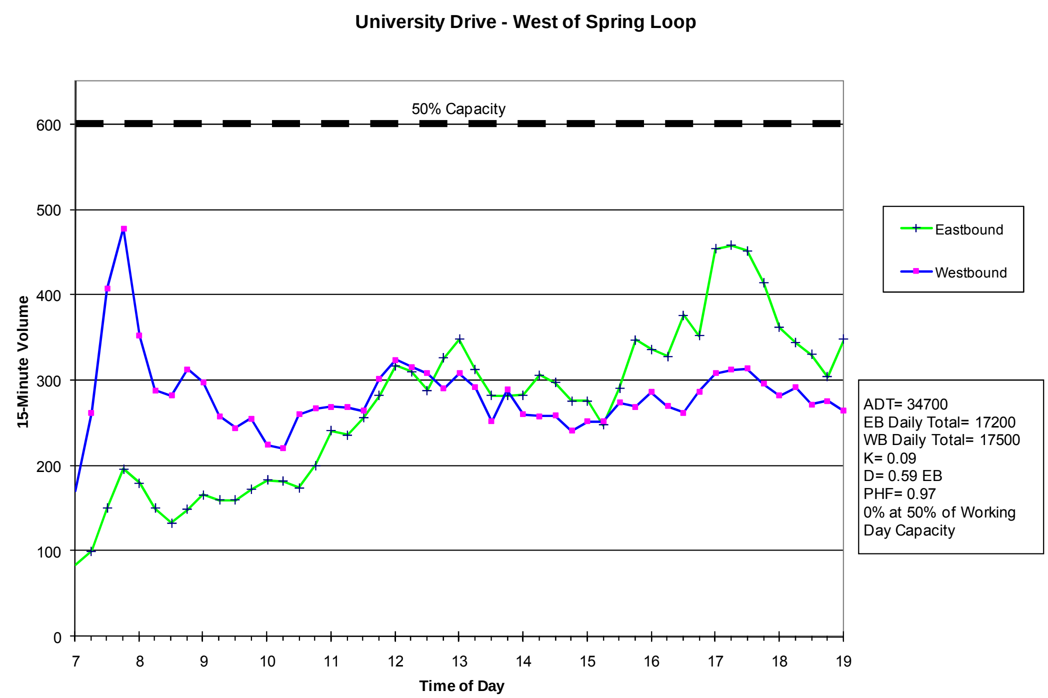


Figure B-16. University Drive - West of Spring Loop, Volume and Capacity Characteristics.

University Drive - East of SH 6

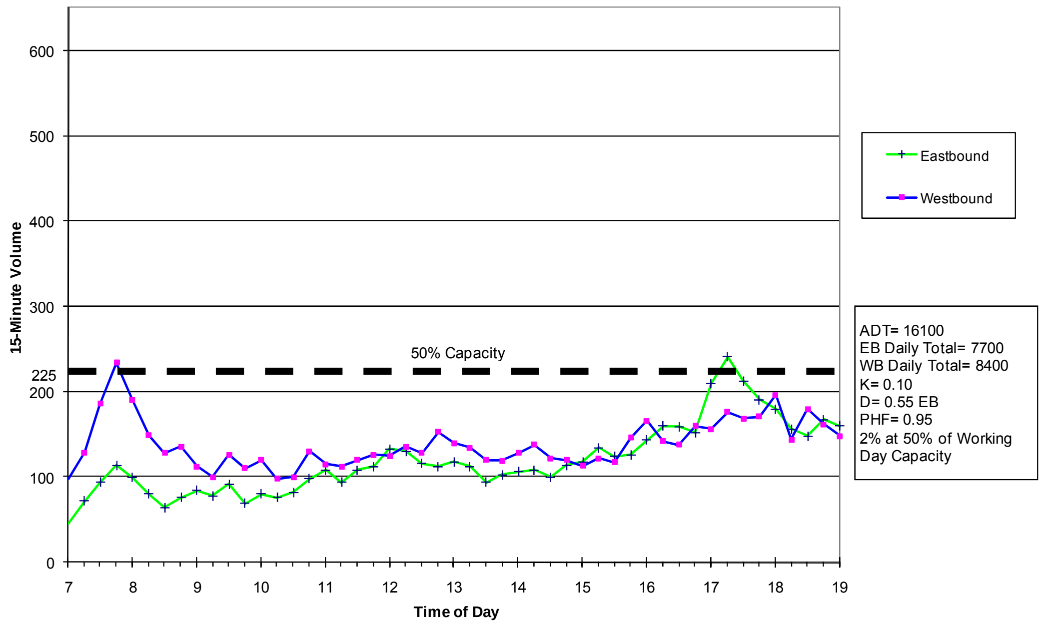


Figure B-17. University Drive - East of SH 6, Volume and Capacity Characteristics.

FM 2818 - East of Texas Avenue

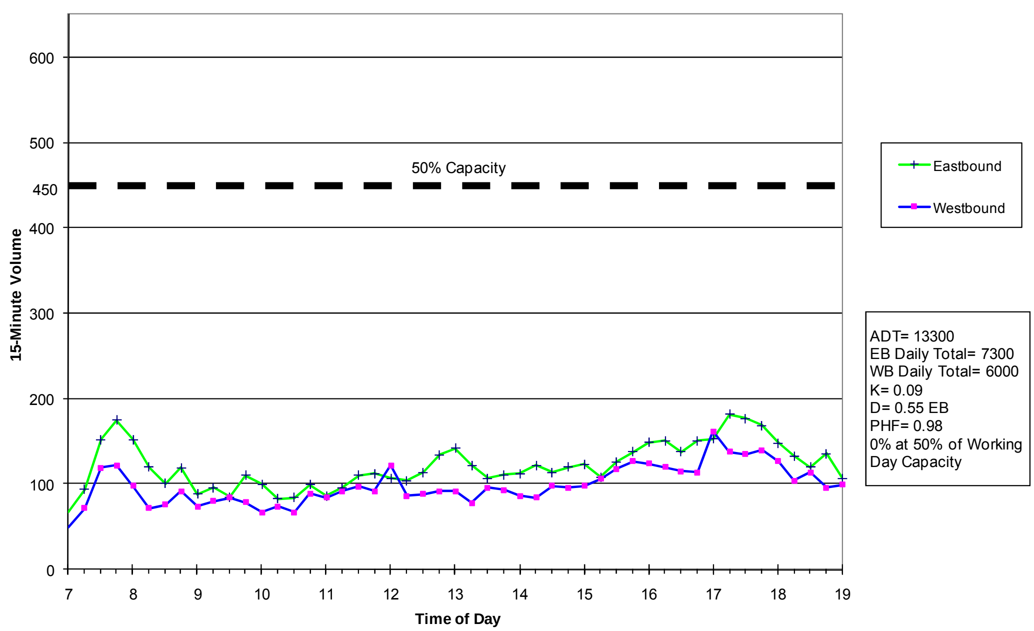


Figure B-18. FM 2818 - East of Texas Avenue, Volume and Capacity Characteristics.

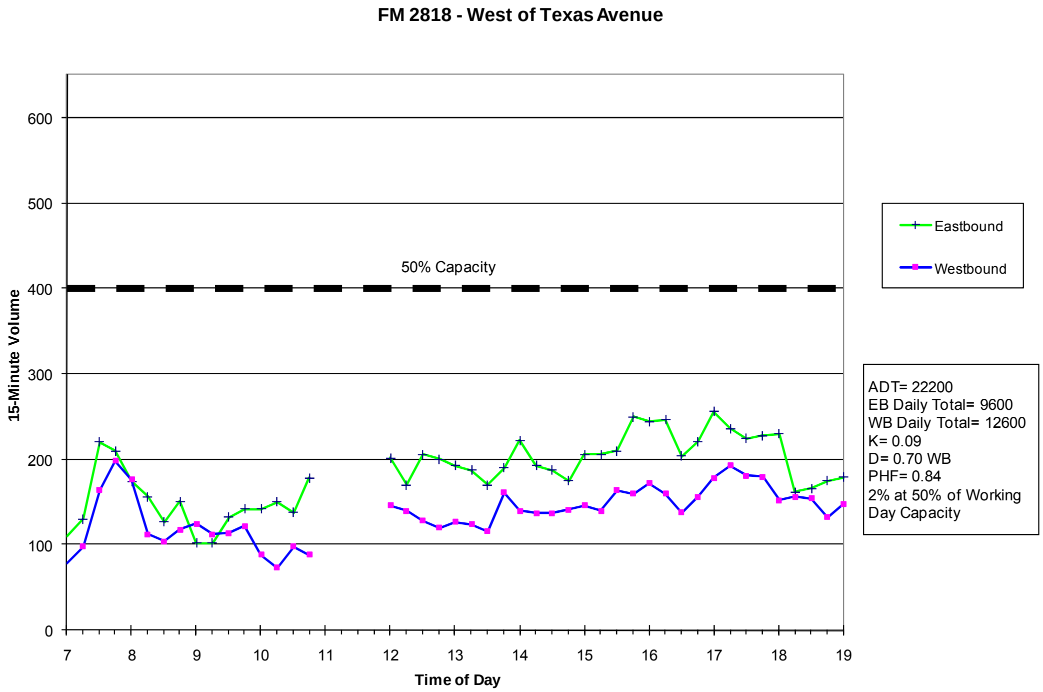


Figure B-19. FM 2818 - West of Texas Avenue, Volume and Capacity Characteristics.

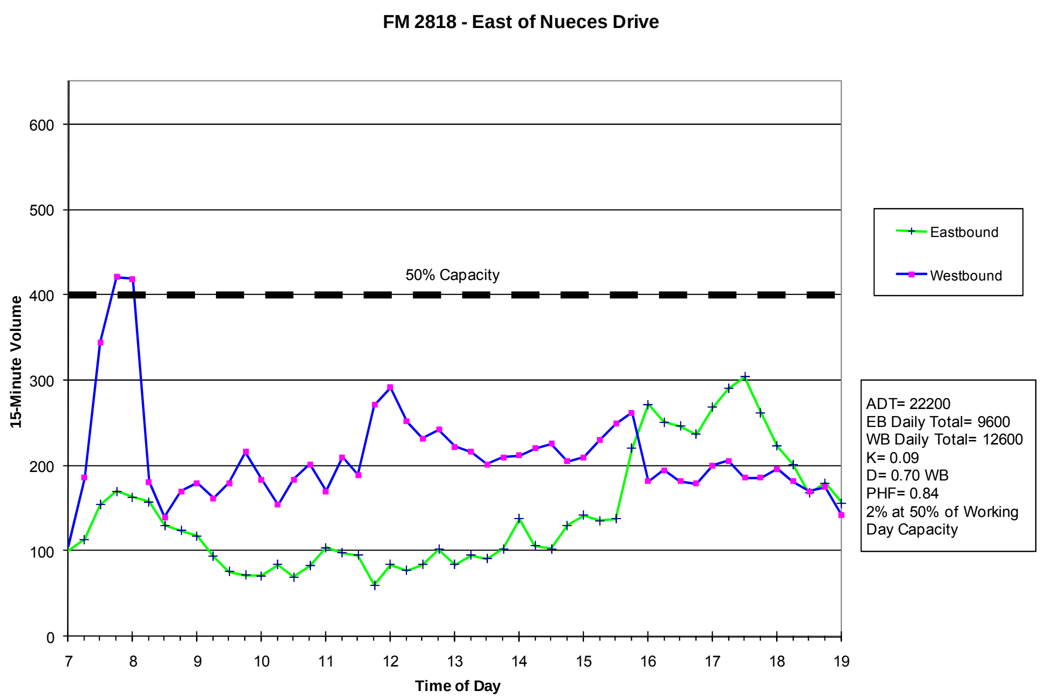


Figure B-20. FM 2818 - East of Nueces Drive, Volume and Capacity Characteristics.

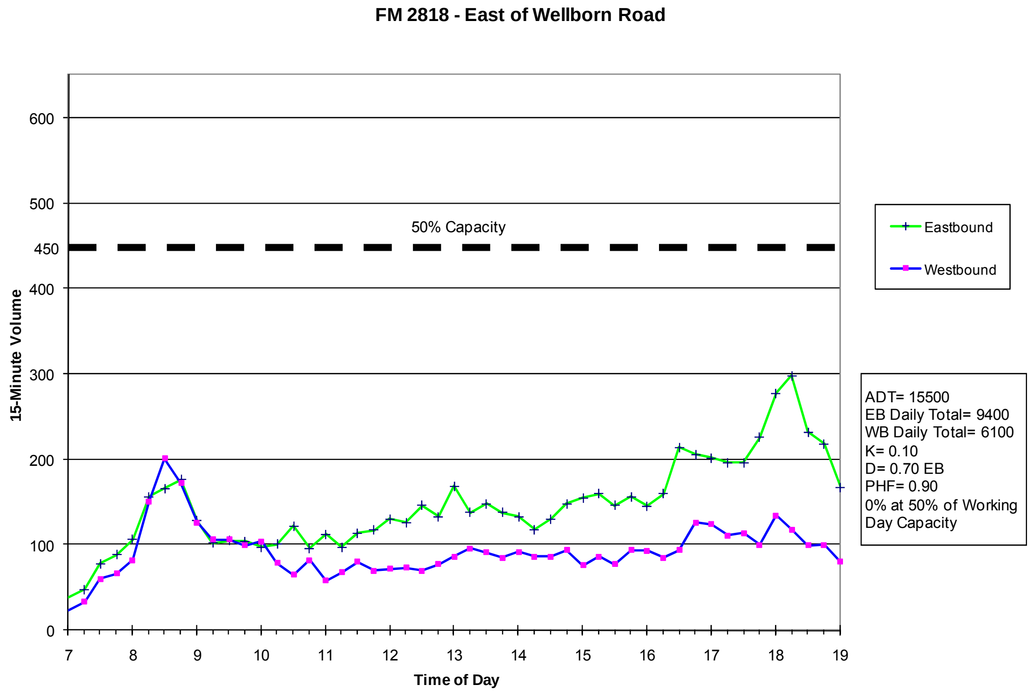


Figure B-21. FM 2818 - East of Wellborn Road, Volume and Capacity Characteristics.

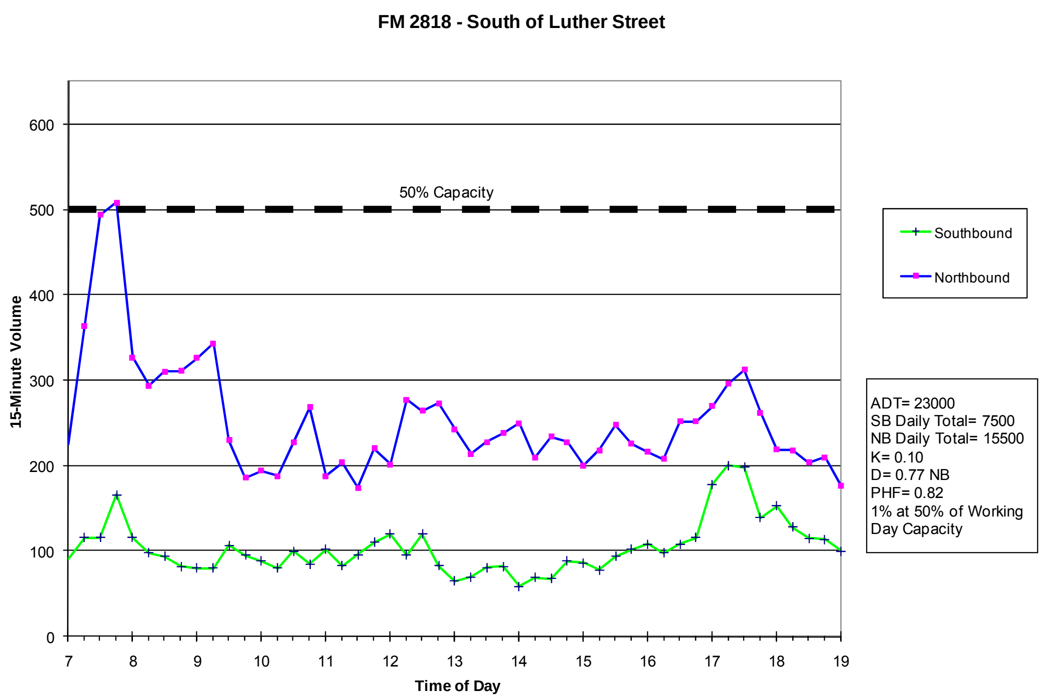


Figure B-22. FM 2818 - South of Luther Street, Volume and Capacity Characteristics.

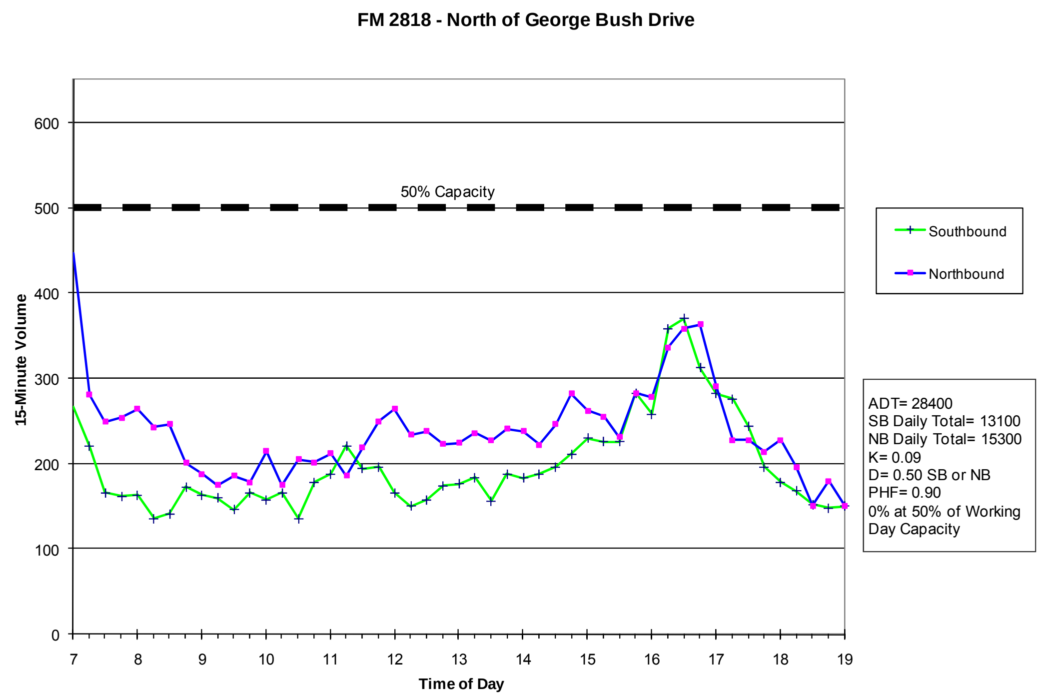


Figure B-23. FM 2818 - North of George Bush Drive, Volume and Capacity Characteristics.

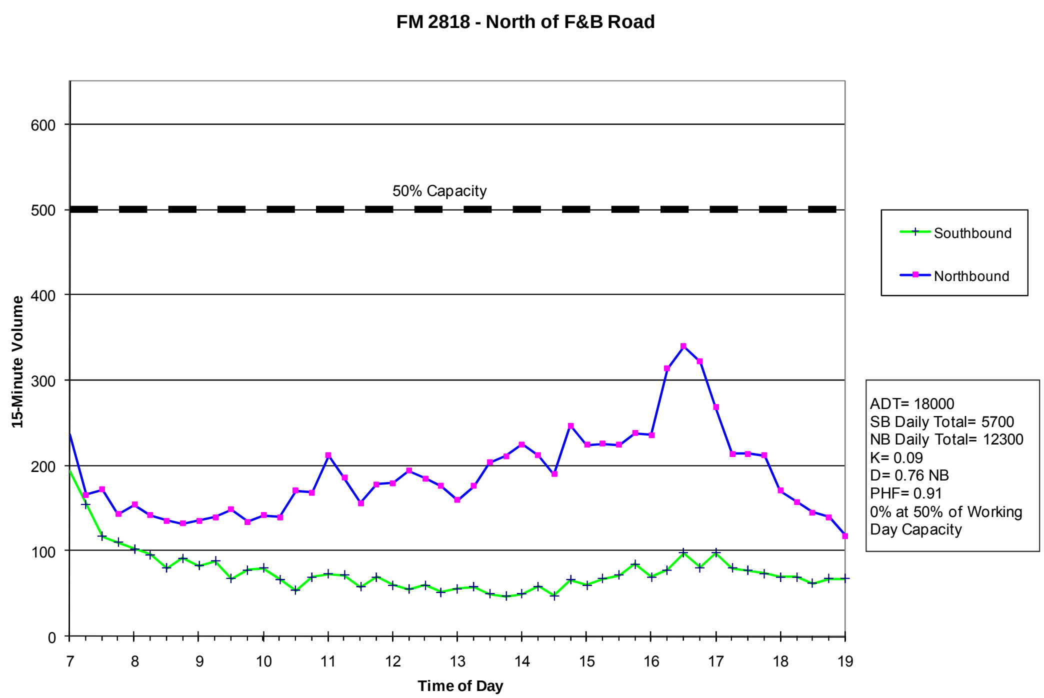


Figure B-24. FM 2818 - North of F&B Road, Volume and Capacity Characteristics.

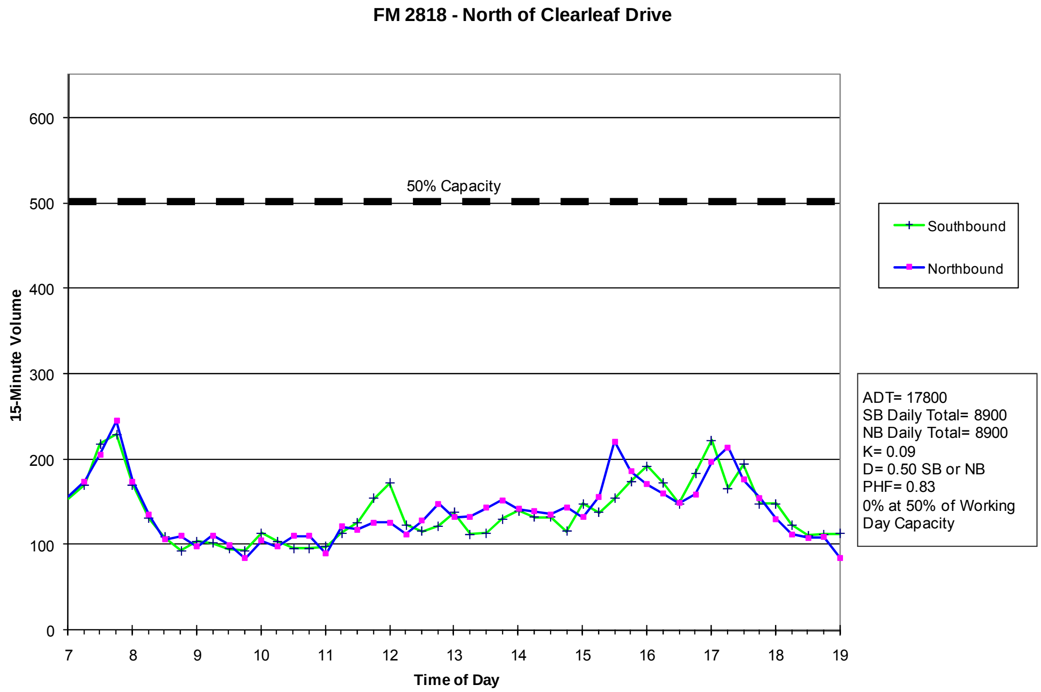


Figure B-25. FM 2818 - North of Clearleaf Drive, Volume and Capacity Characteristics.

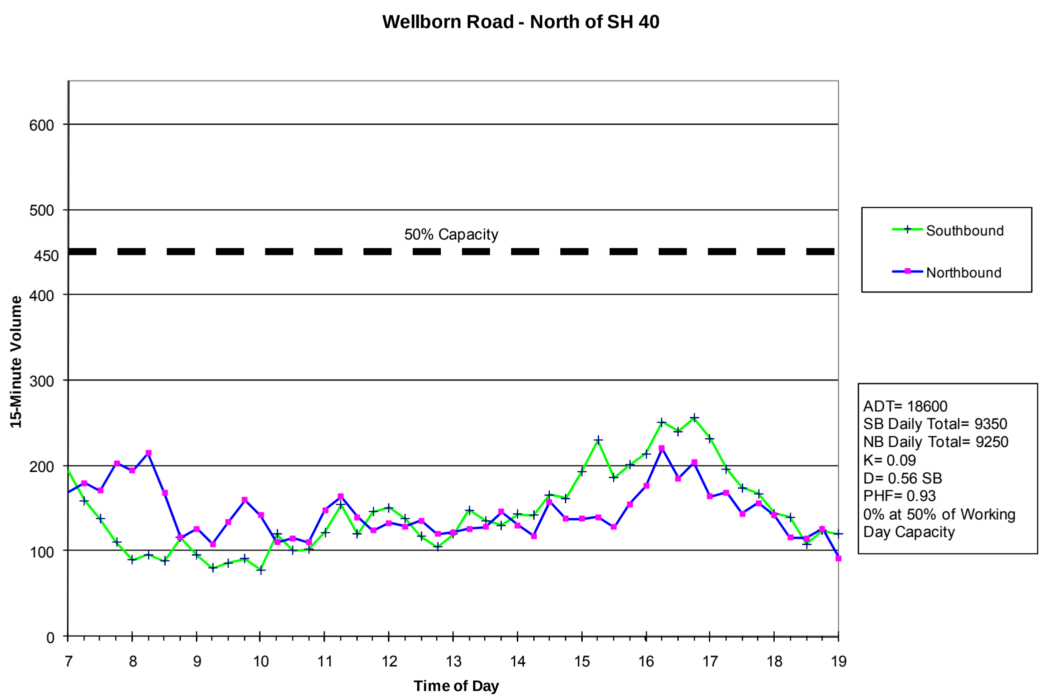


Figure B-26. Wellborn Road - North of SH 40, Volume and Capacity Characteristics.

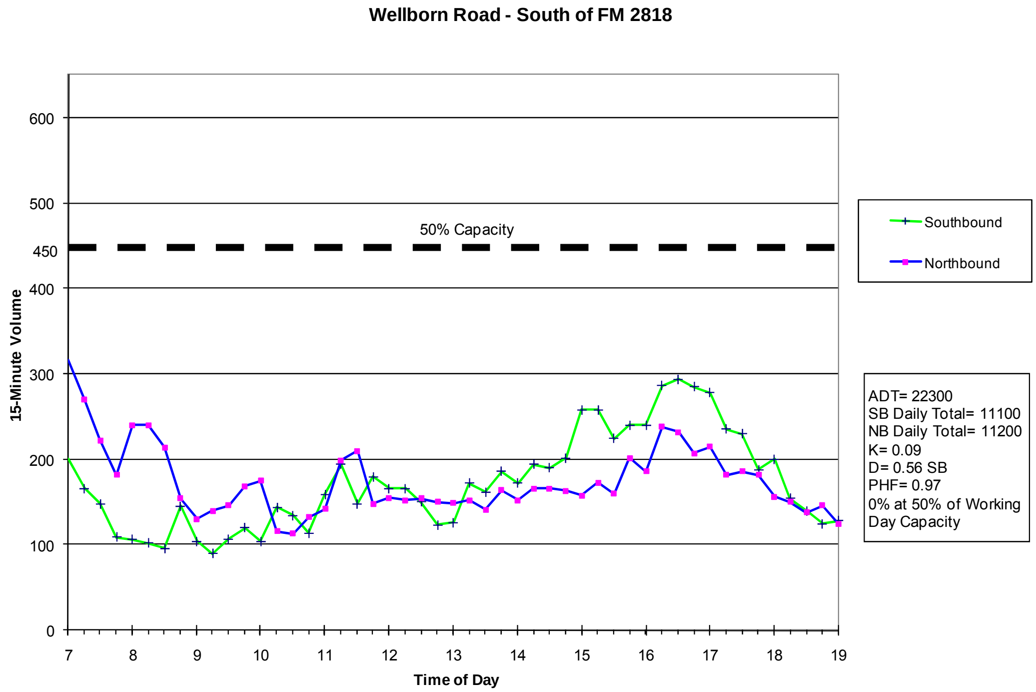


Figure B-27. Wellborn Road - South of FM 2818, Volume and Capacity Characteristics.

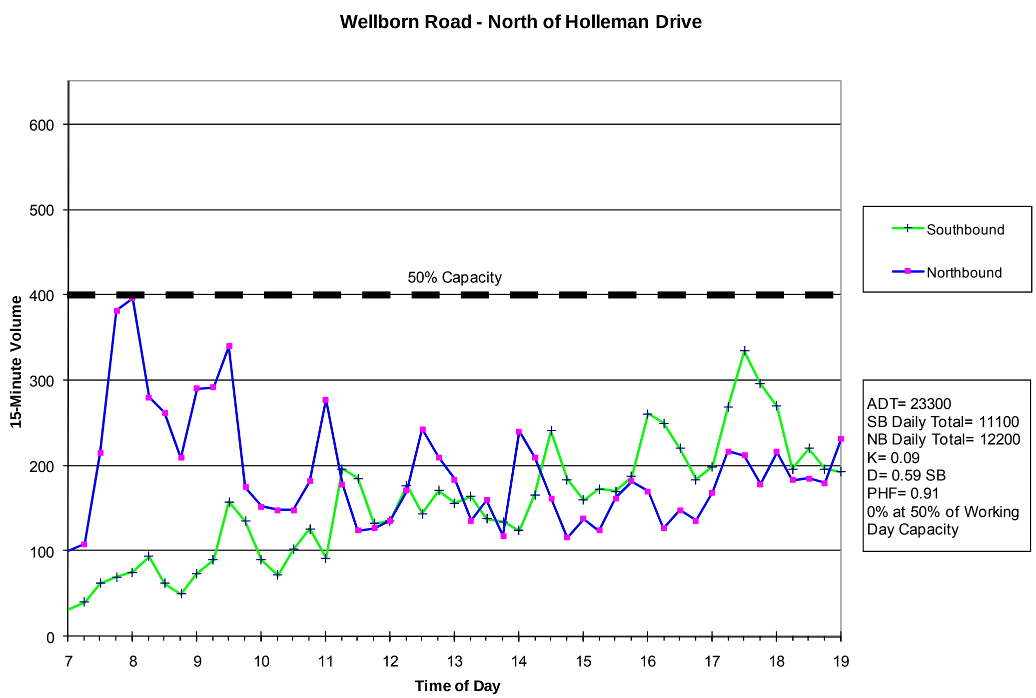


Figure B-28. Wellborn Road - North of Holleman Drive, Volume and Capacity Characteristics.

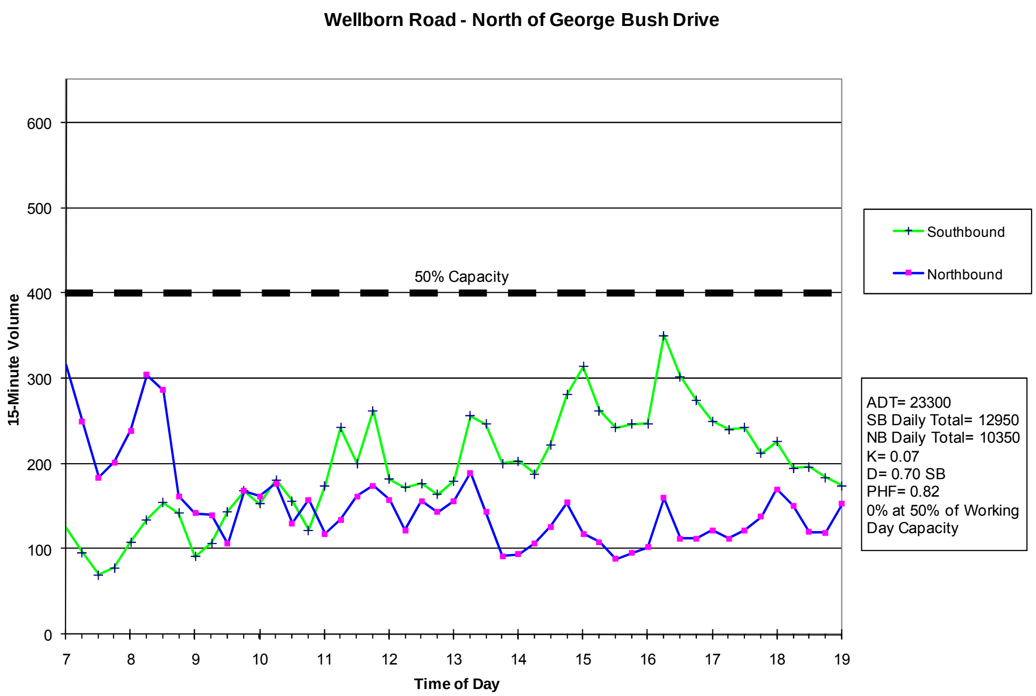


Figure B-29. Wellborn Road - North of George Bush Drive, Volume and Capacity Characteristics.

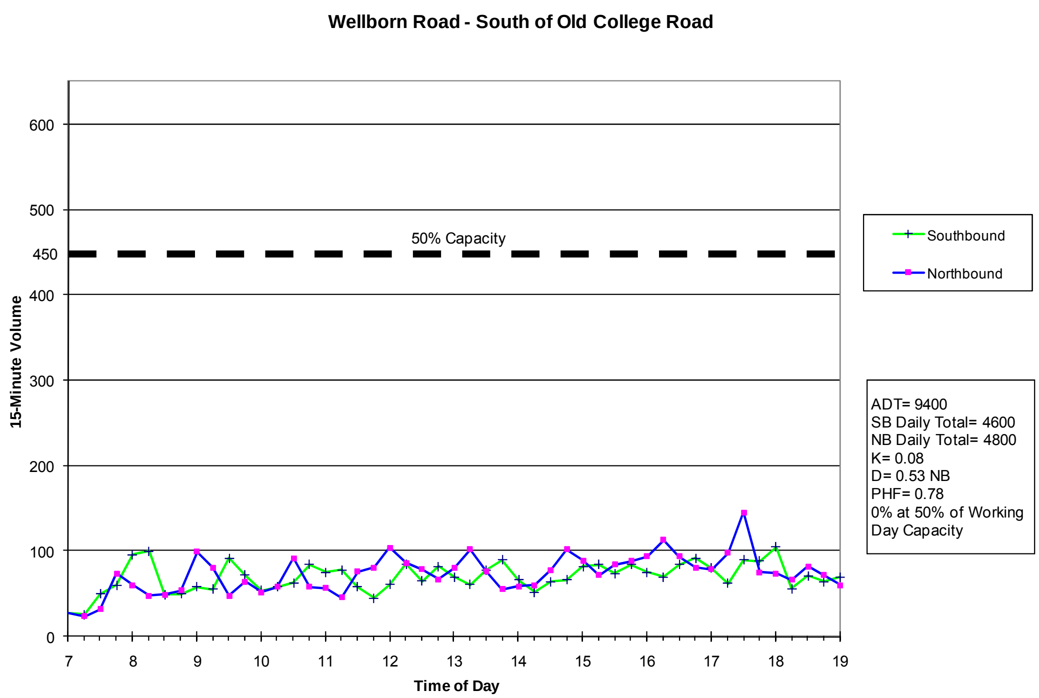


Figure B-30. Wellborn Road - South of Old College Road, Volume and Capacity Characteristics.

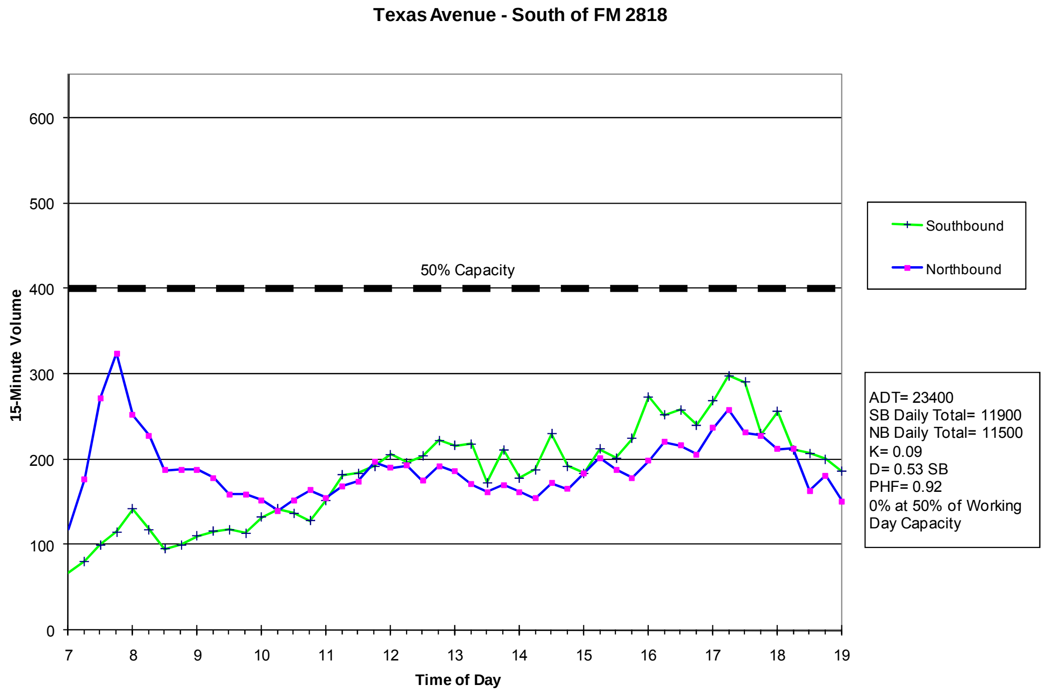


Figure B-31. Texas Avenue - South of FM 2818, Volume and Capacity Characteristics.

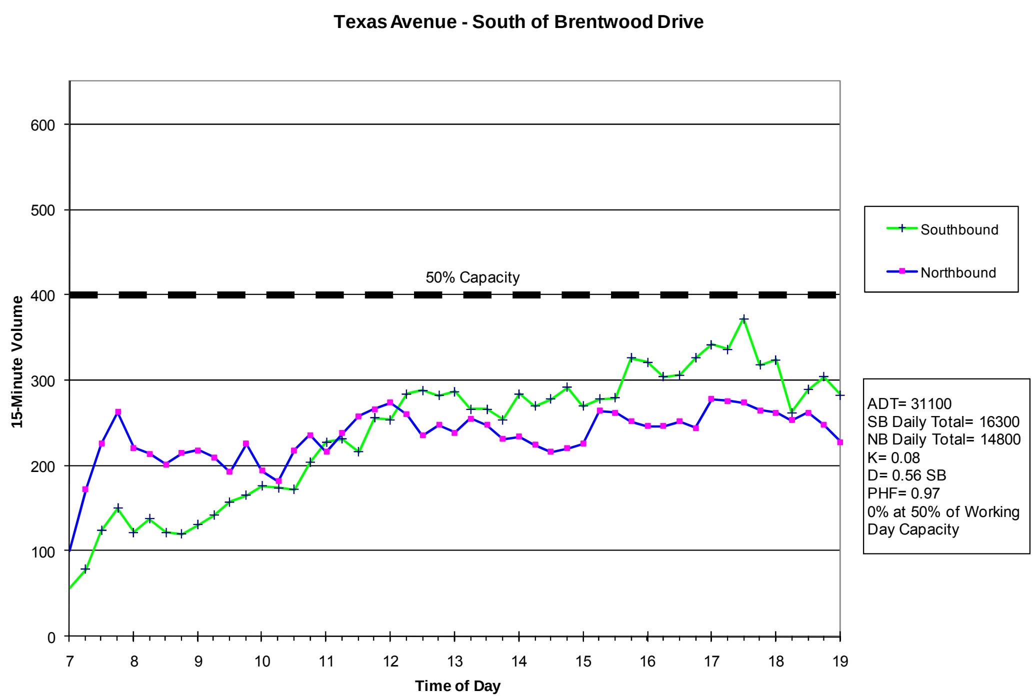


Figure B-32. Texas Avenue - South of Brentwood Drive, Volume and Capacity Characteristics.

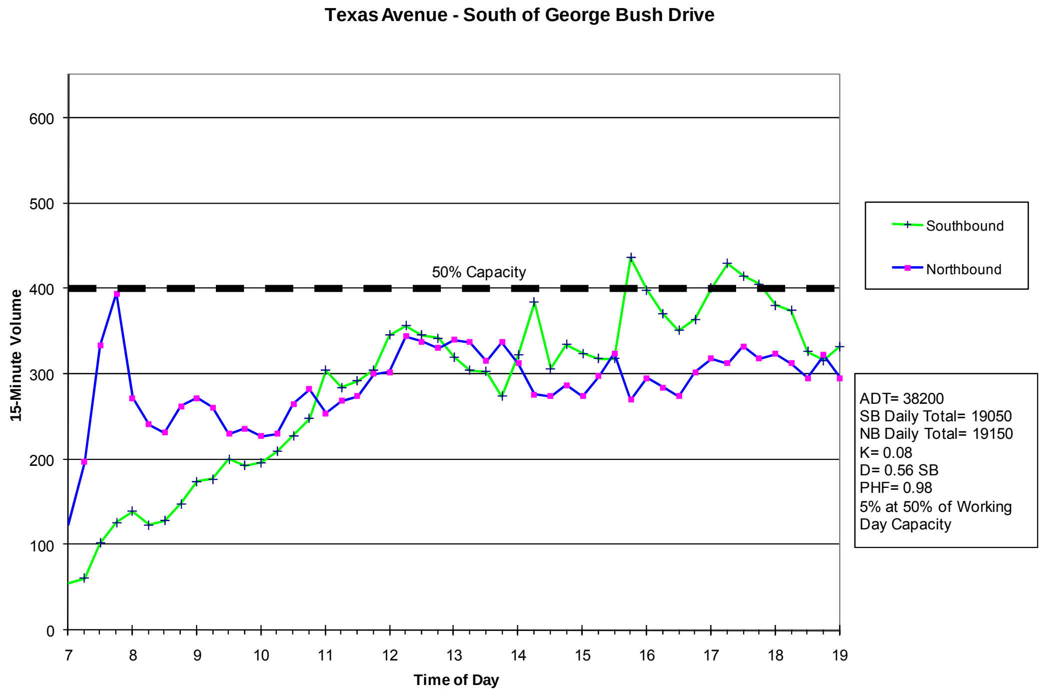


Figure B-33. Texas Avenue - South of George Bush Drive, Volume and Capacity Characteristics.

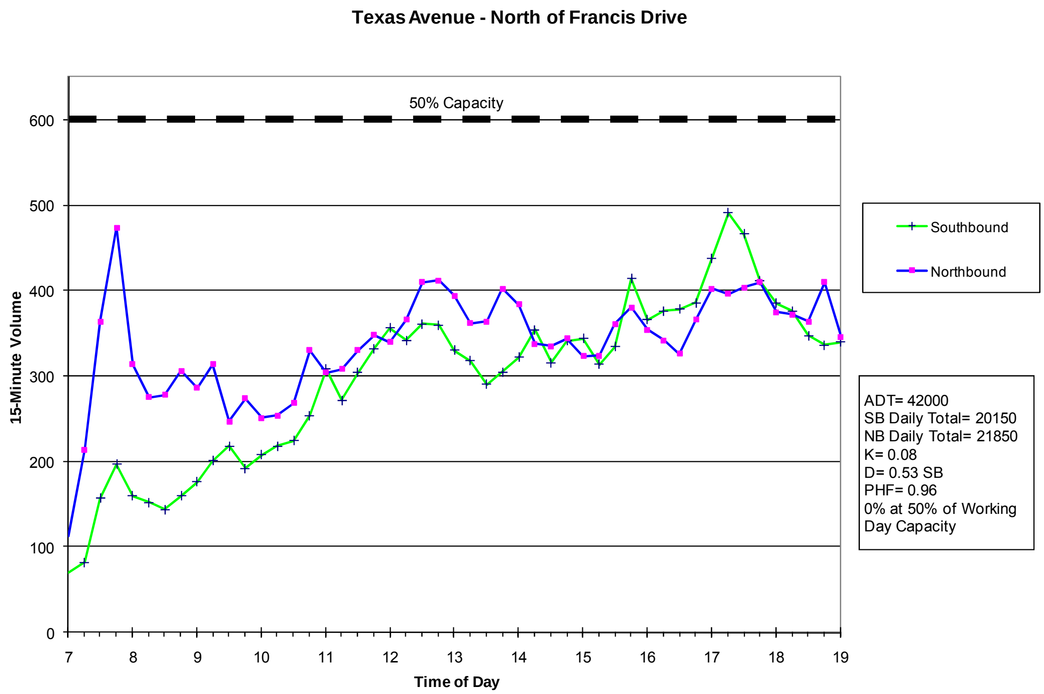


Figure B-34. Texas Avenue - North of Francis Drive, Volume and Capacity Characteristics.

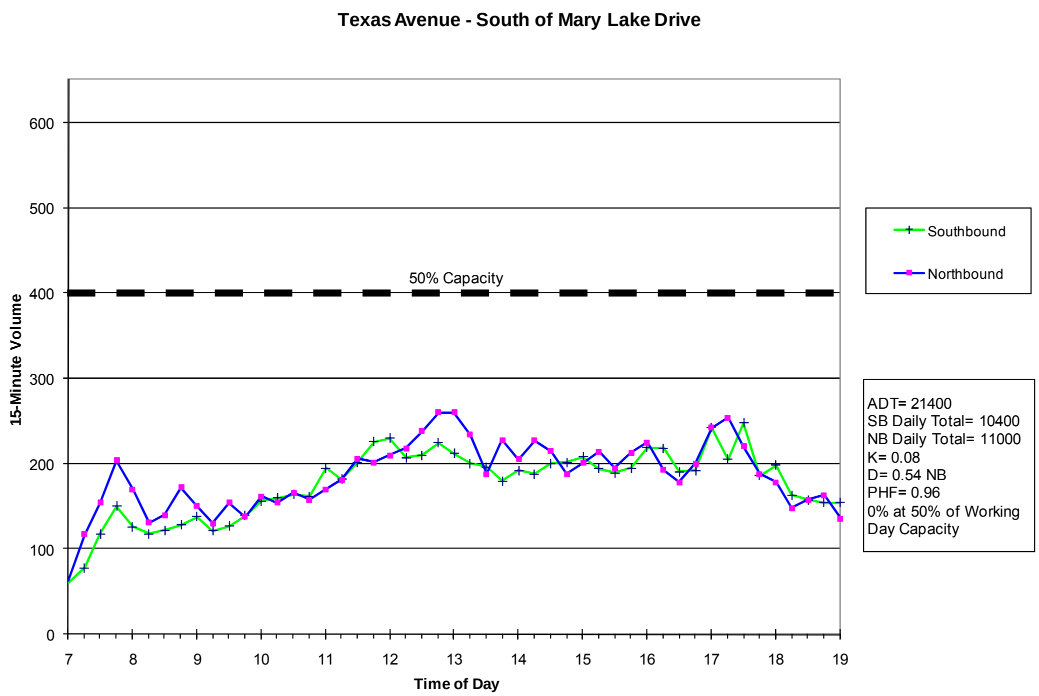


Figure B-35. Texas Avenue - South of Mary Lake Drive, Volume and Capacity Characteristics.

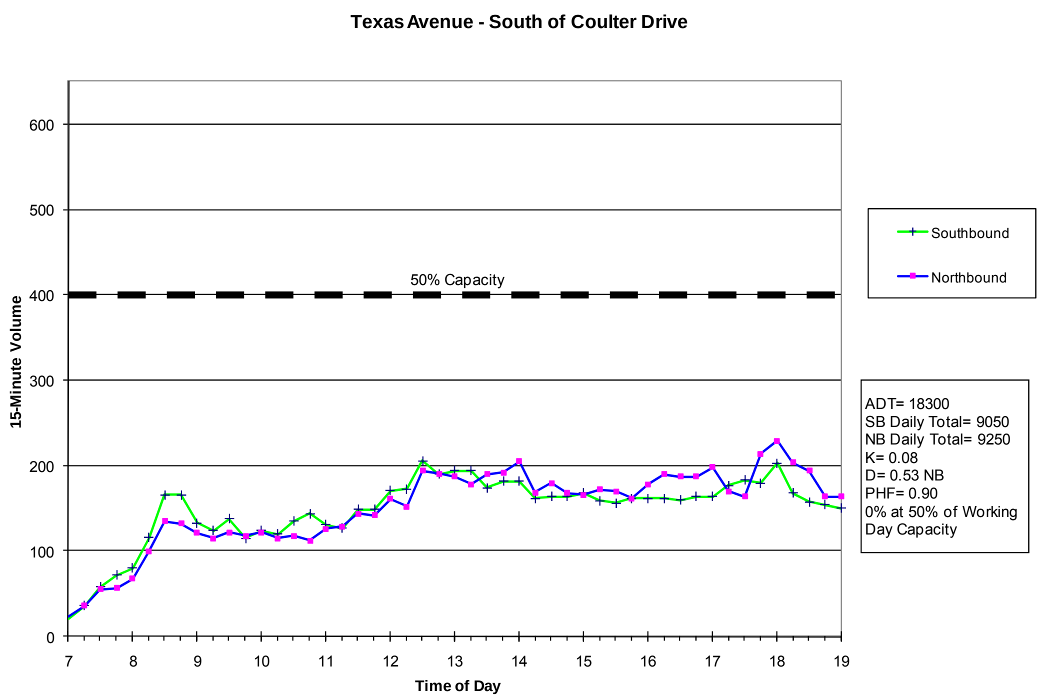


Figure B-36. Texas Avenue - South of Coulter Drive, Volume and Capacity Characteristics.

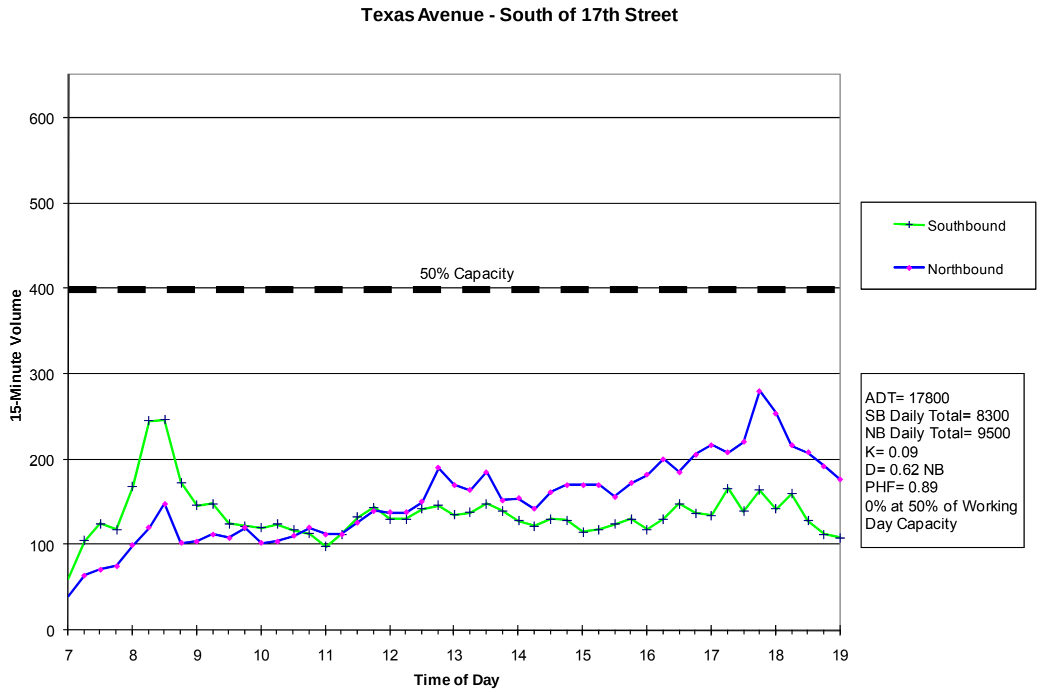


Figure B-37. Texas Avenue - South of 17th Street, Volume and Capacity Characteristics.

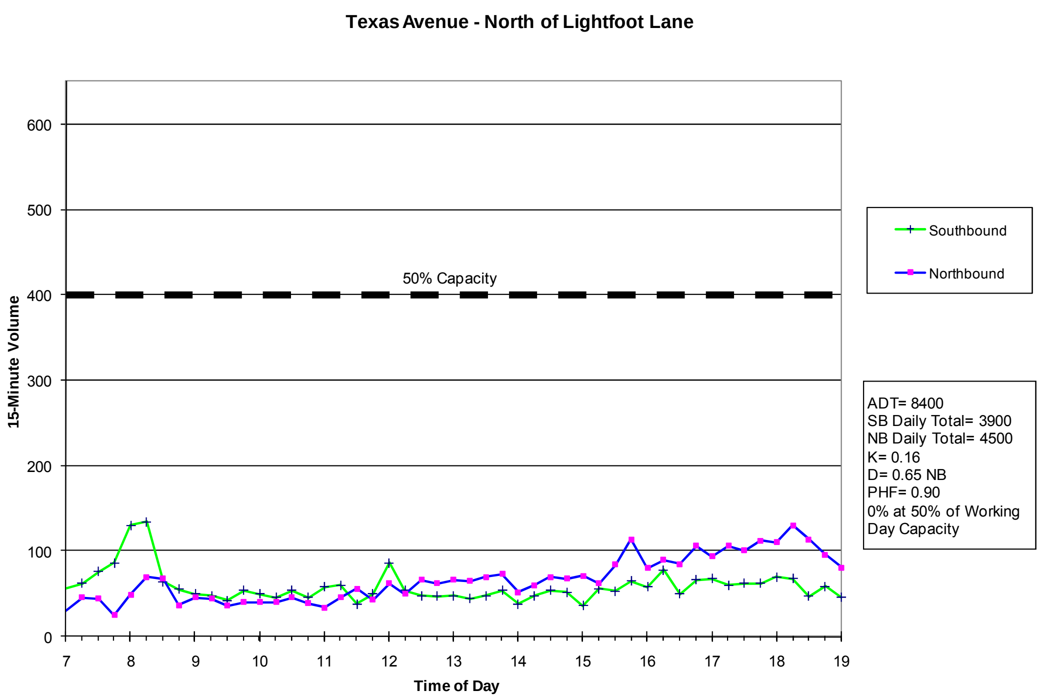


Figure B-38. Texas Avenue - North of Lightfoot Lane, Volume and Capacity Characteristics.

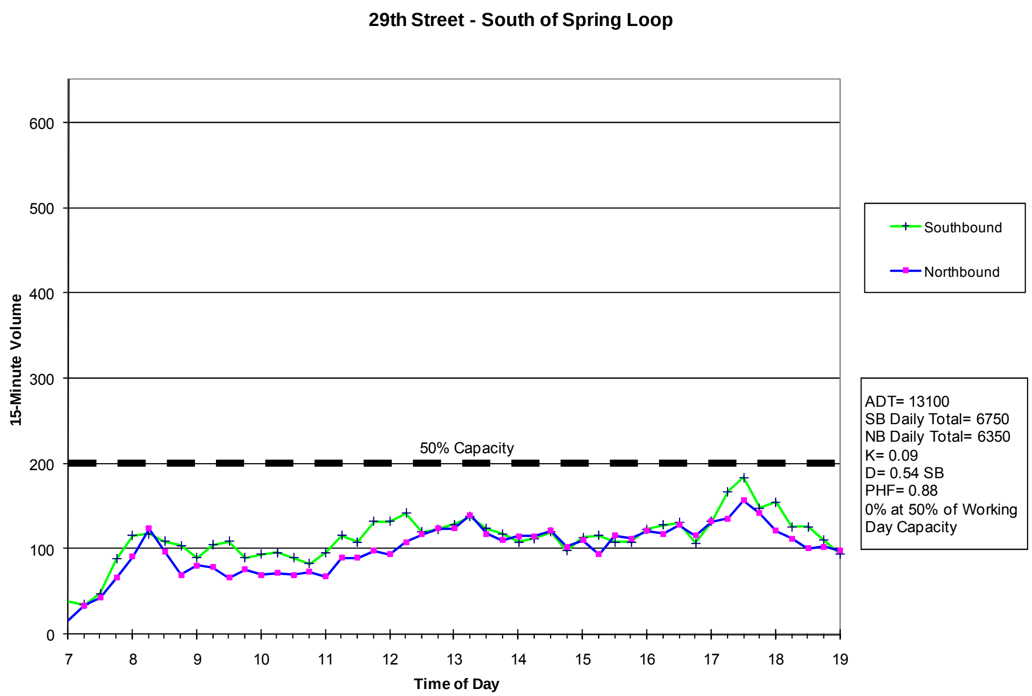


Figure B-39. 29th Street - South of Spring Loop, Volume and Capacity Characteristics.

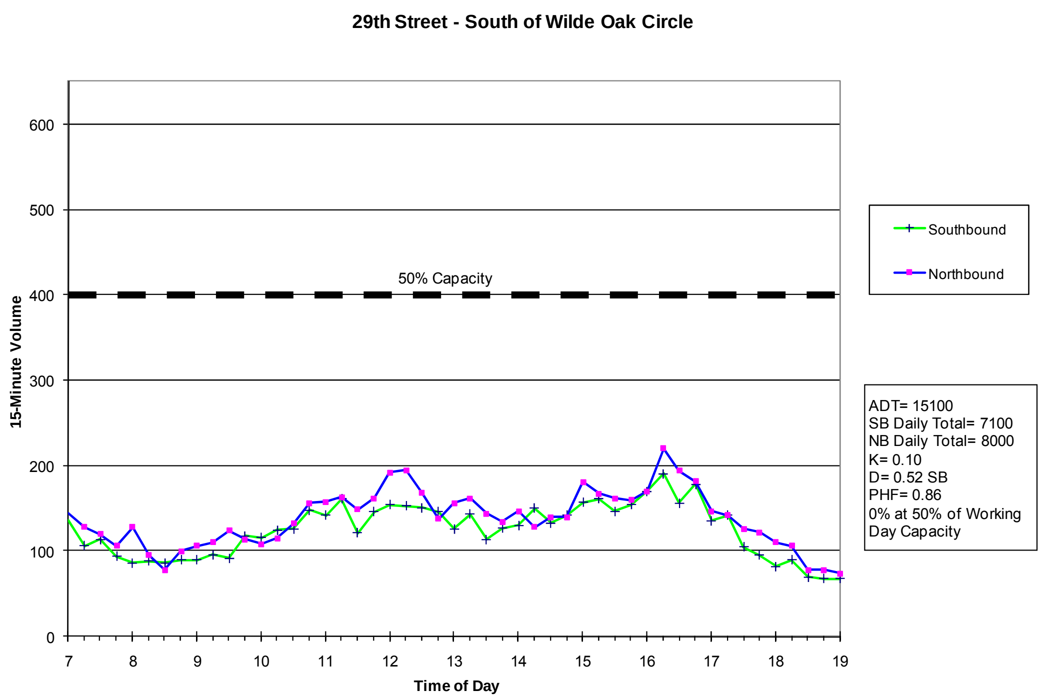


Figure B-40. 29th Street - South of Wilde Oak Circle, Volume and Capacity Characteristics.

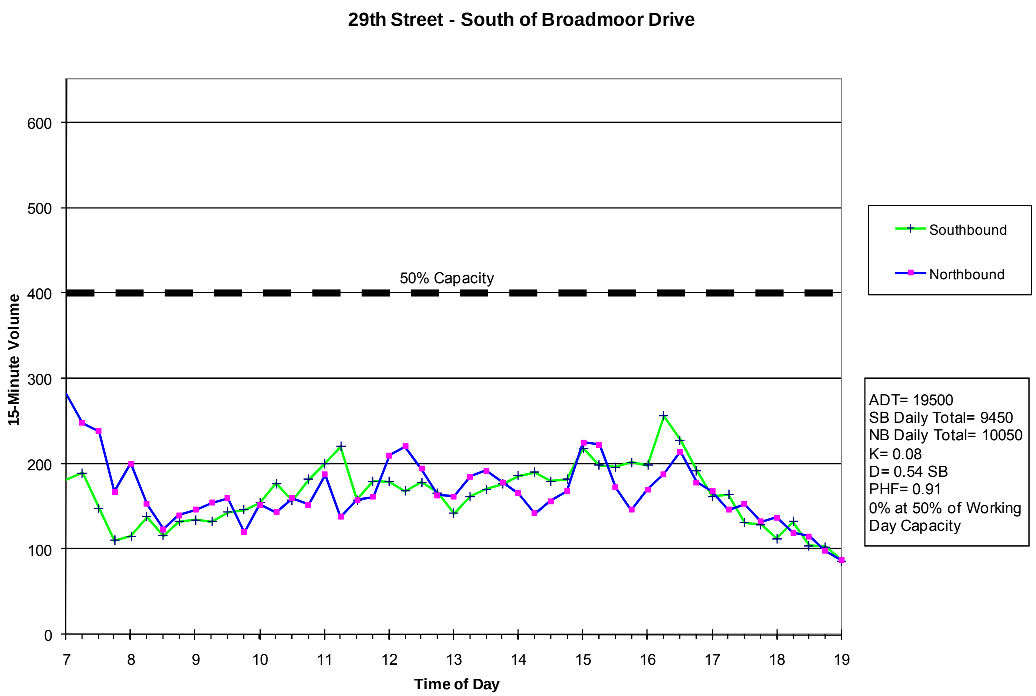


Figure B-41. 29th Street - South of Broadmoor Drive, Volume and Capacity Characteristics.

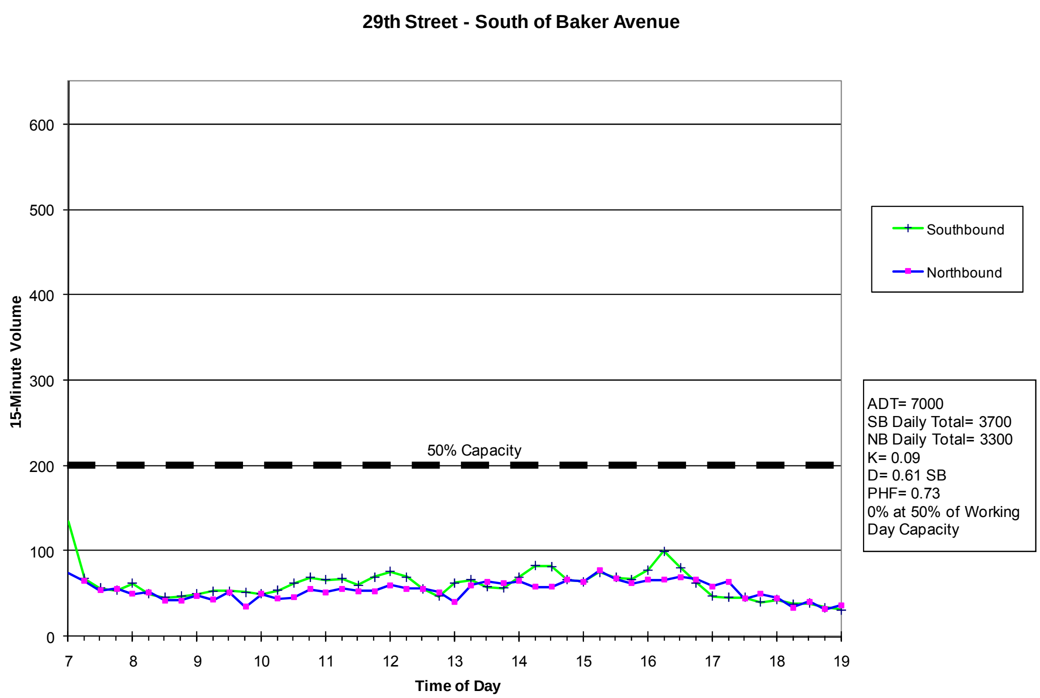


Figure B-42. 29th Street - South of Baker Avenue, Volume and Capacity Characteristics.

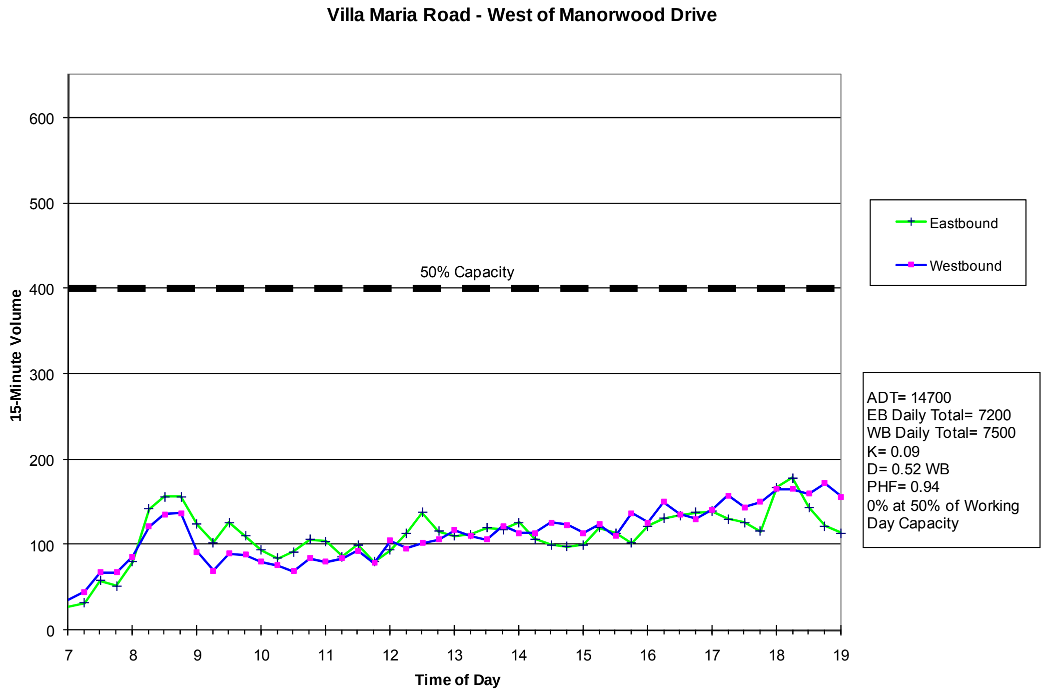


Figure B-43. Villa Maria Road - West of Manorwood Drive, Volume and Capacity Characteristics.

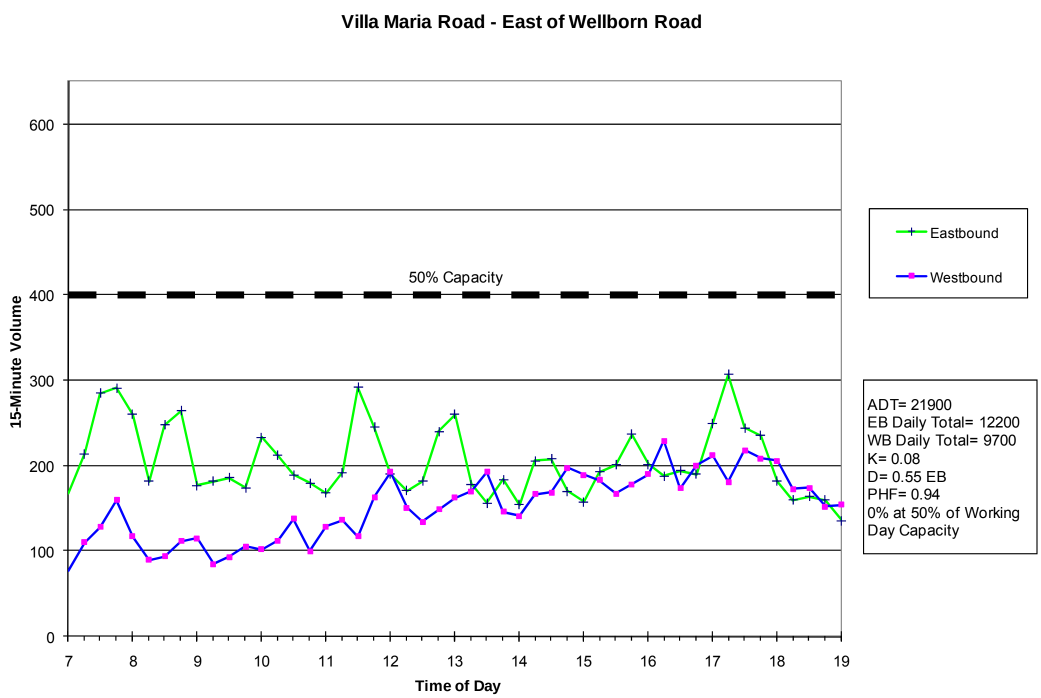


Figure B-44. Villa Maria Road - East of Wellborn Road, Volume and Capacity Characteristics.

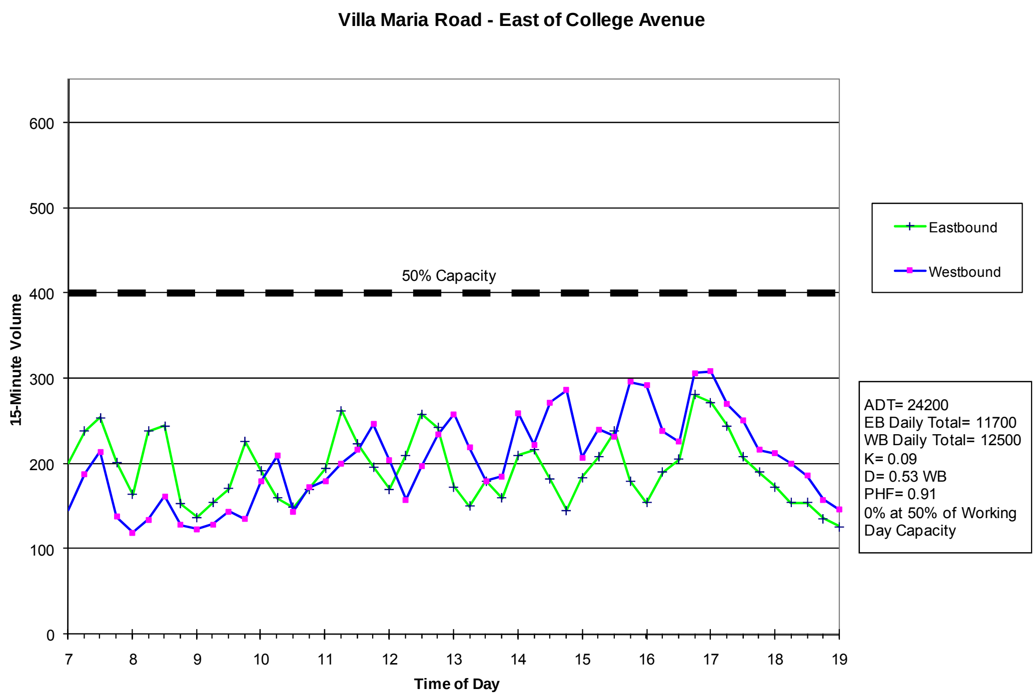


Figure B-45. Villa Maria Road - East of College Avenue, Volume and Capacity Characteristics.

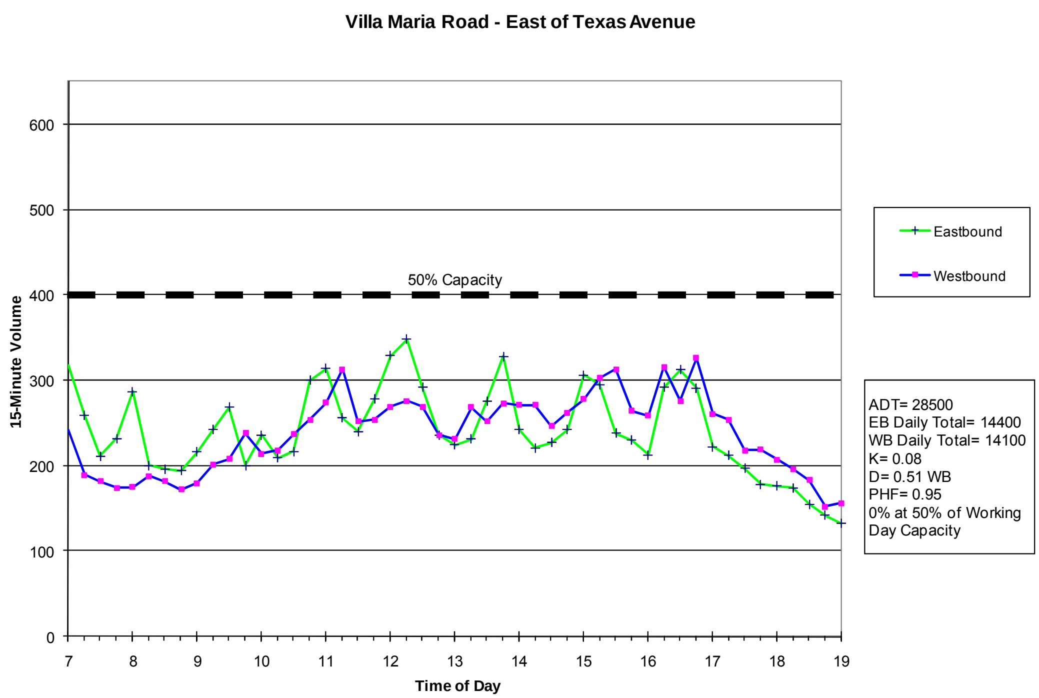


Figure B-46. Villa Maria Road - East of Texas Avenue, Volume and Capacity Characteristics.

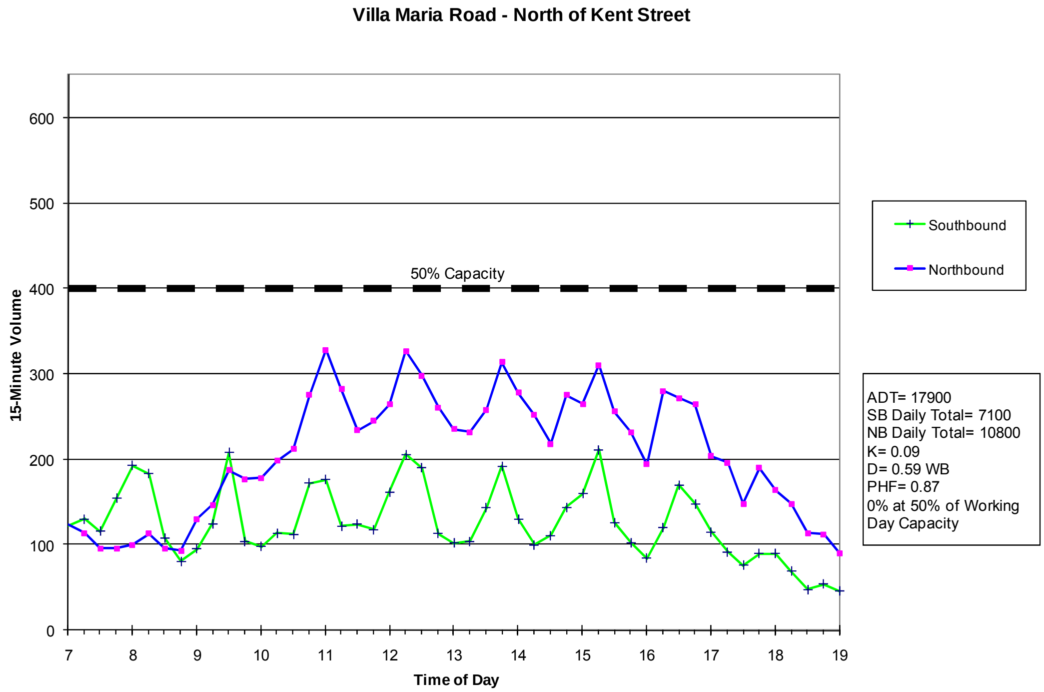


Figure B-47. Villa Maria Road - North of Kent Street, Volume and Capacity Characteristics.

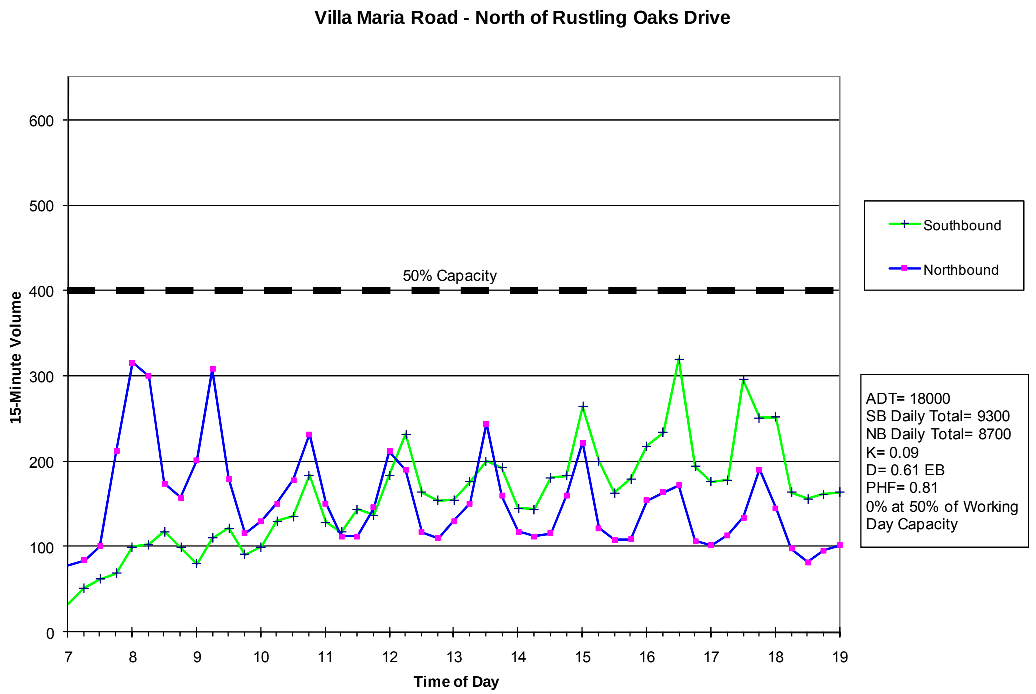


Figure B-48. Villa Maria Road - North of Rustling Oaks Drive, Volume and Capacity Characteristics.

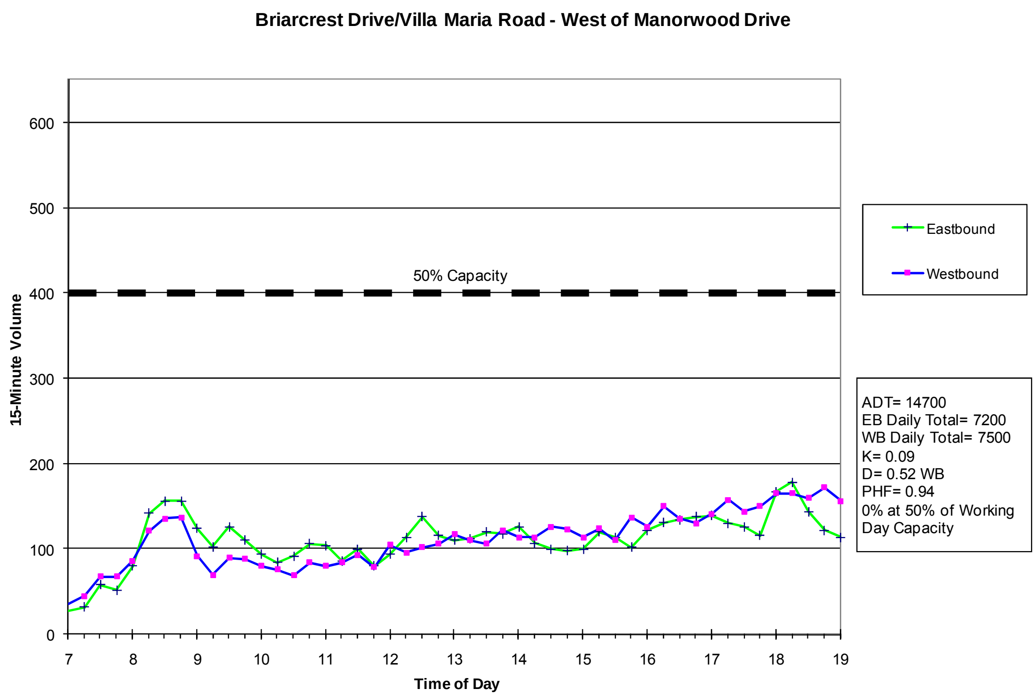


Figure B-49. Briarcrest Drive/Villa Maria Road - West of Manorwood Drive, Volume and Capacity Characteristics.

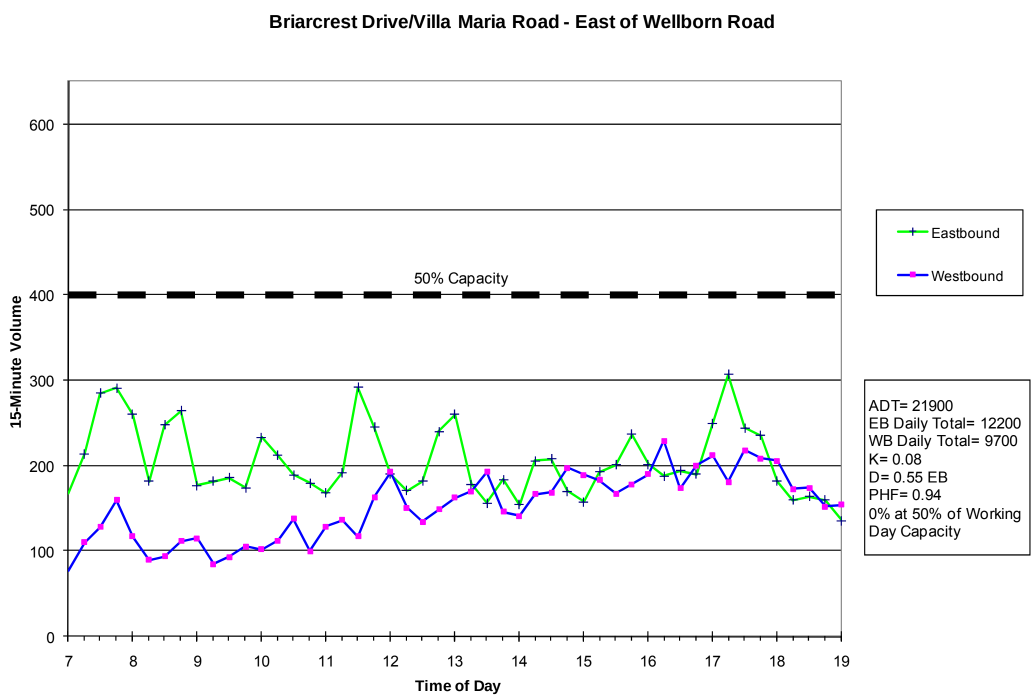


Figure B-50. Briarcrest Drive/Villa Maria Road - East of Wellborn Road, Volume and Capacity Characteristics.

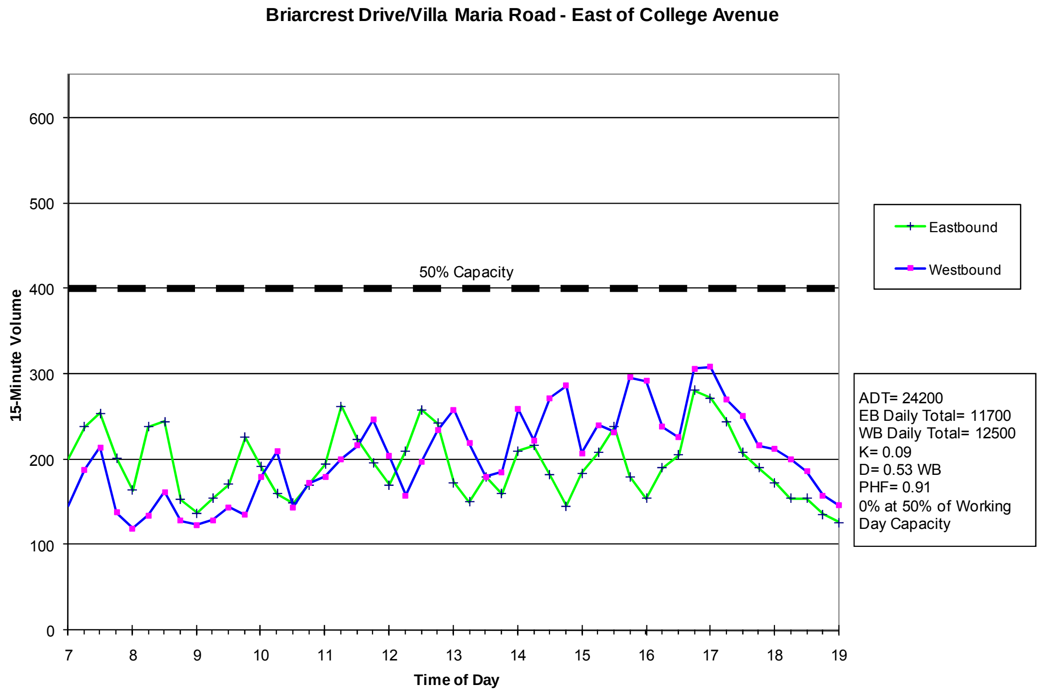


Figure B-51. Briarcrest Drive/Villa Maria Road - East of College Avenue, Volume and Capacity Characteristics.

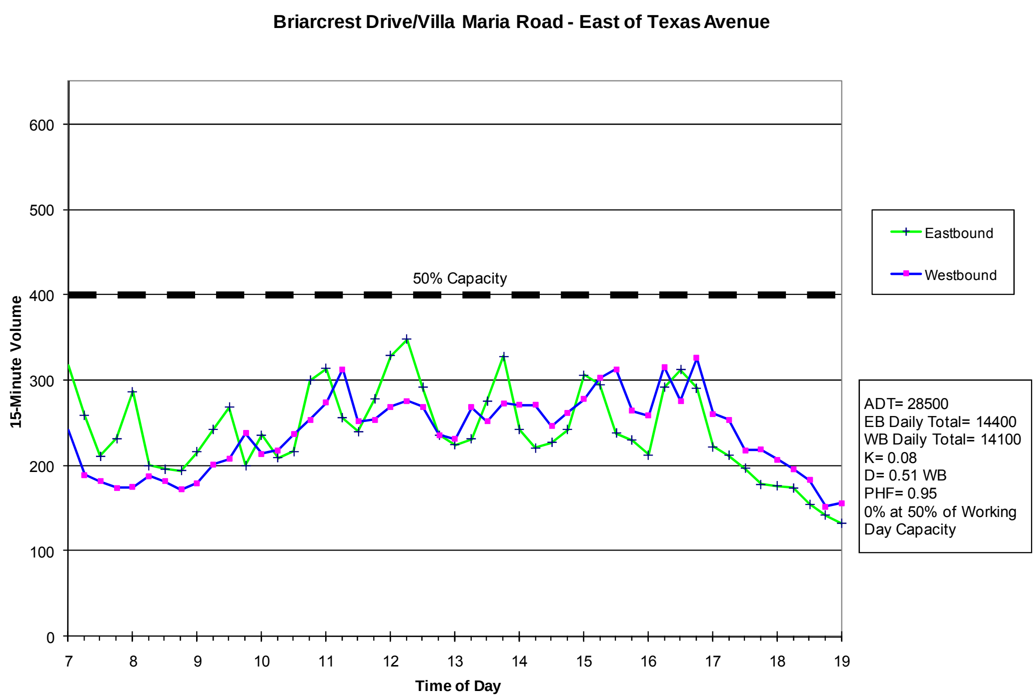


Figure B-52. Briarcrest Drive/Villa Maria Road - East of Texas Avenue, Volume and Capacity Characteristics.

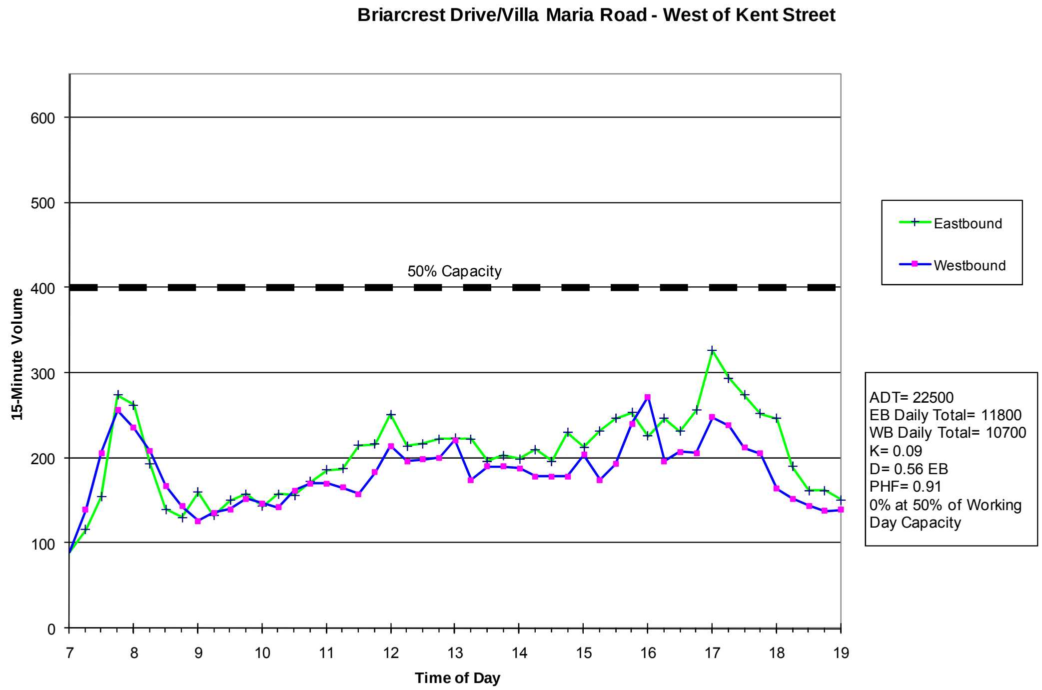


Figure B-53. Briarcrest Drive/Villa Maria Road - West of Kent Street, Volume and Capacity Characteristics.

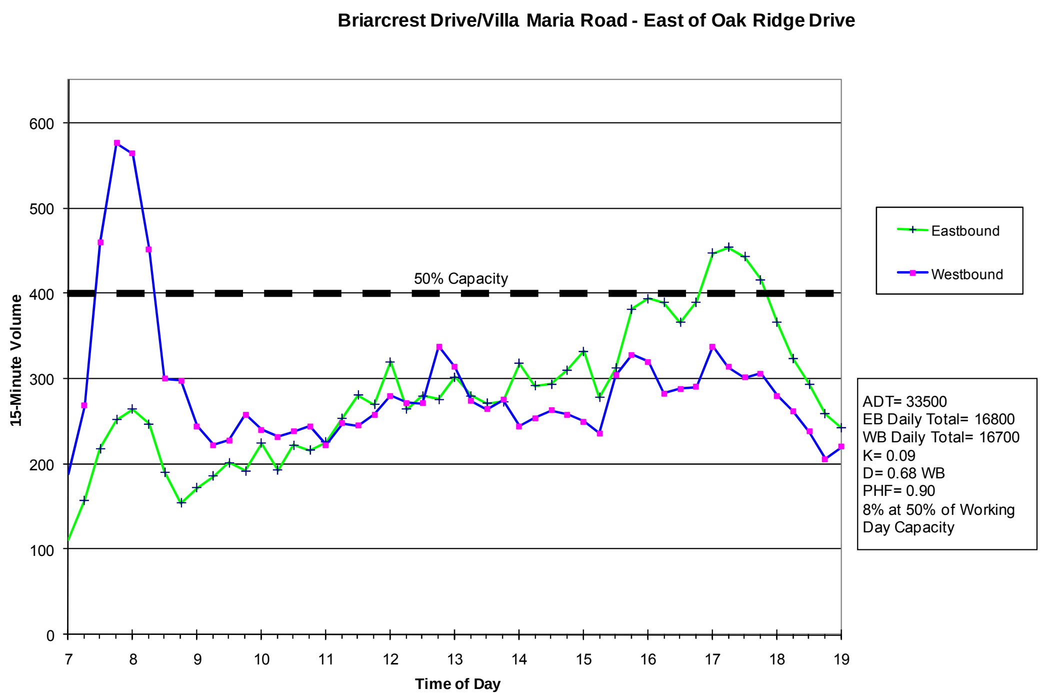


Figure B-54. Briarcrest Drive/Villa Maria Road - East of Oak Ridge Drive, Volume and Capacity Characteristics.

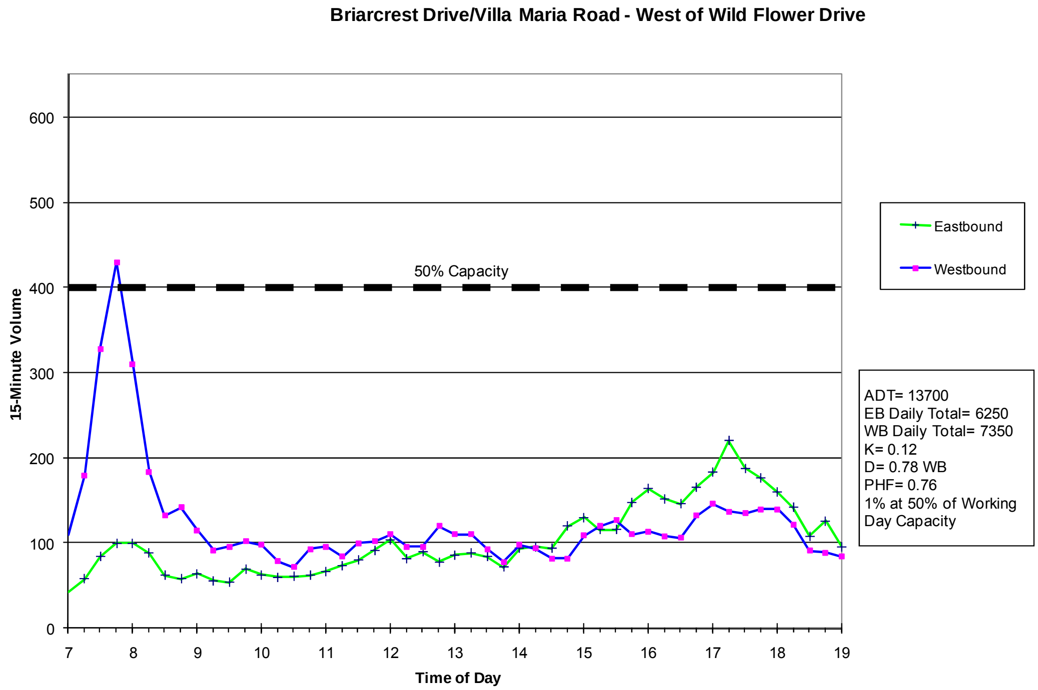


Figure B-55. Briarcrest Drive/Villa Maria Road -West of Wild Flower Drive, Volume and Capacity Characteristics.

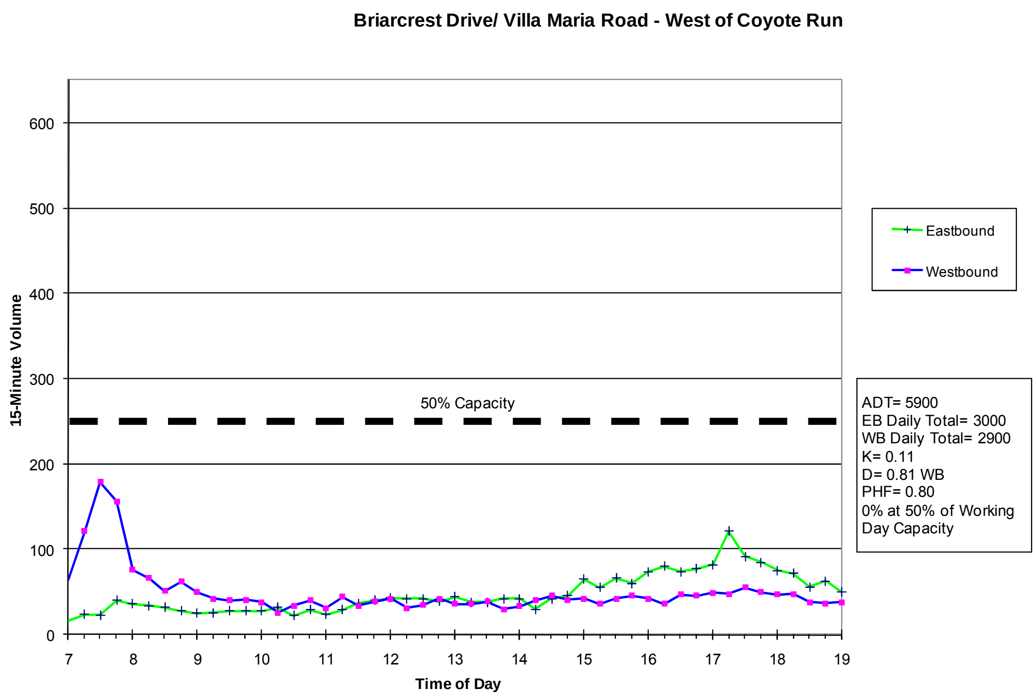


Figure B-56. Briarcrest Drive/Villa Maria Road -West of Coyote Run, Volume and Capacity Characteristics.

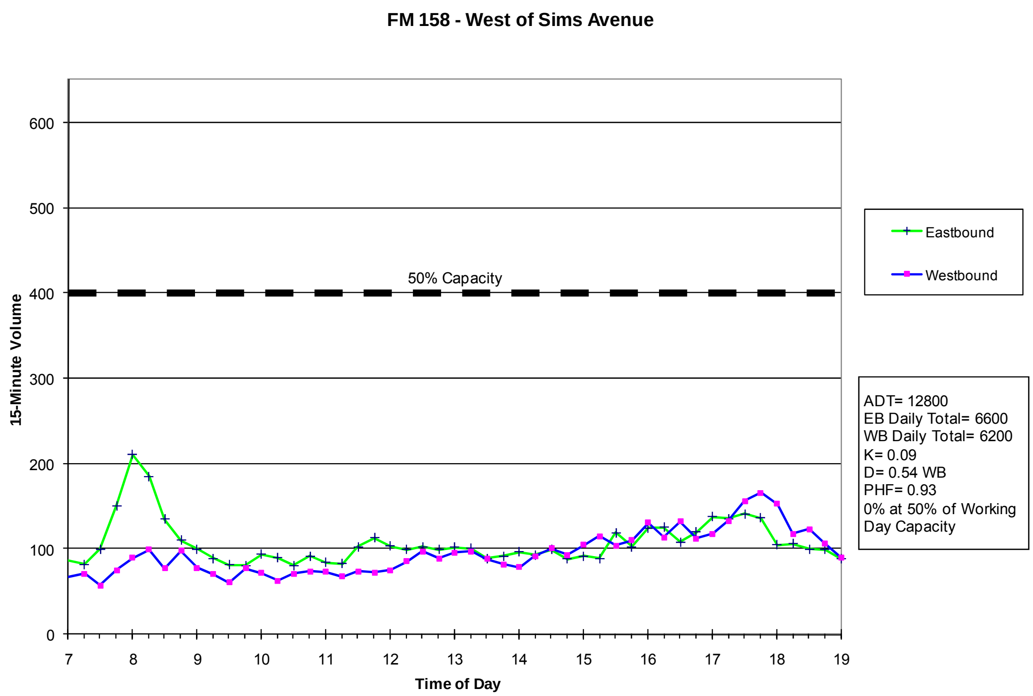


Figure B-57. FM 158 - West of Sims Avenue, Volume and Capacity Characteristics.

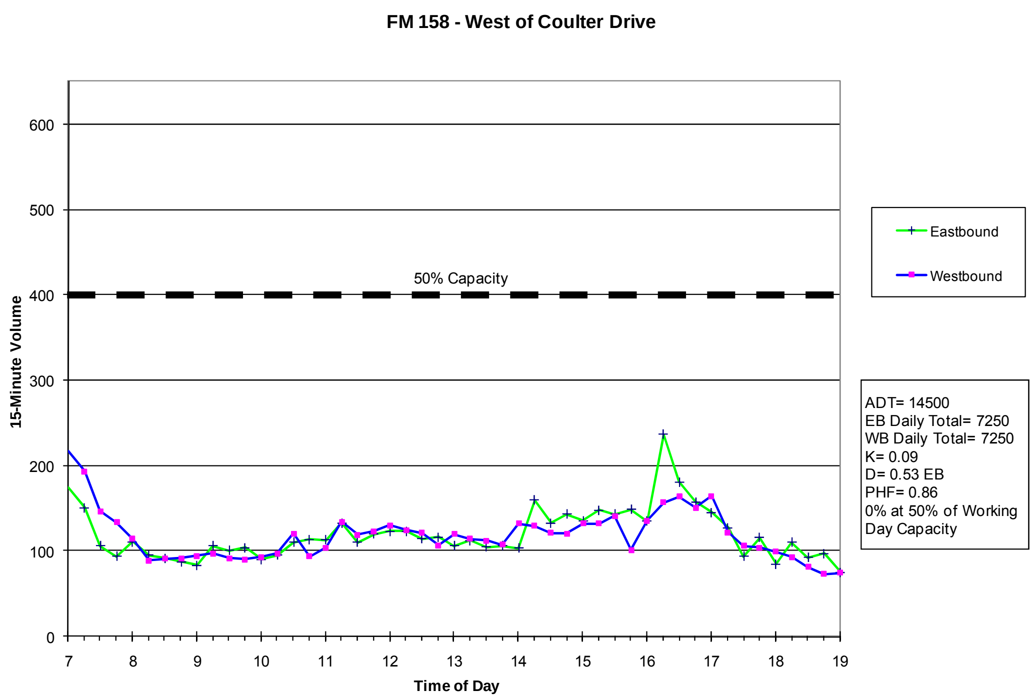


Figure B-58. FM 158 - West of Coulter Drive, Volume and Capacity Characteristics.

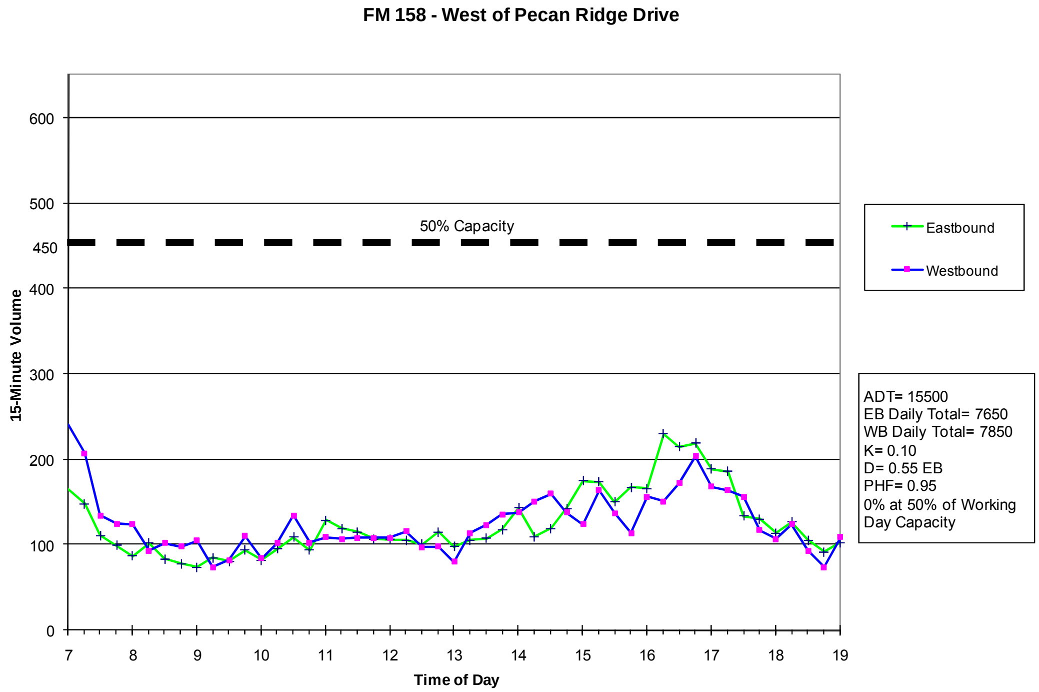


Figure B-59. FM 158 - West of Pecan Ridge Drive, Volume and Capacity Characteristics.

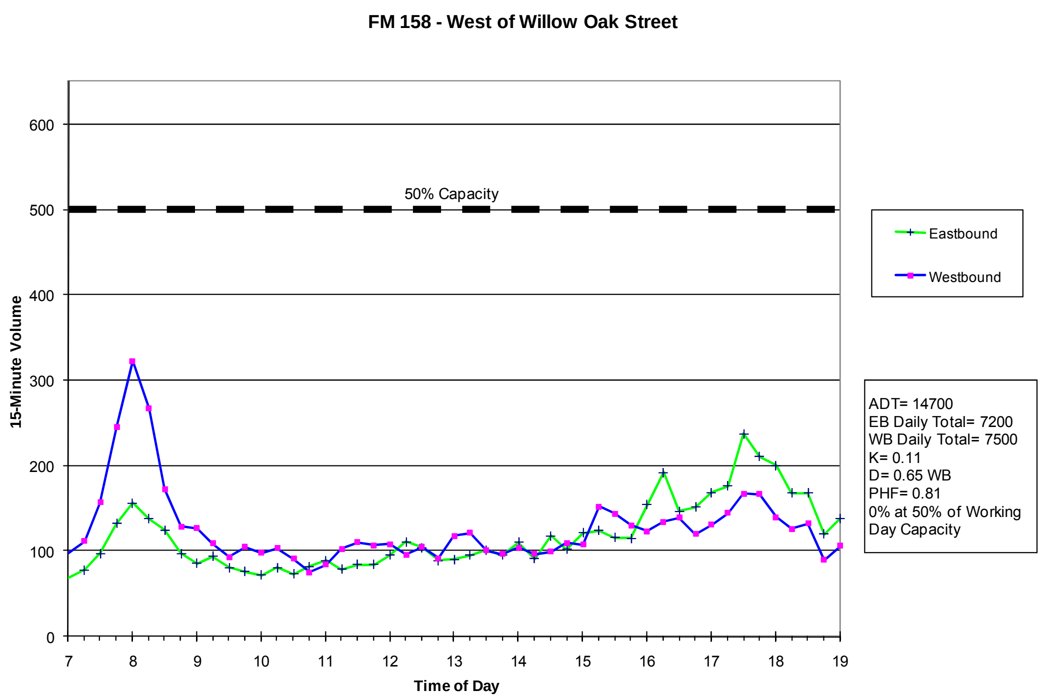


Figure B-60. FM 158 - West of Willow Oak Street, Volume and Capacity Characteristics.

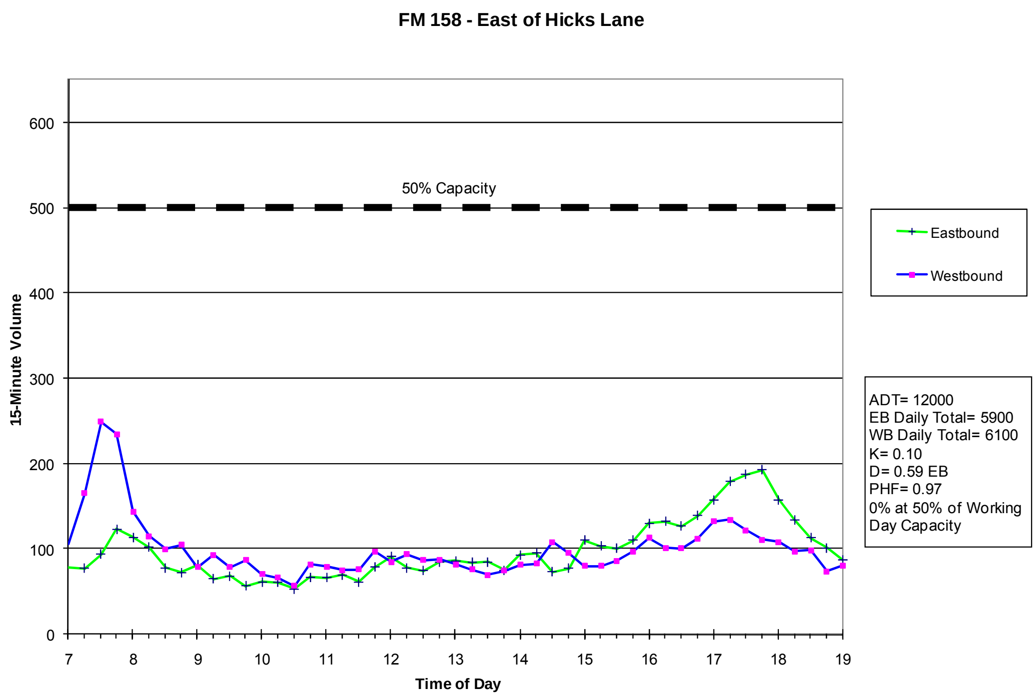


Figure B-61. FM 158 - East of Hicks Lane, Volume and Capacity Characteristics.

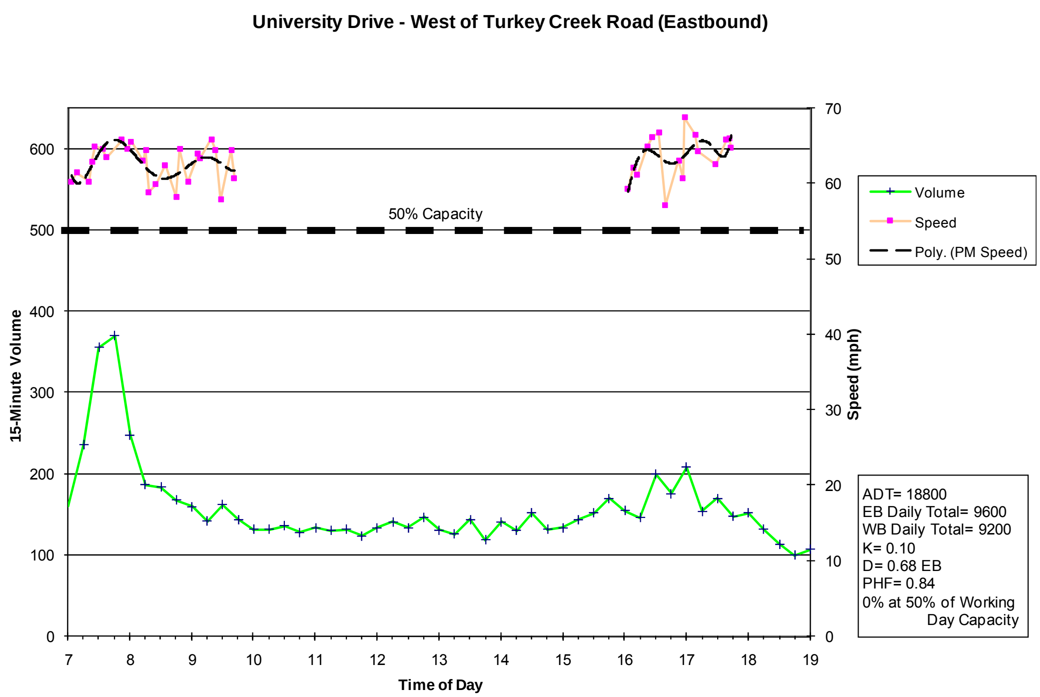


Figure B-62. University Drive - West of Turkey Creek Road (Eastbound), Volume and Speed Characteristics.

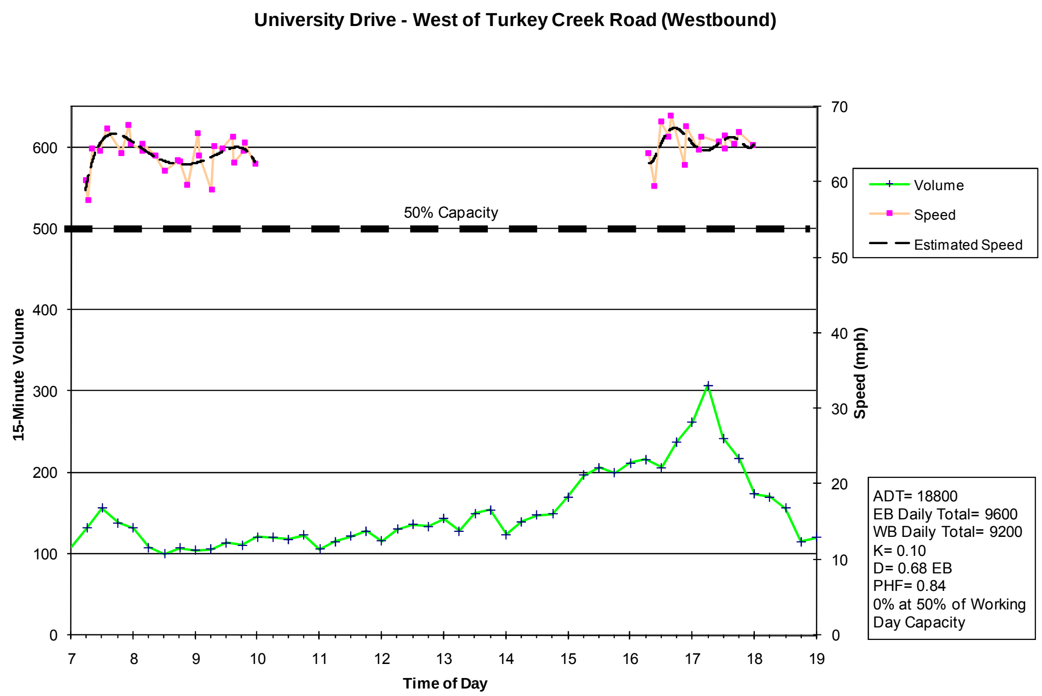


Figure B-63. University Drive - West of Turkey Creek Road (Westbound), Volume and Speed Characteristics.

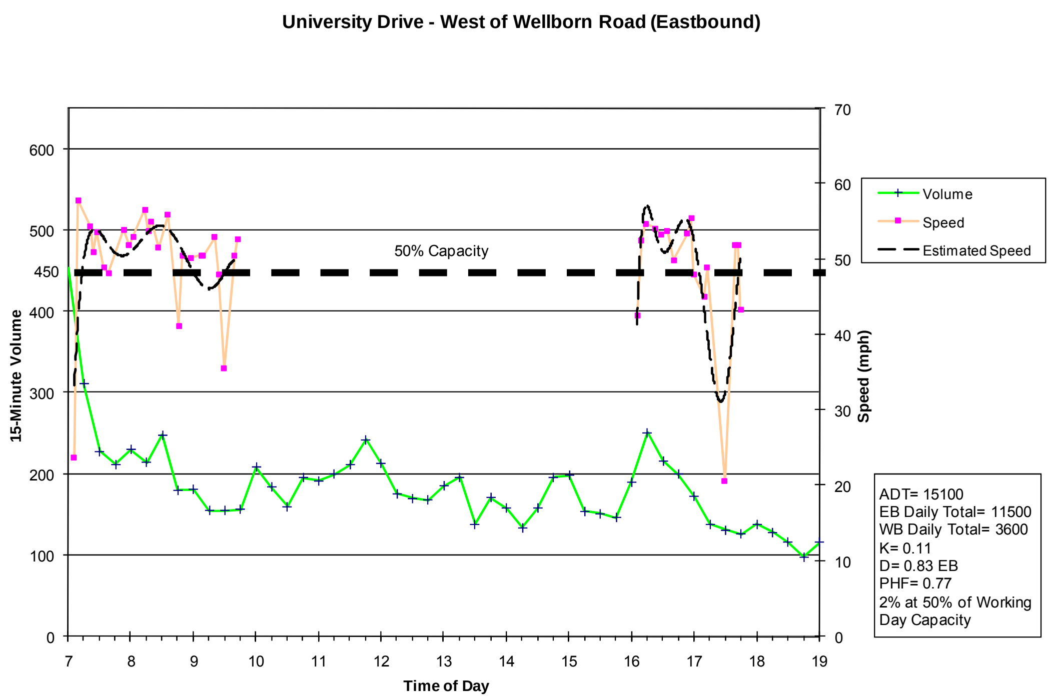


Figure B-64. University Drive - West of Wellborn Road (Eastbound), Volume and Speed Characteristics.

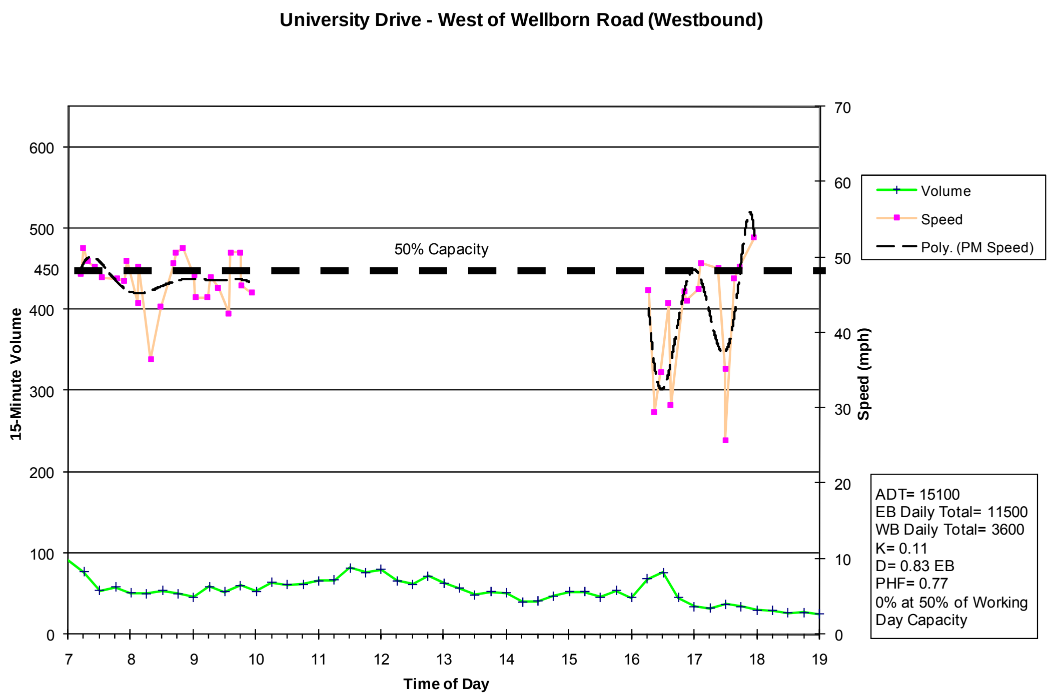


Figure B-65. University Drive - West of Wellborn Road (Westbound), Volume and Speed Characteristics.

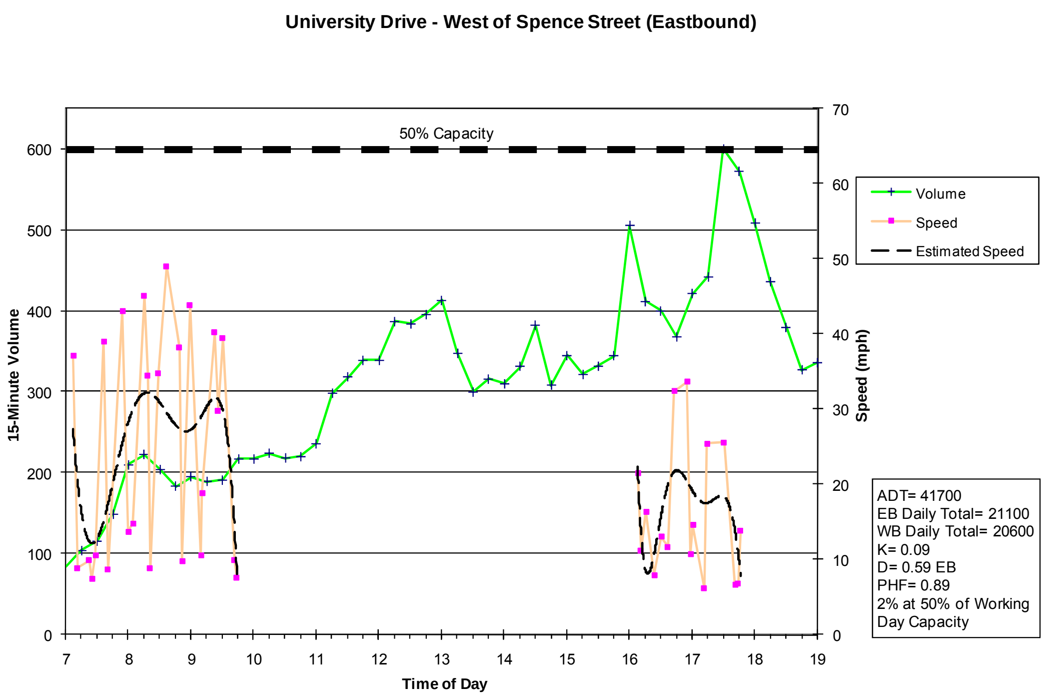


Figure B-66. University Drive - West of Spence Street (Eastbound), Volume and Speed Characteristics.

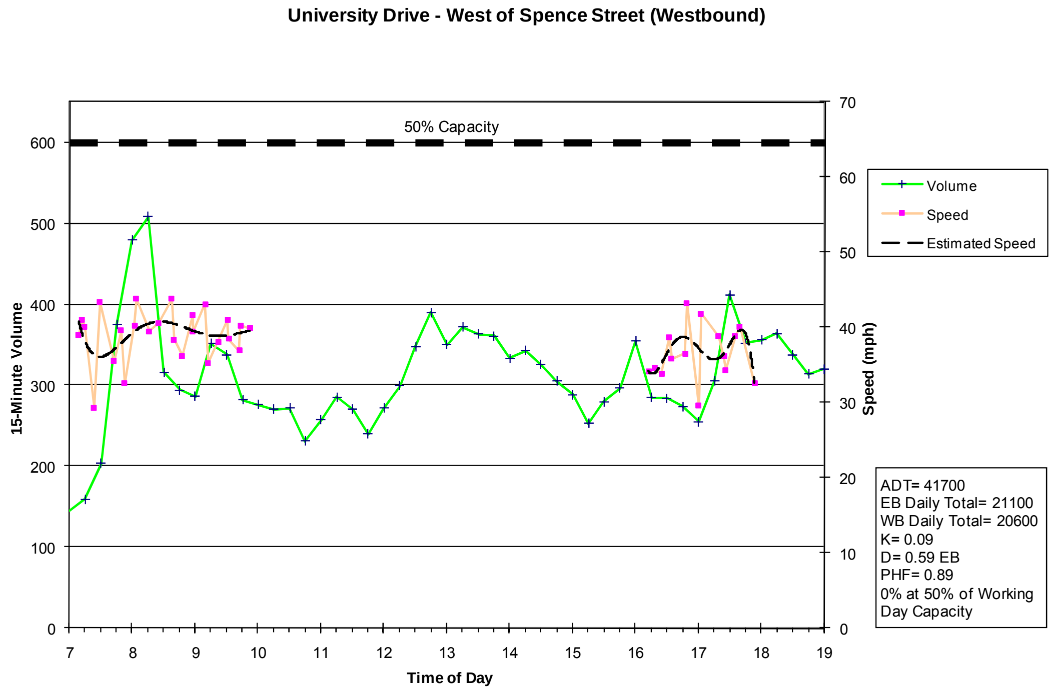


Figure B-67. University Drive - West of Spence Street (Westbound), Volume and Speed Characteristics.

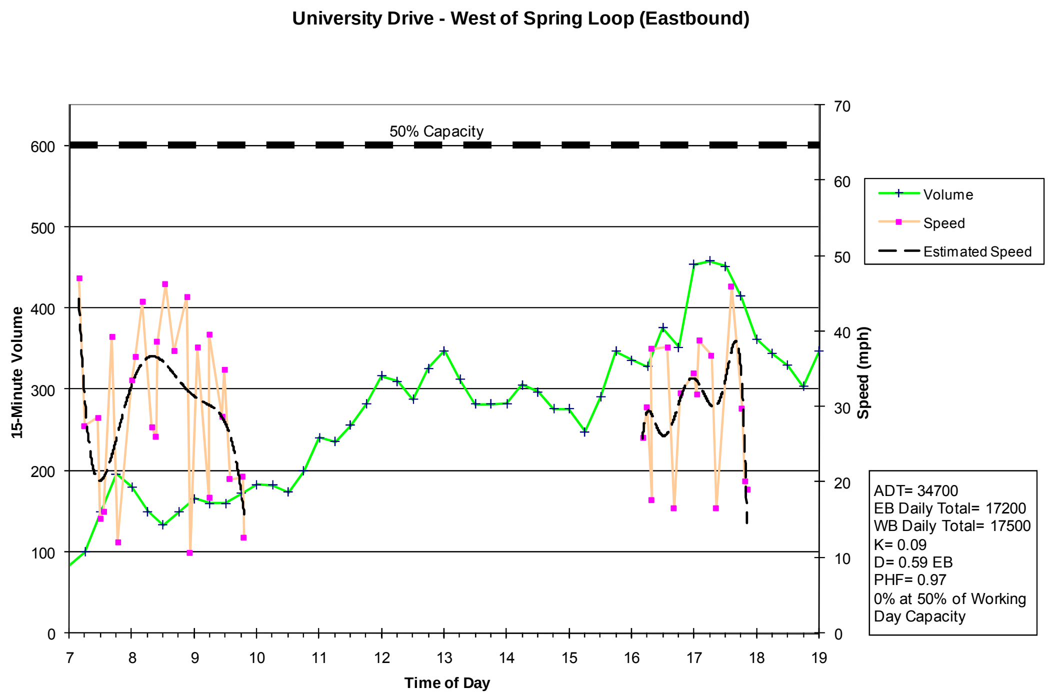


Figure B-68. University Drive - West of Spring Loop (Eastbound), Volume and Speed Characteristics.

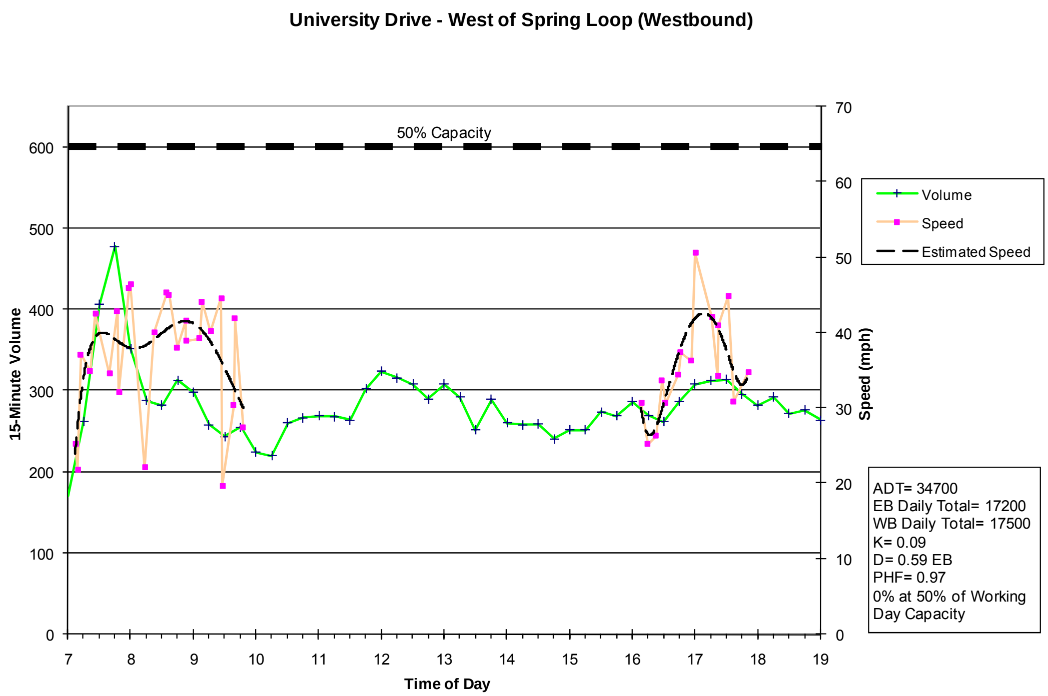


Figure B-69. University Drive - West of Spring Loop (Westbound), Volume and Speed Characteristics.

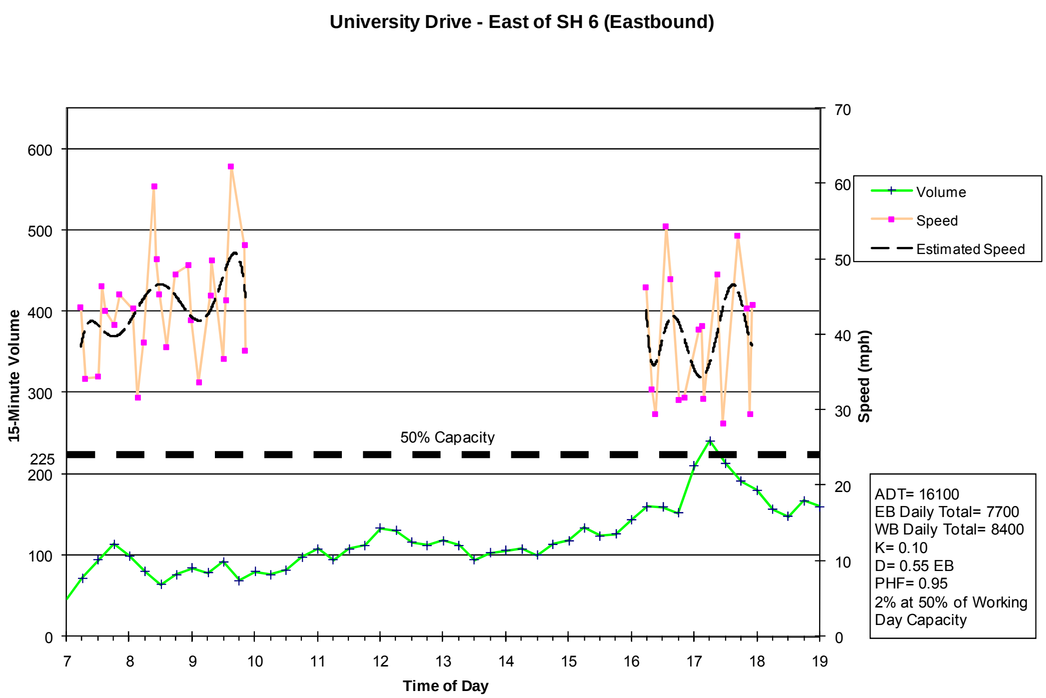


Figure B-70. University Drive - East of SH 6 (Eastbound), Volume and Speed Characteristics.

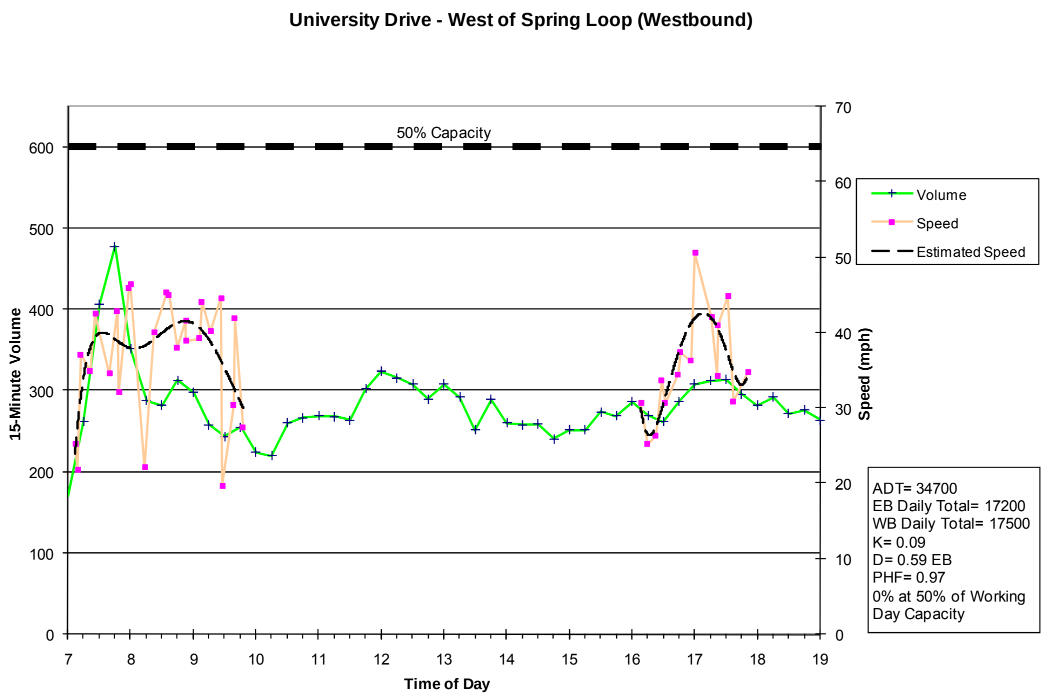


Figure B-71. University Drive - East of SH 6 (Westbound), Volume and Speed Characteristics.

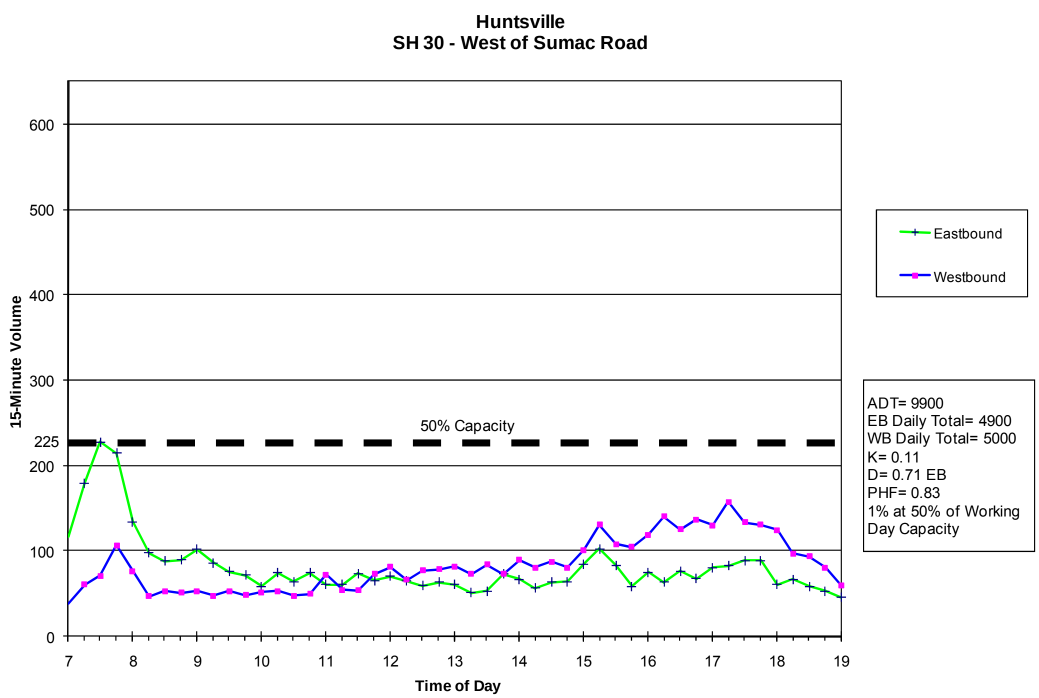


Figure B-72. SH 30 (Huntsville) - West of Sumac Road, Volume and Capacity Characteristics.

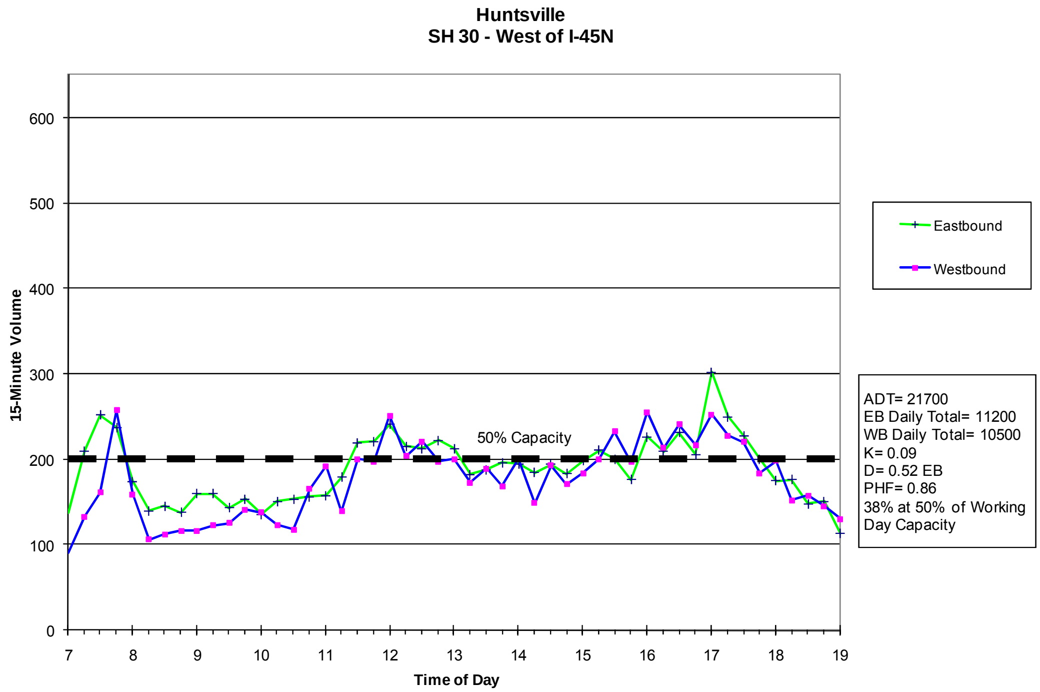


Figure B-73. SH 30 (Huntsville) - West of I-45 N, Volume and Capacity Characteristics.

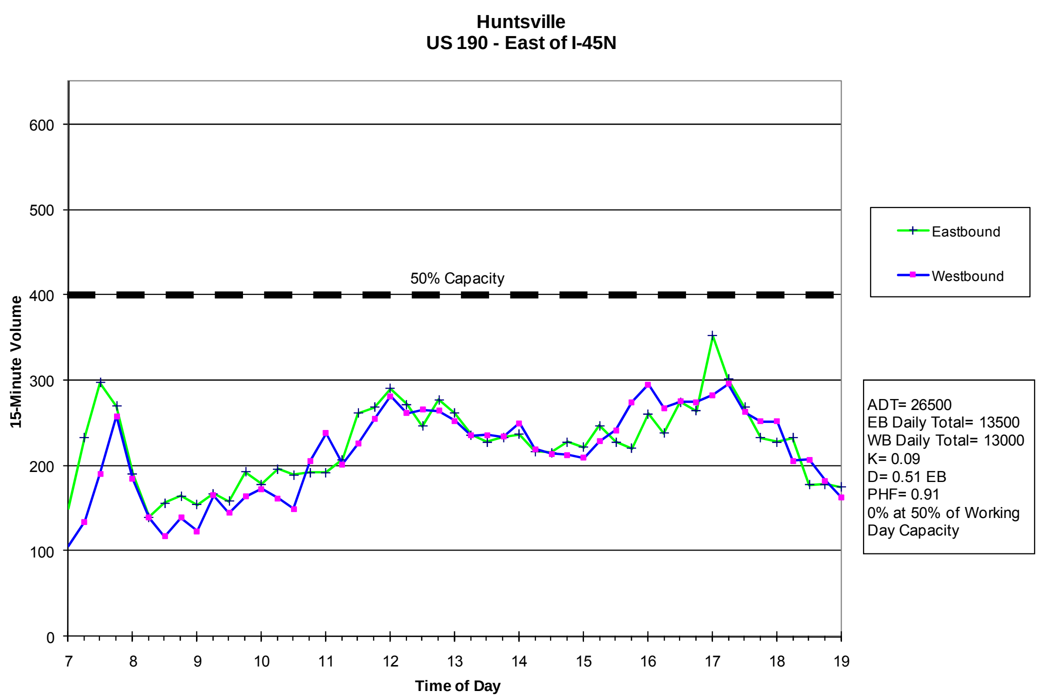


Figure B-74. SH 190 (Huntsville) - East of I-45 N, Volume and Capacity Characteristics.

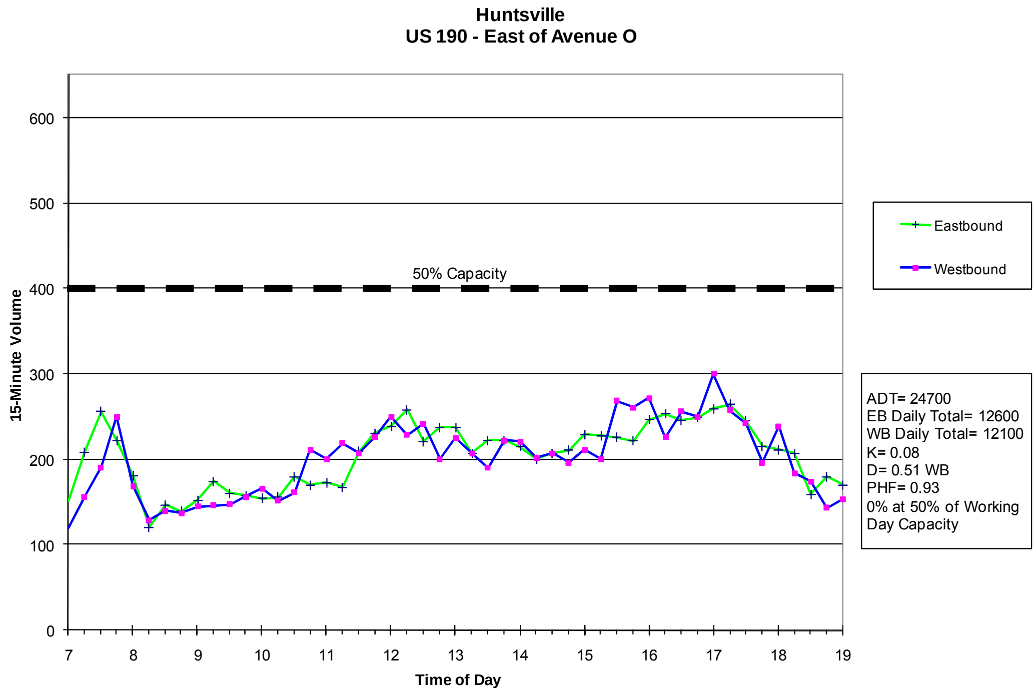


Figure B-75. SH 190 (Huntsville) - East of Avenue O, Volume and Capacity Characteristics.

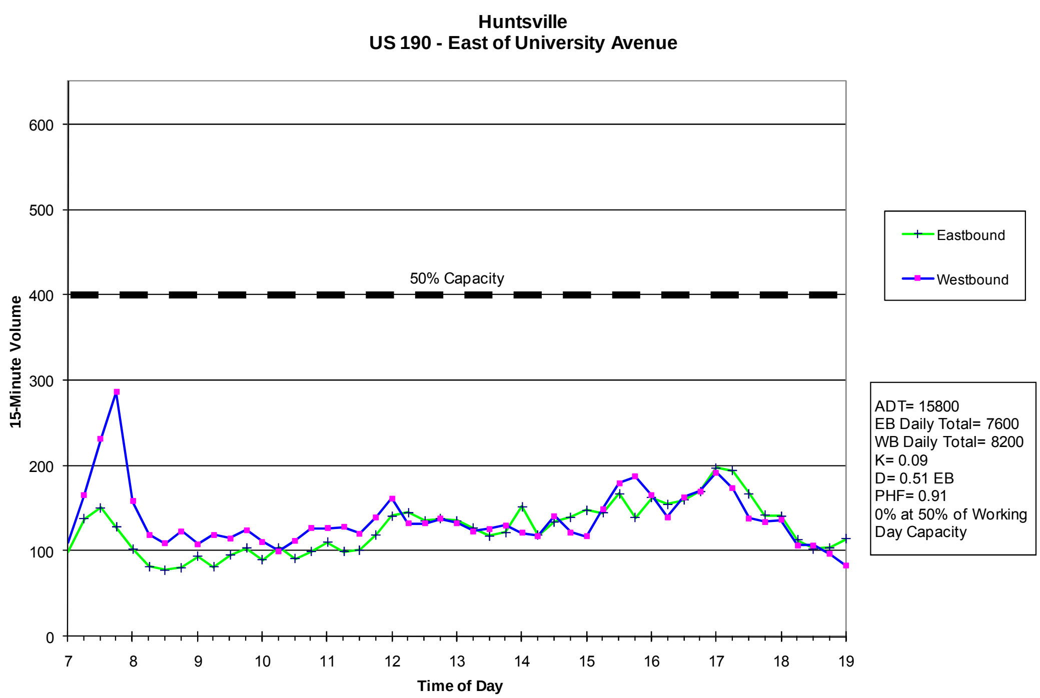


Figure B-76. SH 190 (Huntsville) - East of University Avenue, Volume and Capacity Characteristics.

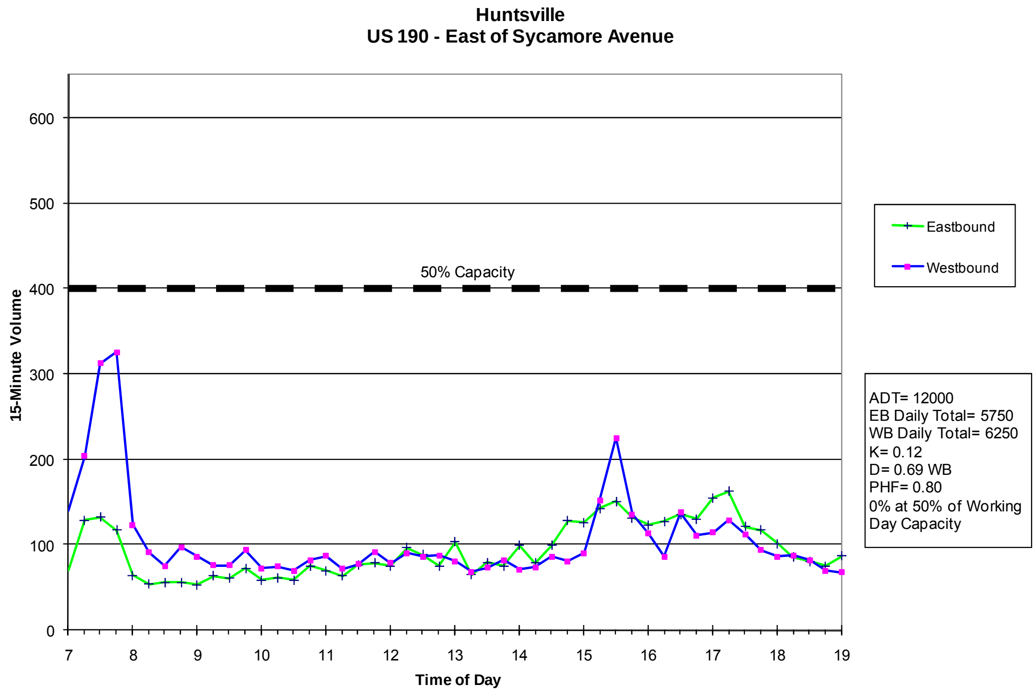


Figure B-77. SH 190 (Huntsville) - East of Sycamore Avenue, Volume and Capacity Characteristics.

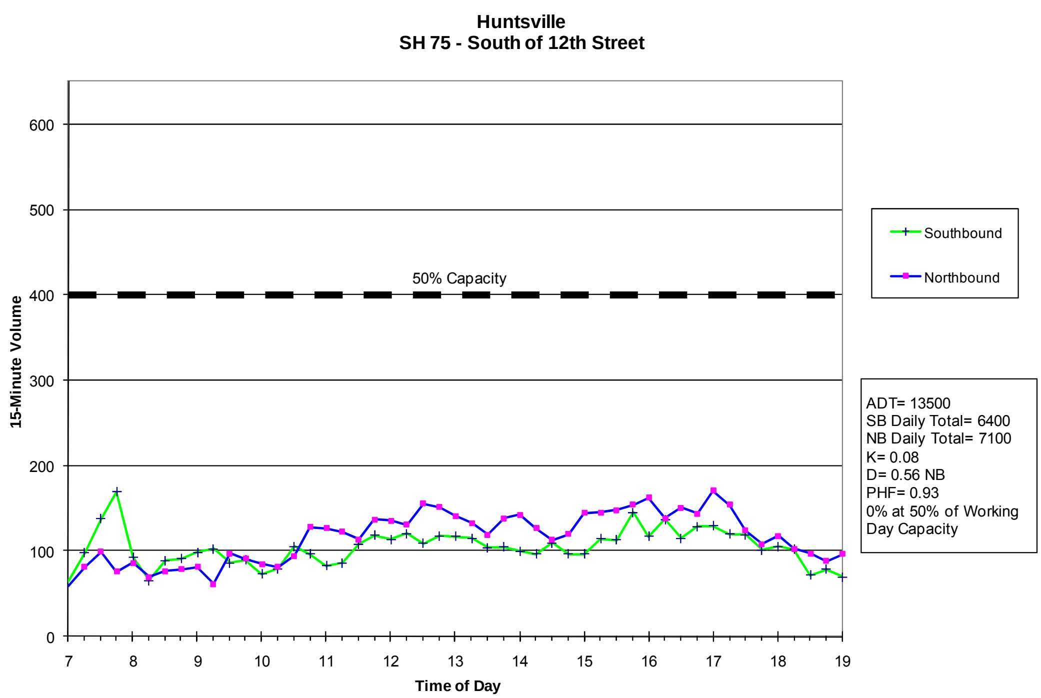


Figure B-78. SH 75 (Huntsville) - South of 12th Street, Volume and Capacity Characteristics.

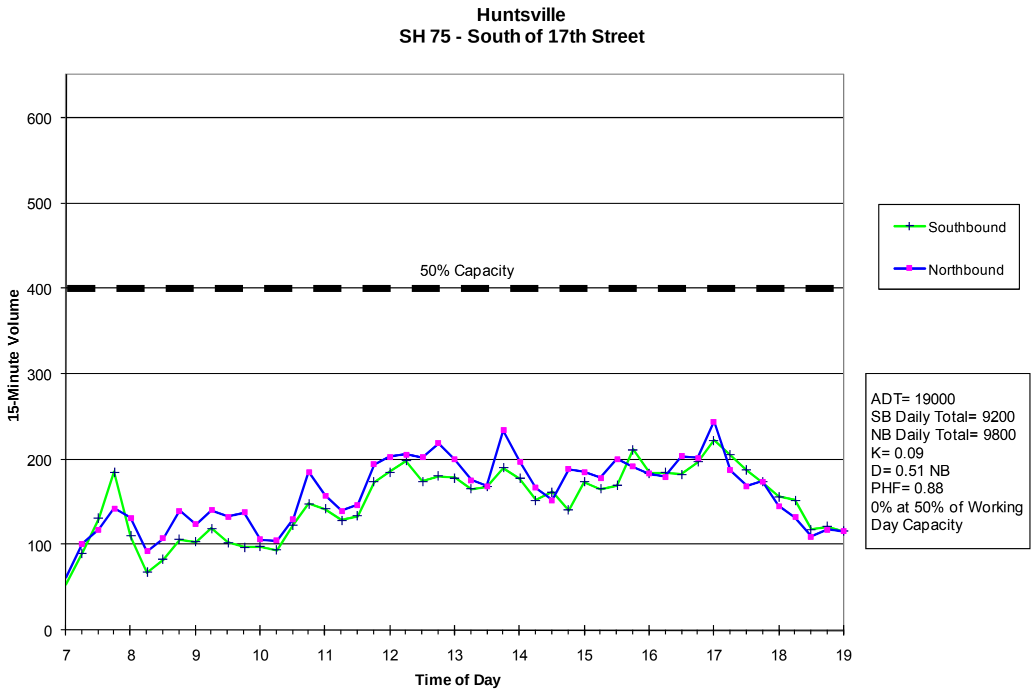


Figure B-79. SH 75 (Huntsville) - South of 17th Street, Volume and Capacity Characteristics.

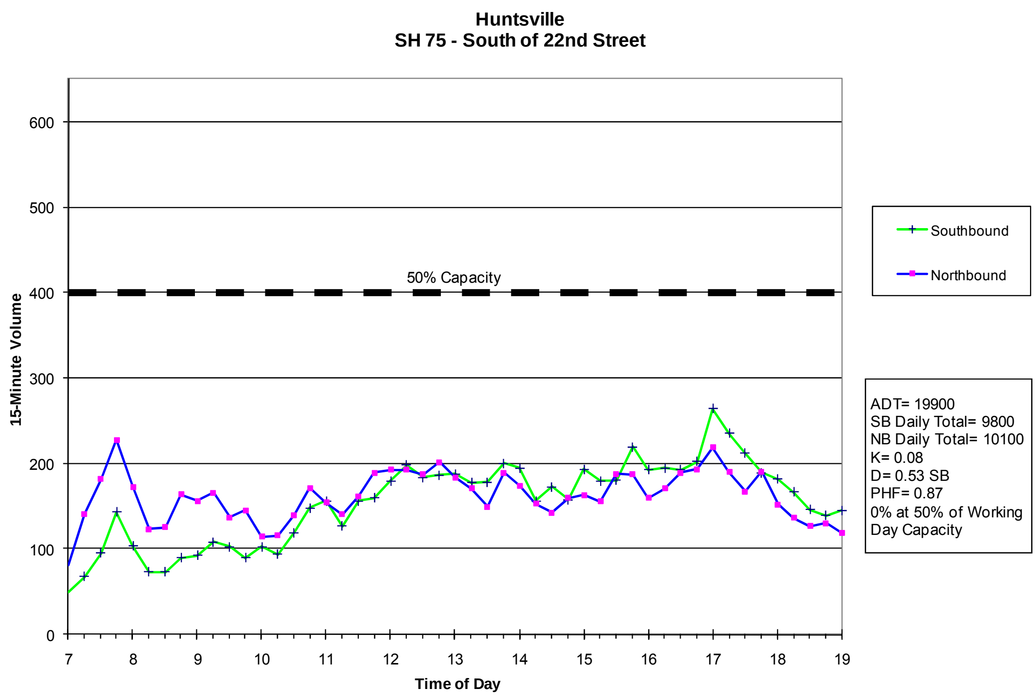


Figure B-80. SH 75 (Huntsville) - South of 22nd Street, Volume and Capacity Characteristics.

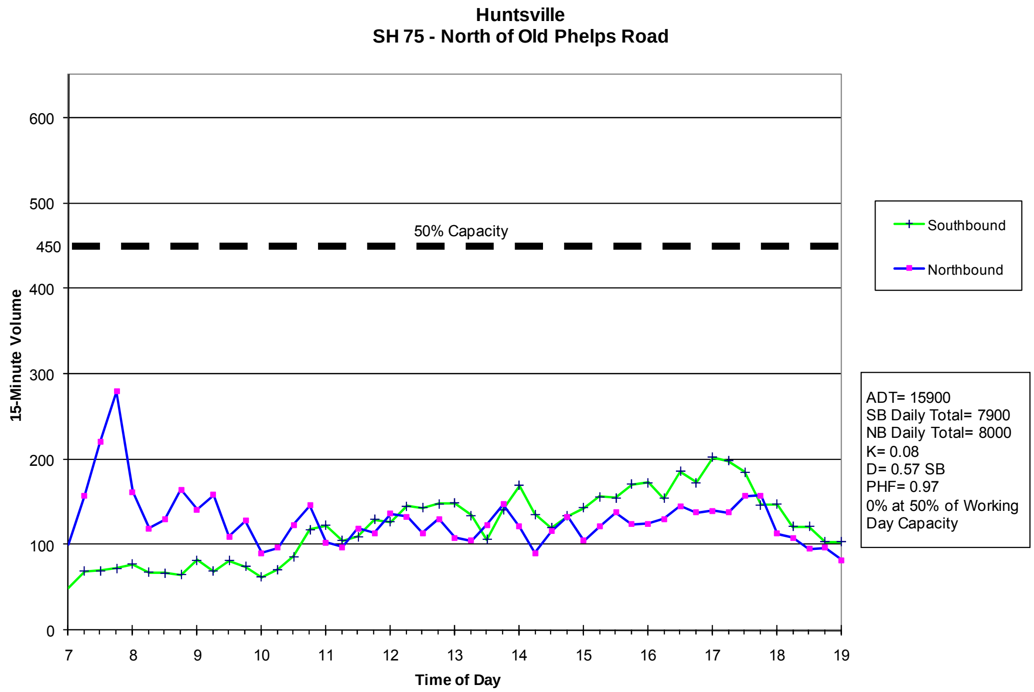


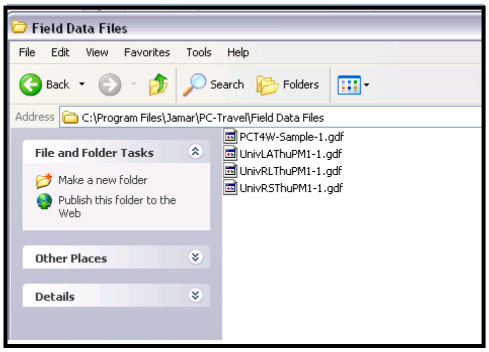
Figure B-81. SH 75 (Huntsville) - North of Old Phelps Road, Volume and Capacity Characteristics.

APPENDIX C

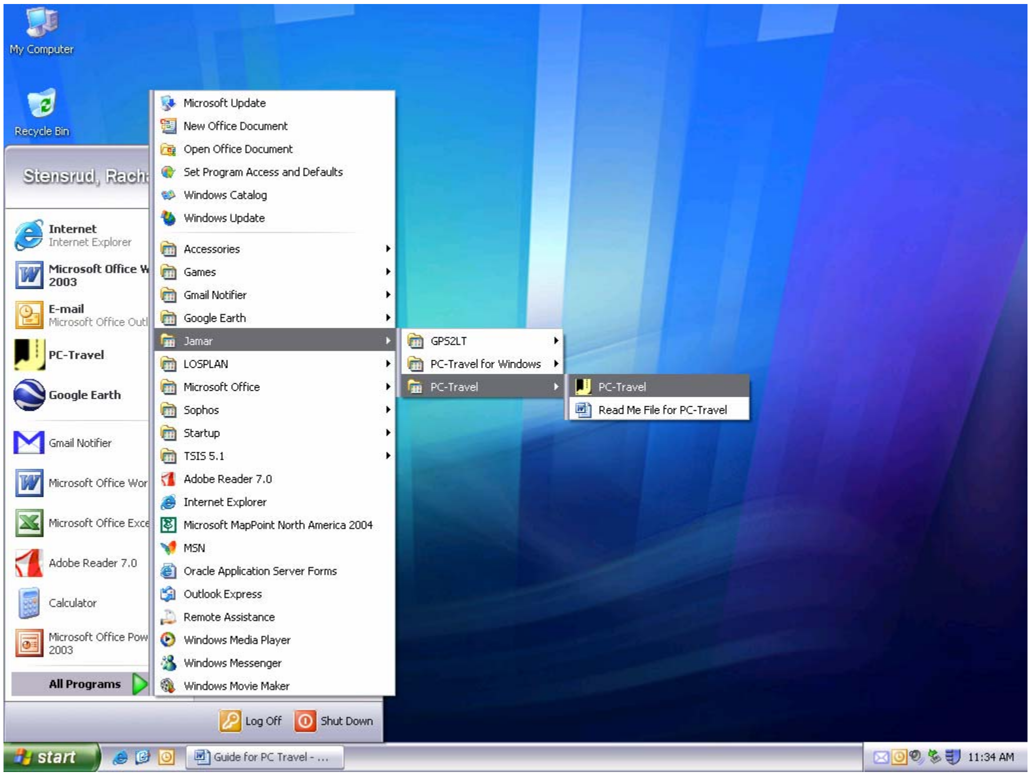
Guide for Travel Time Run Data Reduction Using PC-Travel® and MapPoint®

Guide for Travel Time Run Data Reduction Using PC-Travel® and MapPoint®

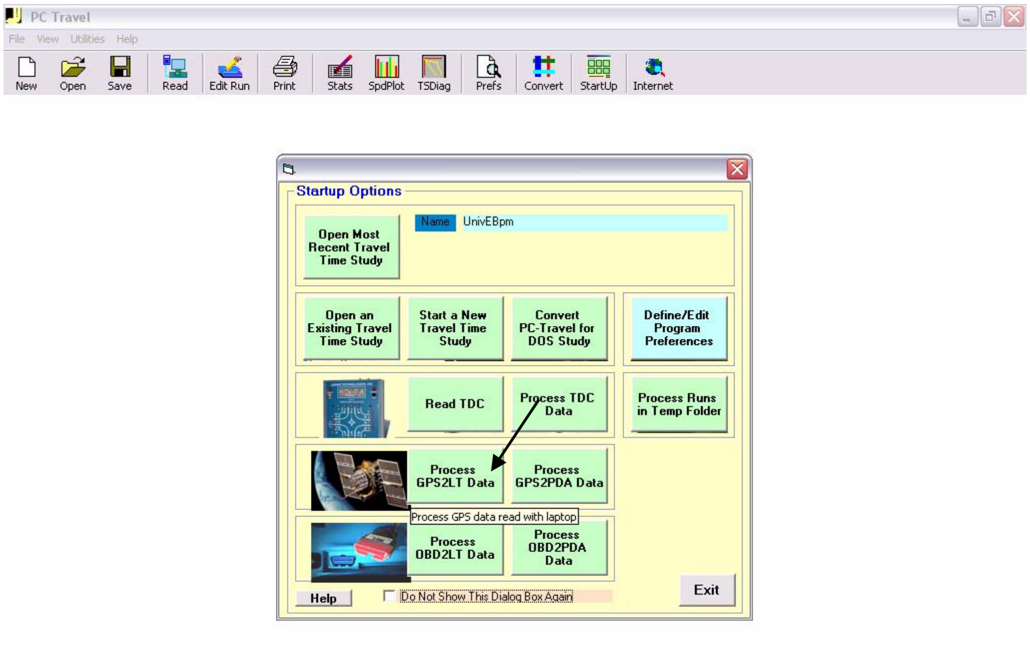
1. COPY all .gdf files in the following directory: C:\Program Files\Jamar\PC-Travel\Field Data Files. They can be stored within separate folders within this directory. (DO NOT move the files to this folder, but make sure to copy them. Once they are altered within PC-Travel, they cannot be restored to their original form.)



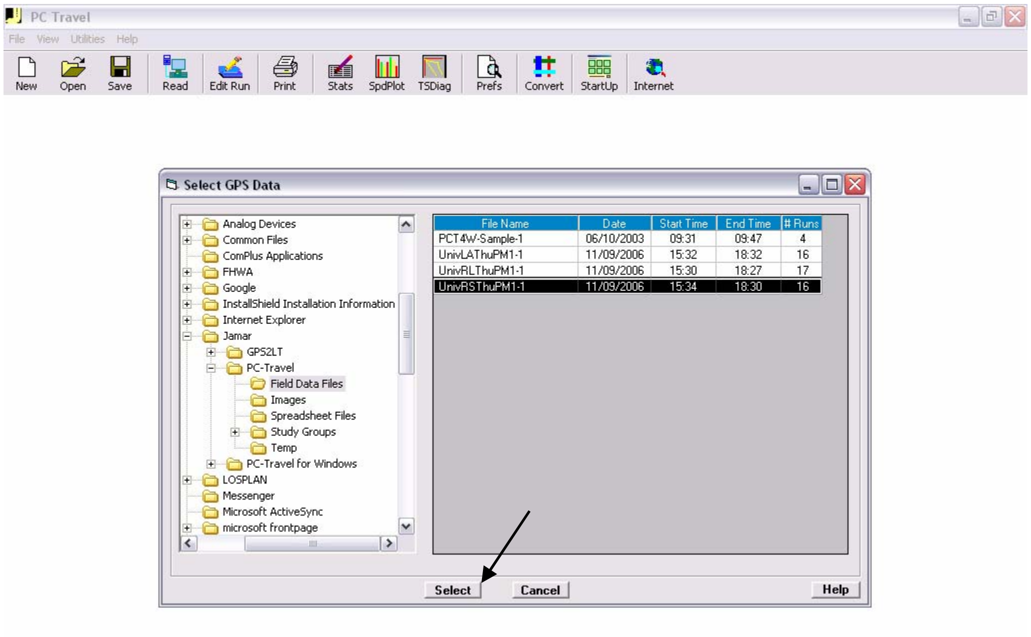
2. Open PC-Travel.



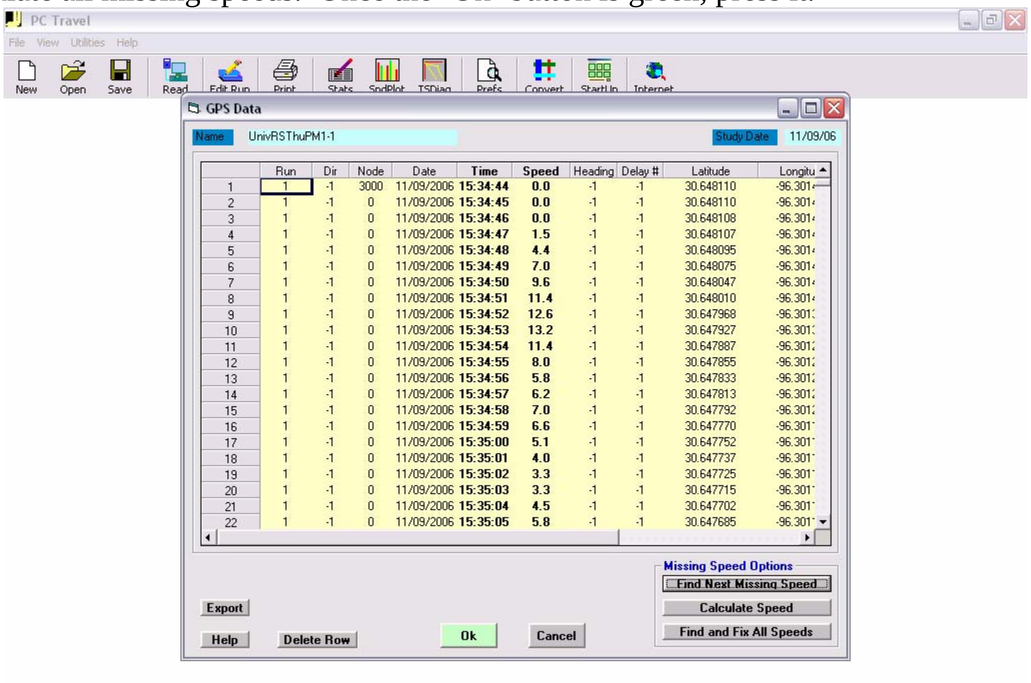
3. Select 'Process GPS2LT Data.'



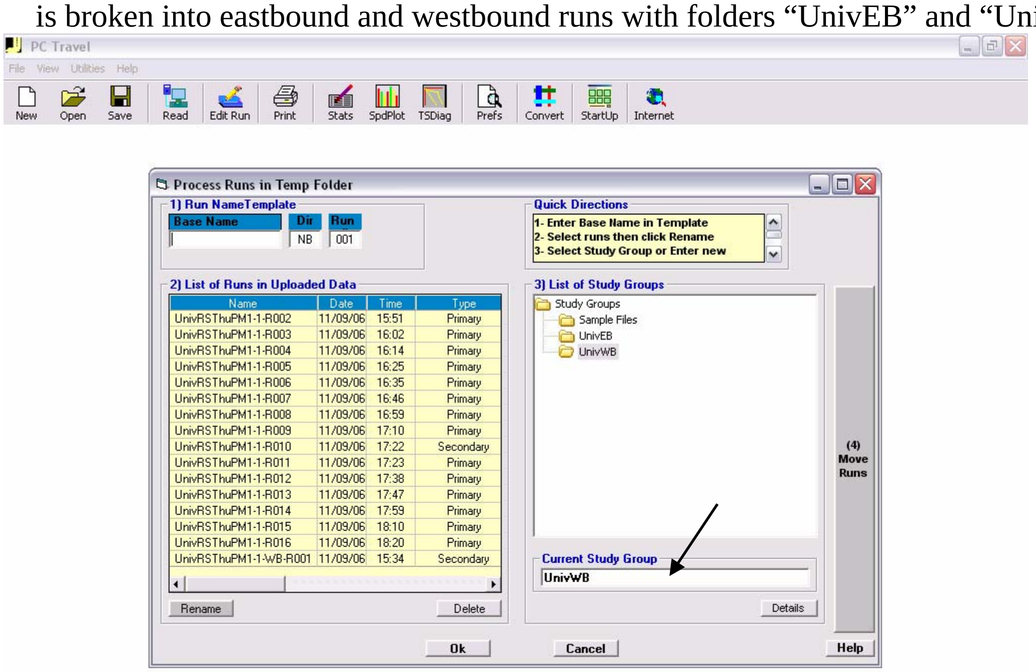
4. Select the file to process from C:\Program Files\Jamar\PC-Travel\Field Data Files and press 'Select.'



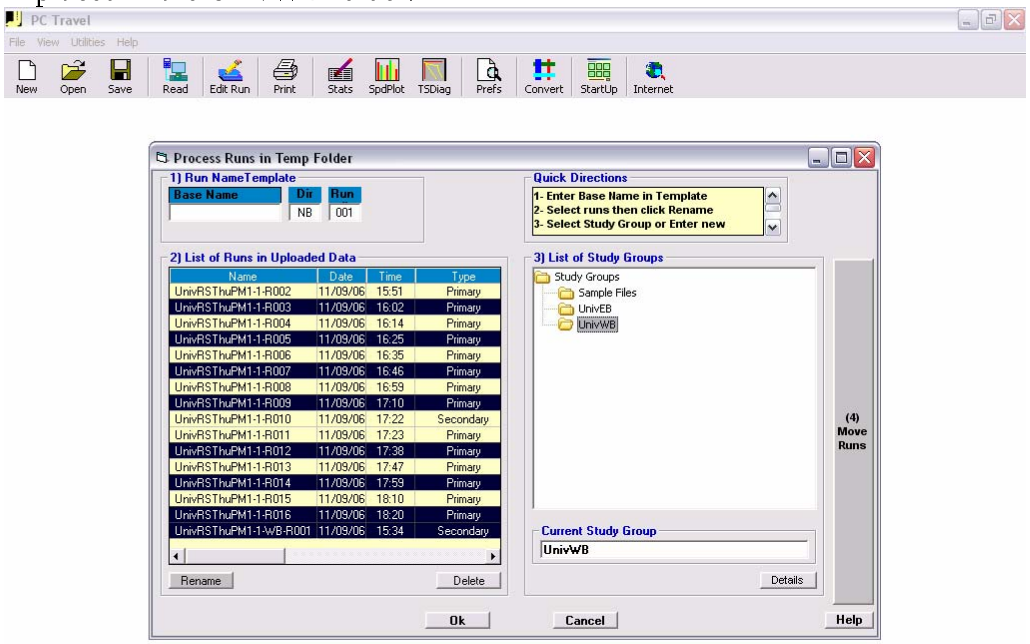
5. On the “GPS Data” screen below, the goal is for the ‘Ok’ button to be green. For the ‘Ok’ button to be green, all missing speeds must be calculated. If the ‘Ok’ button is already green, click it and proceed. If the ‘Ok’ button is not green, click on ‘Find Next Missing Speed’ and calculate all missing speeds. Once the ‘Ok’ button is green, press it.



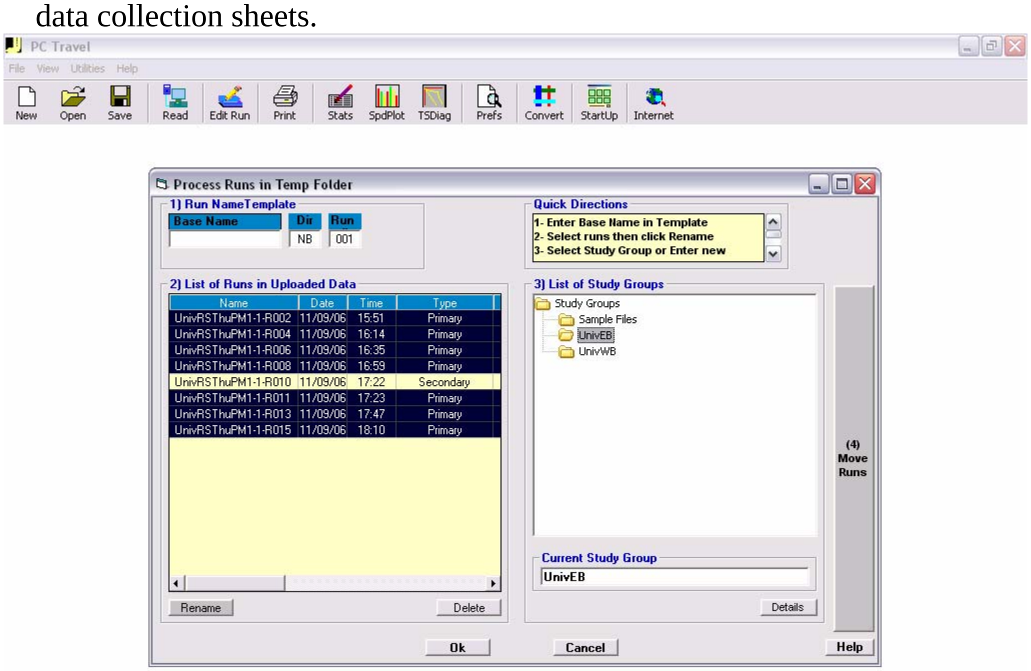
6. In the “Process Runs in Temp Folder” screen several steps are taken as follows:
   a. Create a folder for each direction and corridor by typing in the folder name below ‘Current Study Group’ (see arrow below). After each folder is added, it will appear as a subfolder in the window below ‘3) List of Study Groups.’ Here University Drive is broken into eastbound and westbound runs with folders “UnivEB” and “UnivWB.”



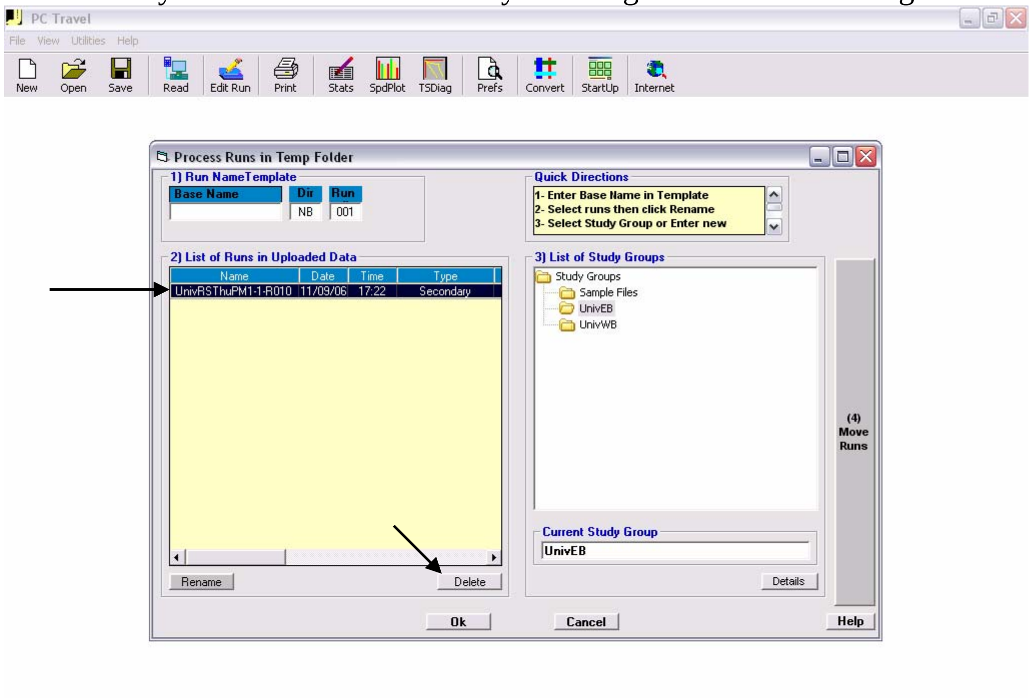
b. Field data collection sheets should be used to assist in the data reduction (i.e. knowing which runs are in a particular direction). Use the field data collection sheets to determine which runs belong in each folder. Click on each run for one direction and then click on the folder in which they belong. Finally click on '(4) Move Runs' to move the files to the specified folder. Here all of the WB runs are highlighted to be placed in the UnivWB folder.



c. Move the runs for the opposite direction into their folder. Here all of the runs are highlighted to be placed in the UnivEB folder. Note that run #10 was not included in either study folder because it was a faulty run, which was determined from the field data collection sheets.

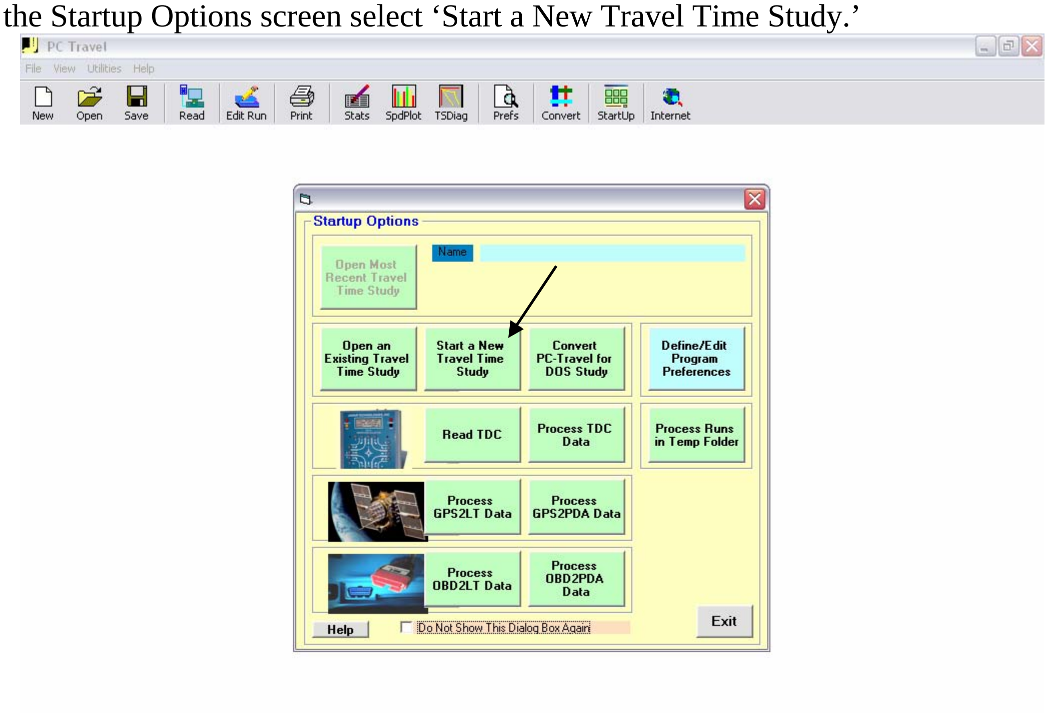


d. Delete any runs that have bad data by selecting the runs and clicking delete.

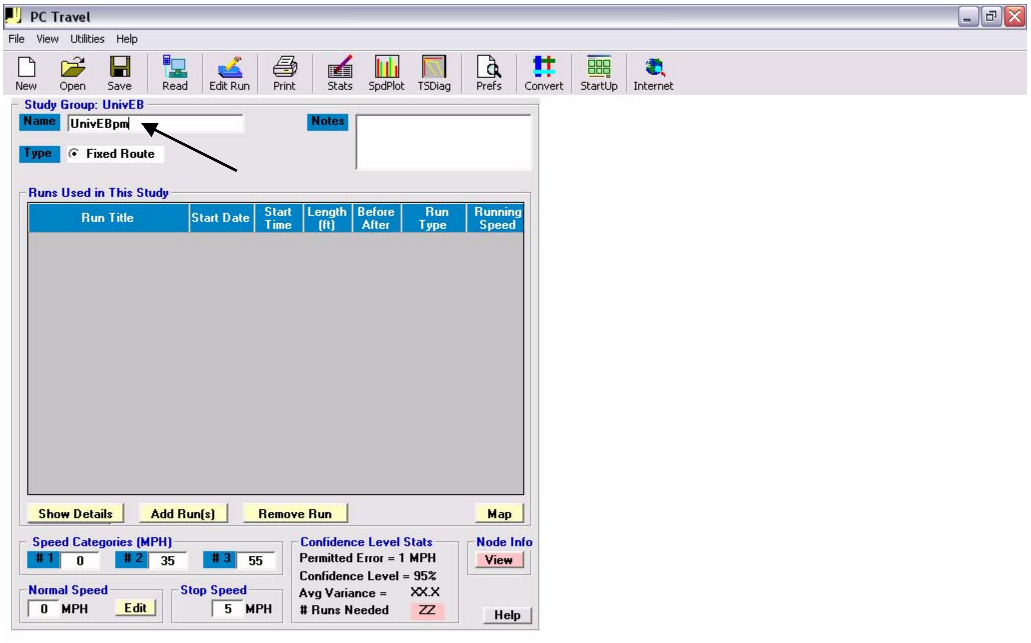


e. Press ‘Ok’ to accept all changes to the run files. Now the runs have been separated for University Drive into eastbound and westbound study groups. Additional travel time runs along the same corridor can be added to these same study groups by returning to step 3, but skipping step 6a (no need to create study group folders again).

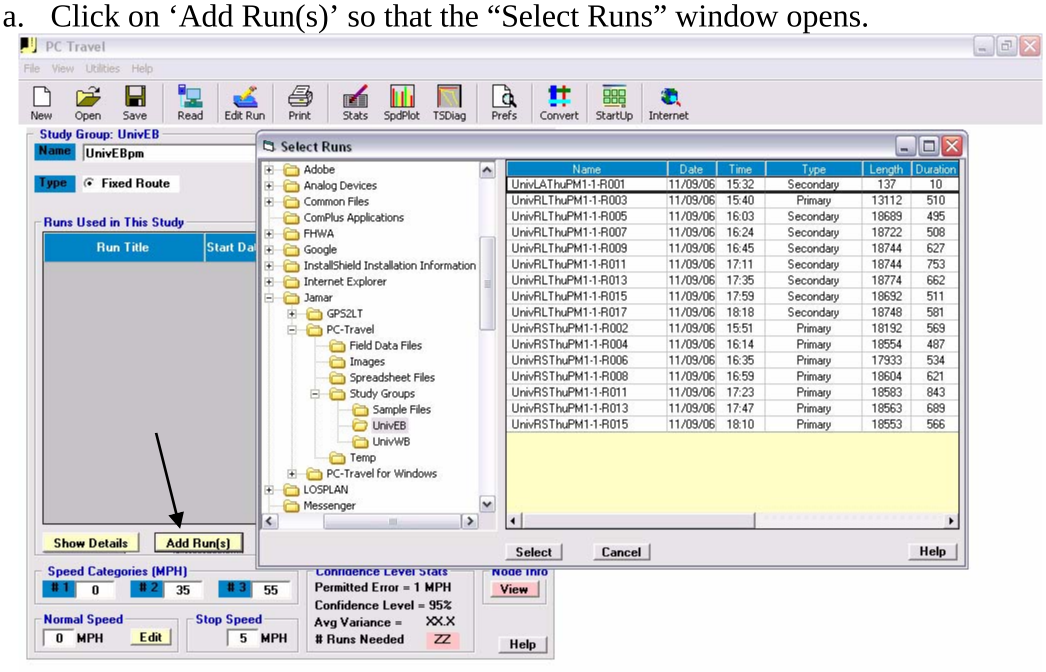
7. On the Startup Options screen select ‘Start a New Travel Time Study.’



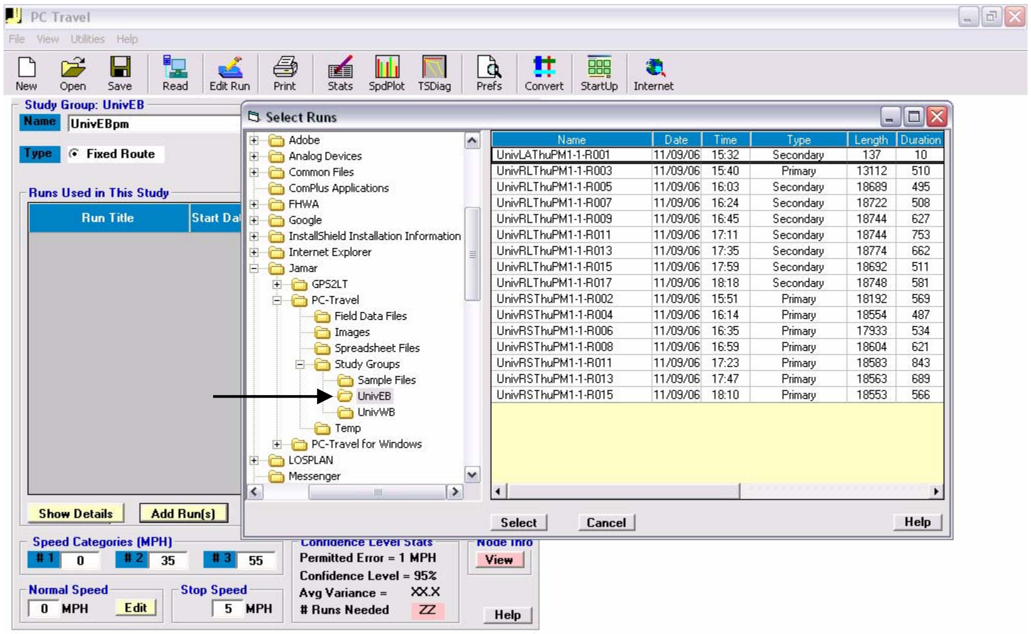
8. Now it is time to name the travel time study. If data in the same study group are collected during different time periods and are going to be compared, the names of the travel time studies need to set them apart. It is recommended to name the travel time study with the name of the corridor, the direction of the runs, and the time of day. Here the travel time study is 'UnivEBpm' for University Drive runs in the eastbound direction in the evening peak.



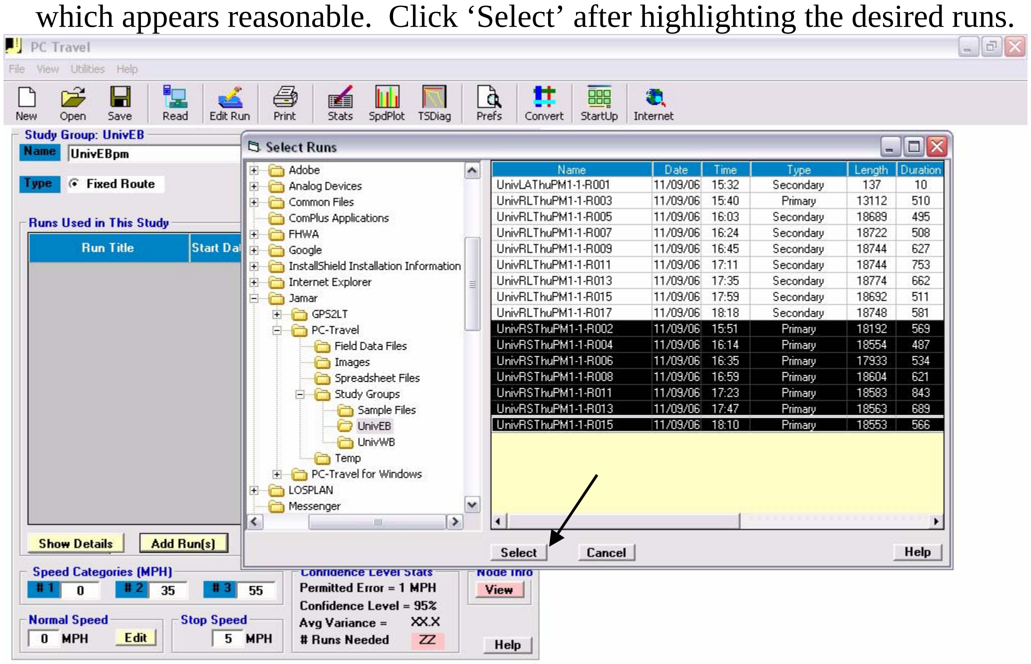
9. Now run files must be added to the study.
    a. Click on 'Add Run(s)' so that the "Select Runs" window opens.



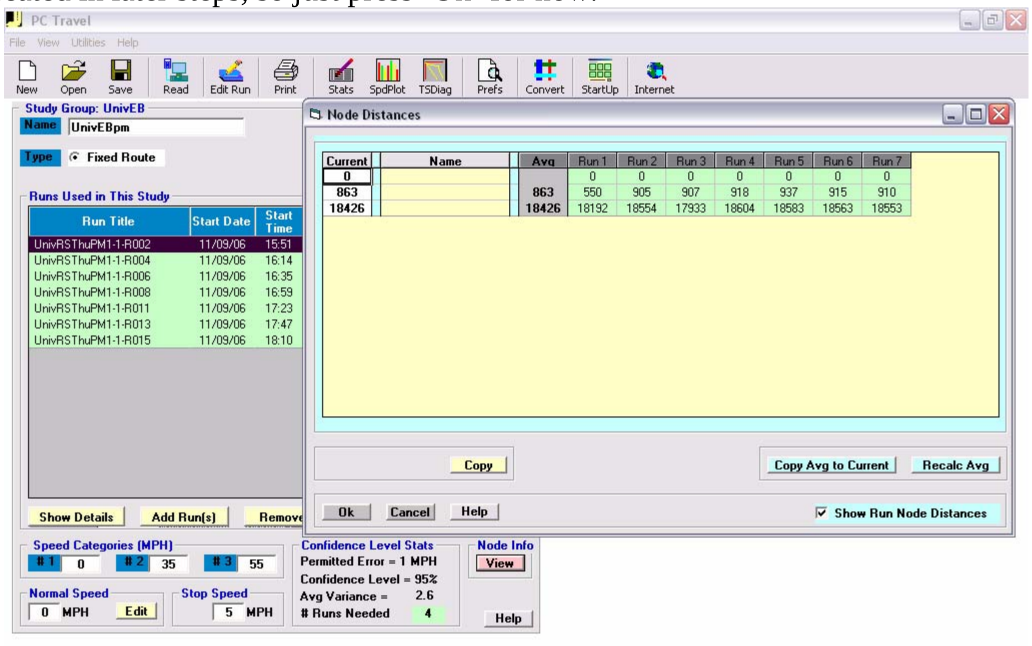
b. In the left pane of the "Select Runs" window, click on the folder within the Study Group folder that contains the runs separated in step 6. Here the 'UnivEB' folder is selected.



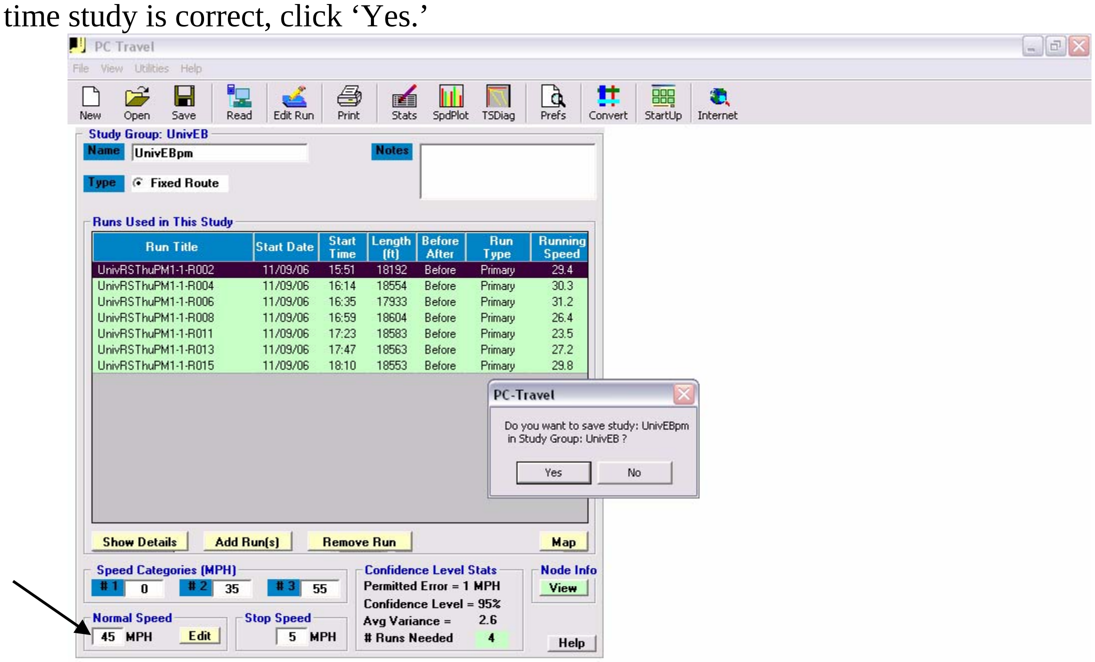
c. In the right pane of the "Select Runs" window click on each of the runs to be evaluated. Take note that they all should be about similar length; otherwise they are probably not a complete run. Here the lengths range from 17,933 feet to 18,583 feet, which appears reasonable. Click 'Select' after highlighting the desired runs.



10. Once back at the “Study Group” window, the ‘View Node Info’ button will be red by default. Click on the ‘View Node Info’ button. The “Node Distances” window will appear. Some of the boxes may appear red instead of green as below. The nodes for the corridor will actually be created in later steps, so just press ‘Ok’ for now.

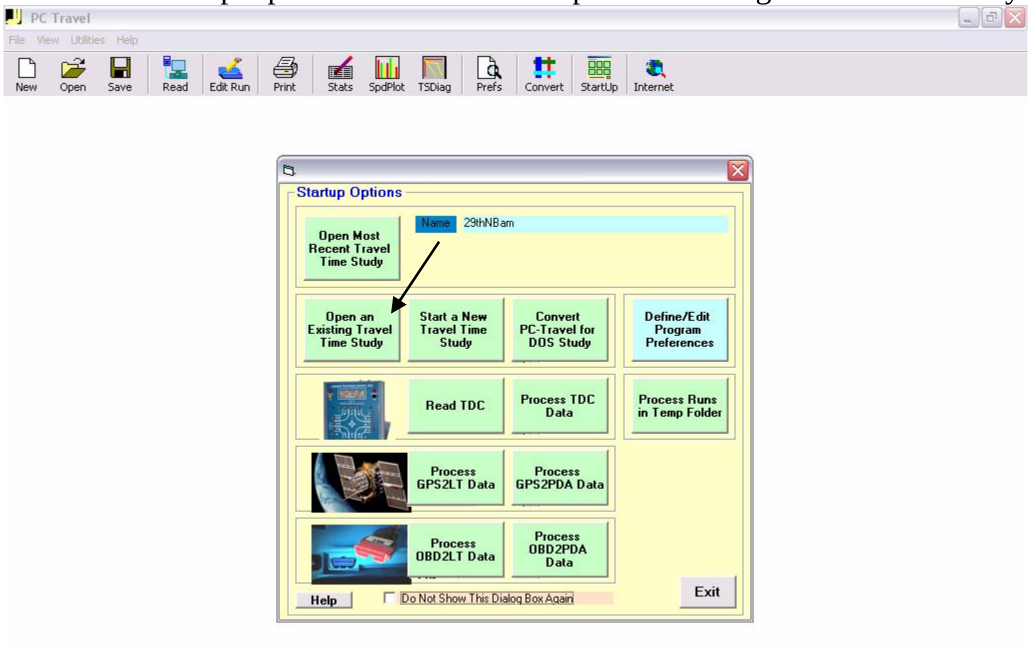


11. In the “Study Group” window the ‘View Node Info’ button should now be green. The Normal Speed needs to be changed to a nonzero value for the program to operate. For now 45 mph is used, but during the analysis this value can be changed. Click on ‘Save,’ and a window will pop up asking if you want to save the study in the specified folder. If the travel time study is correct, click ‘Yes.’

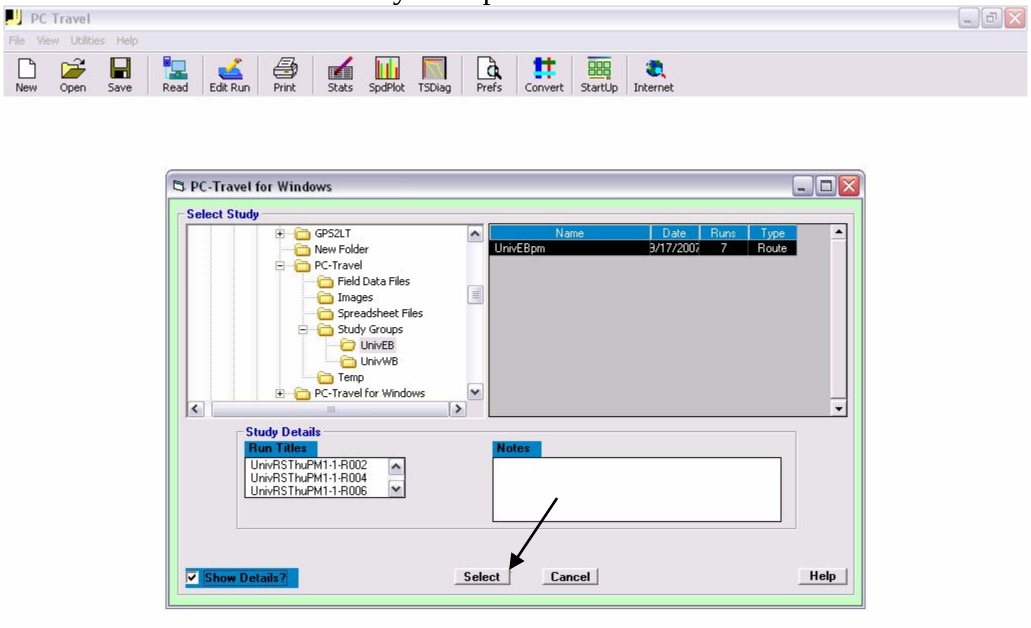


12. A travel time run where all node data are stored needs to be added to the travel time study. This file will be used in PC-Travel to separate each run for an entire corridor into links between each intersection.
    a. The run must be added to the study group the same way the other runs were added by following steps 1 – 6 (skipping 6a because the study group has already been created).

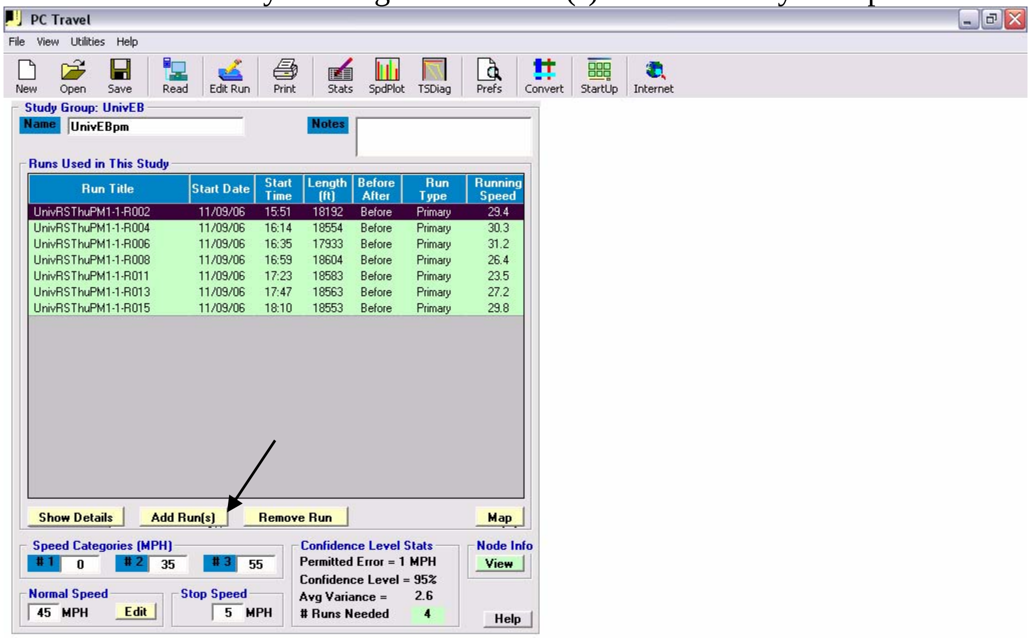
    b. On the “Startup Options” screen select ‘Open an Existing Travel Time Study.’



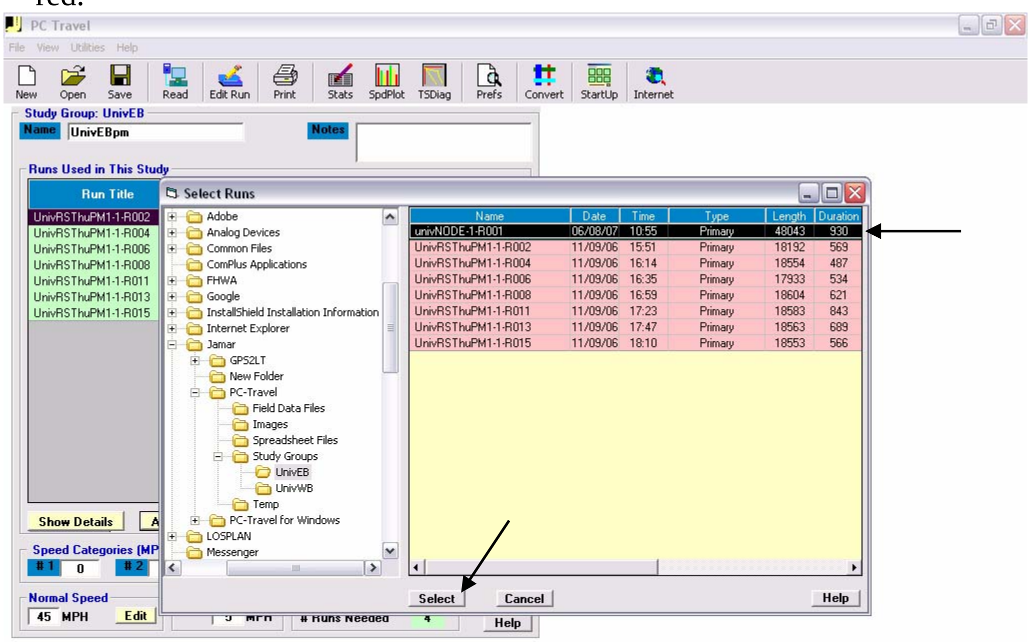
    c. Select the travel time study created in step 6a from the directory C:\Program Files\Jamar\PC-Travel\Study Groups and click on ‘Select.’



d. Add the run file by clicking on ‘Add Run(s)’ on the “Study Group” screen.

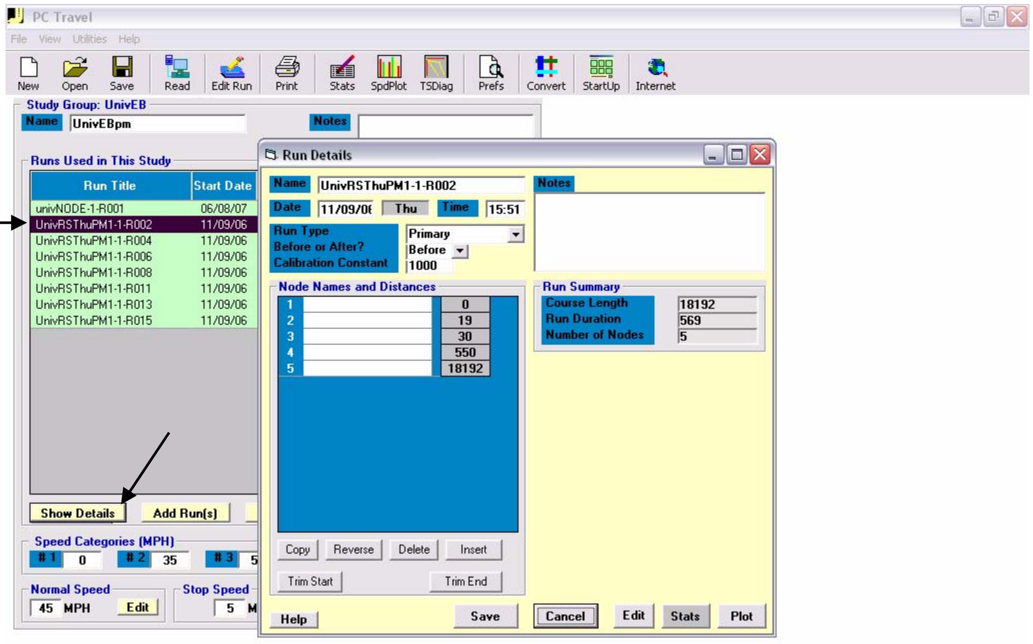


e. When the “Select Runs” window opens, click on the run to be used as the node run and click on ‘Select.’ Notice that the runs already added to the travel time study are red.

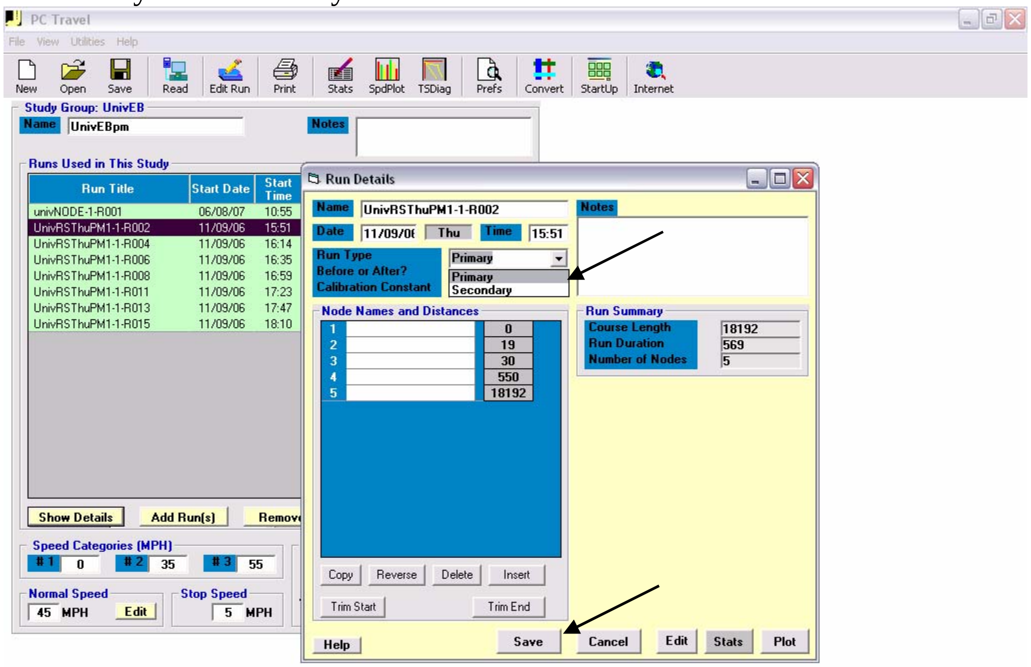


13. Now the travel time study should have all the runs from before plus the node run just added. Click on ‘Save,’ and a window will pop up asking if you want to save the study in the specified folder. If the travel time study is correct, click ‘Yes.’

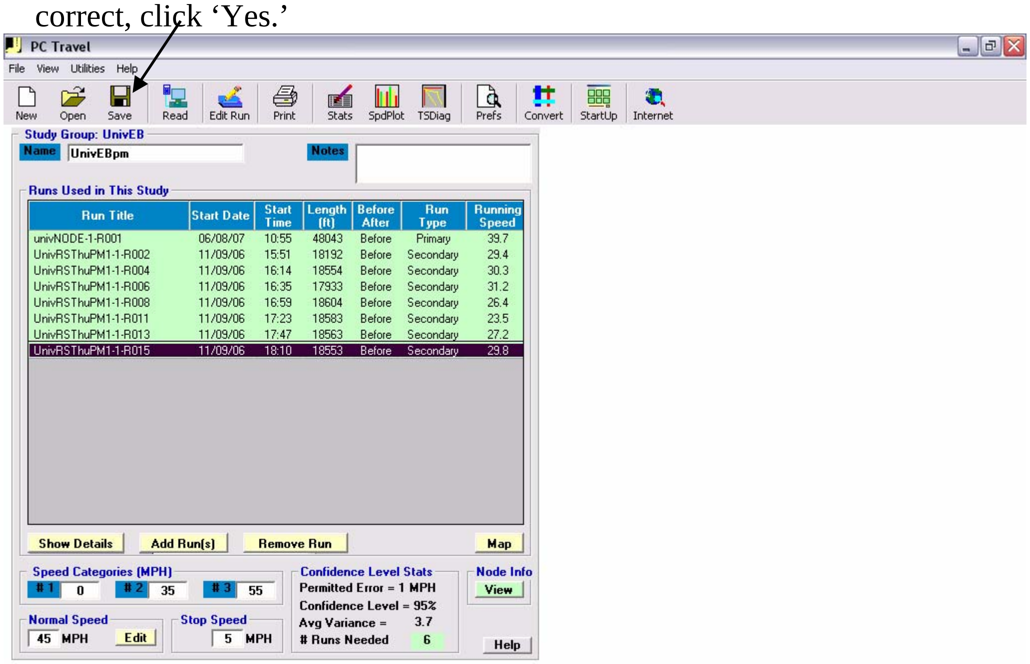
14. Primary runs store node information, while secondary runs use node information from a primary run. Only one primary run is needed for a travel time study, which will be the node run with nodes for each intersection.
    a. All of the runs from the data collection need to be changed to secondary runs. Select a run and click on 'Show Details.'



    b. The "Run Details" window will open. Toggle the box next to Run Type from 'Primary' to 'Secondary.' Click on 'Save.'

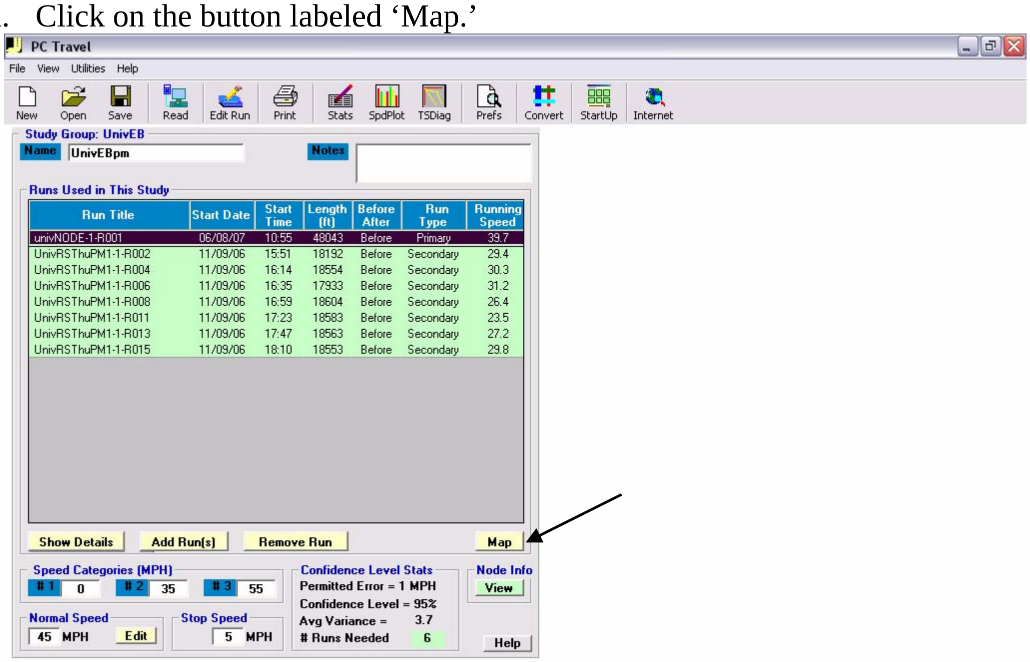


c. Change all runs to Secondary except for the node run. The "Study Group" window should appear as below. Click on 'Save,' and a window will pop up asking if you want to save the travel time study in the specified folder. If the travel time study is correct, click 'Yes.'

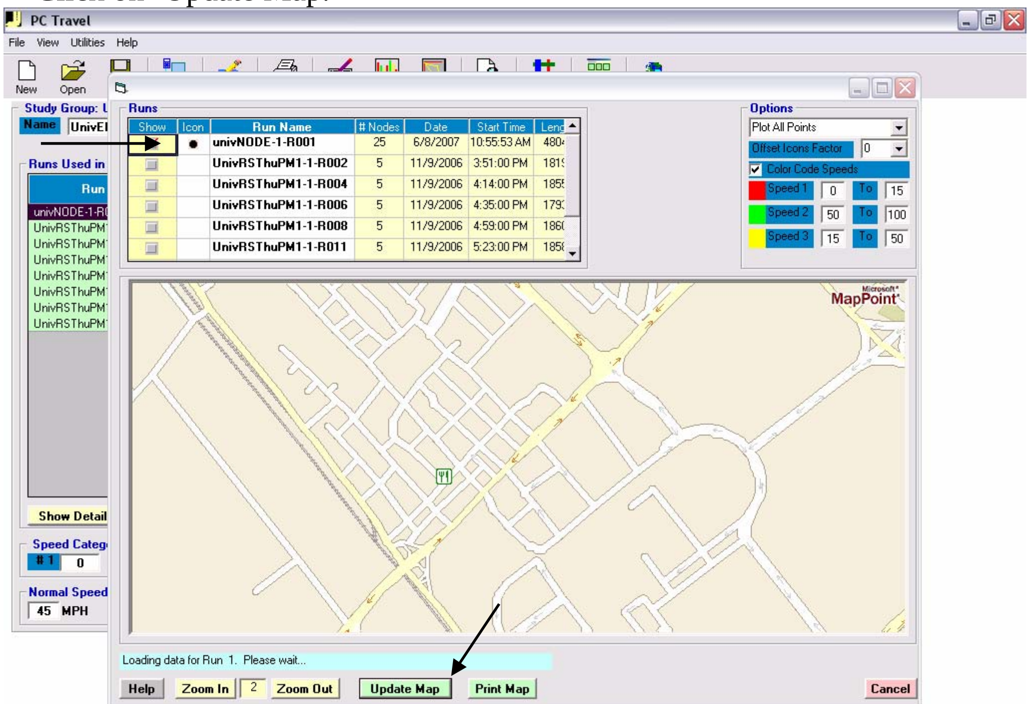


15. Now it is time to edit the node run for this corridor. This is done within the mapping function of PC-Travel, which requires the installation of MapPoint.

a. Click on the button labeled 'Map.'

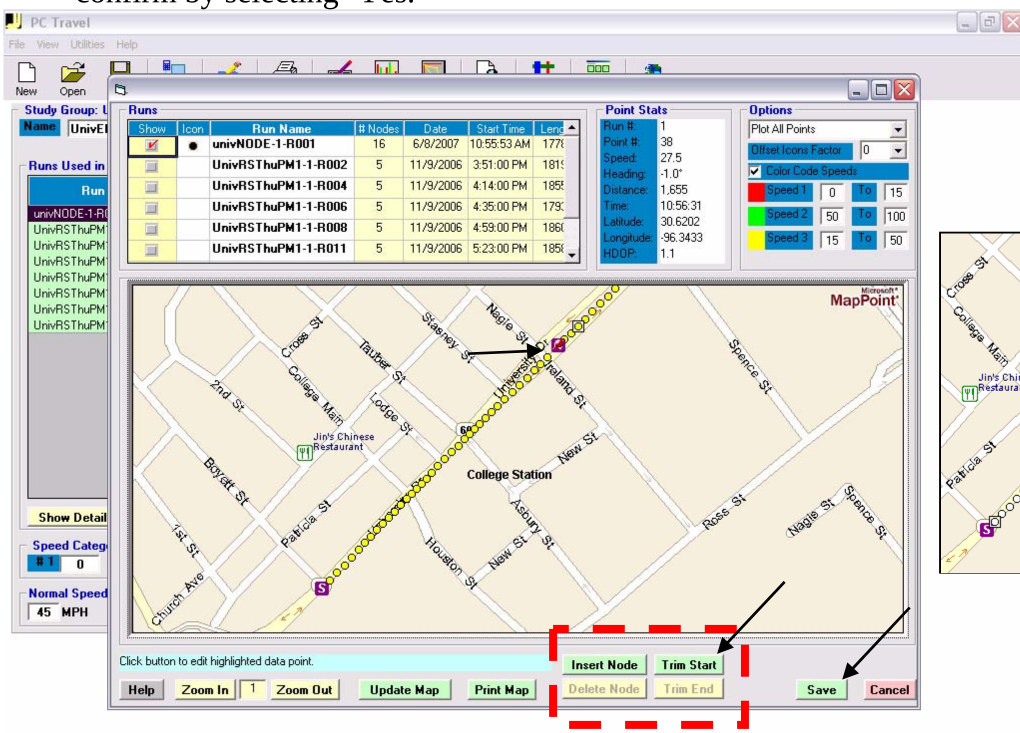


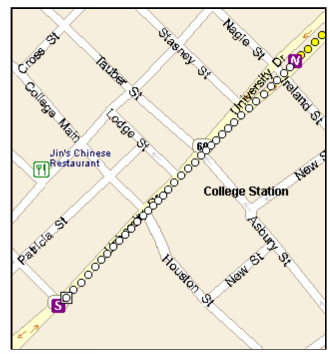
b. The “Mapping” window will open. In the “Runs” pane, select the ‘Show’ box for the node (primary) run (univNODE-1-R001). Under “Options” select ‘Plot All Points.’ Leave the ‘Offset Icon Factor’ at zero. The default speed ranges are acceptable. Click on ‘Update Map.’



c. The map may scroll on the screen as the data loads. You may get a “Please Wait” message while it processes the data. Be patient! Leave the computer alone while it processes. Once it finishes loading, scroll back to the beginning of the run by holding down the ALT key and clicking near the edge of the map when a large white arrow appears.

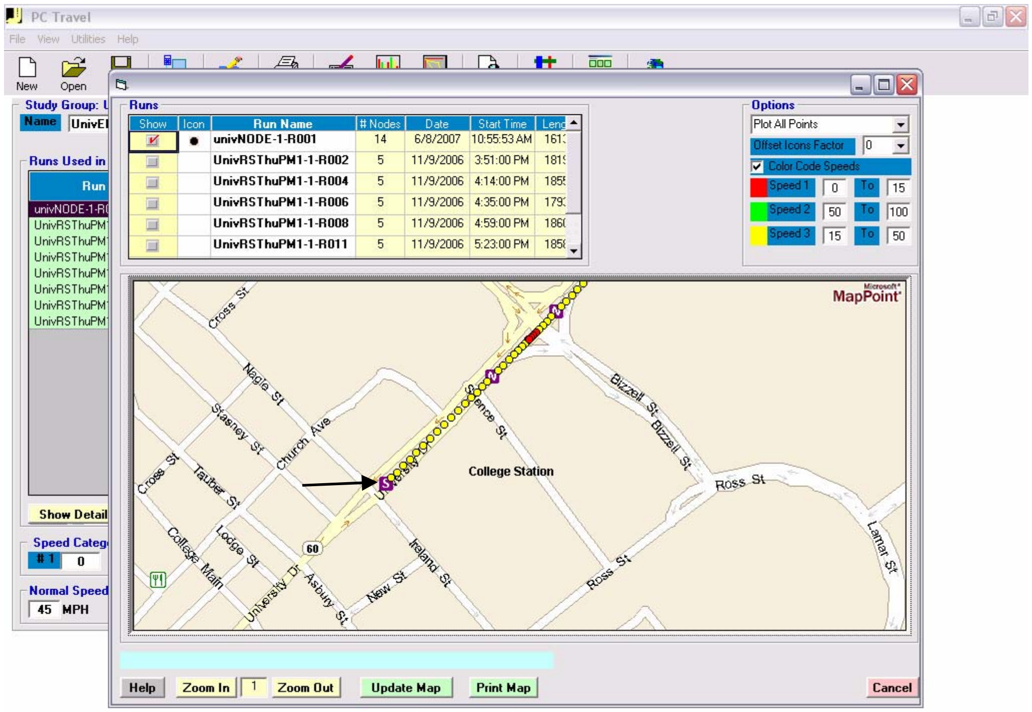
d. The beginning of the run must be trimmed to get rid of the data before the first intersection. Points can only be trimmed in groups less than 50, so if more than 50 points need to be trimmed, it must be done in steps. Below Point #38 is selected, which is indicated by a push pin (see arrow). The "Point Stats" pane (top right of screen) shows information about the point, and four new buttons appear at the bottom of the screen (in dashed box). Select 'Trim Start,' which will turn points 1-38 white to indicate they are removed (as in the picture below on the right). Always click 'Save' after each trim. A window will appear asking if you want to save the file; confirm by selecting 'Yes.'



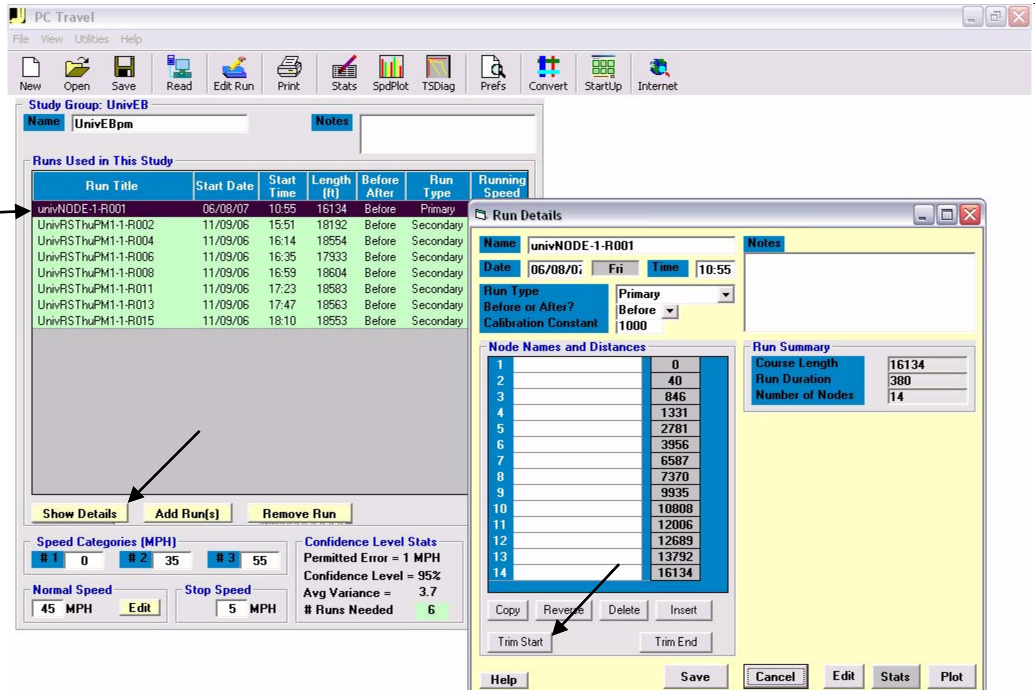


e. Now click on 'Update Map' to refresh the image without the trimmed points. Trim again in groups less than 50 points until the start of the run is at the first intersection, saving after each trim.

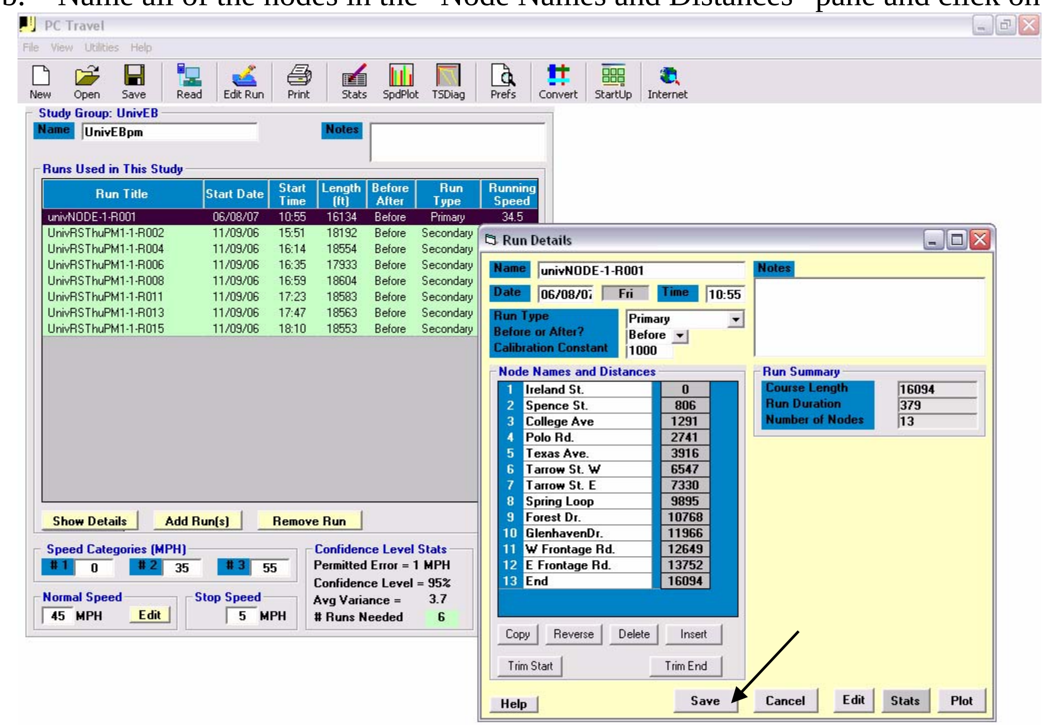
16. Once the run is trimmed to include only the nodes desired, a node needs to be created for the first intersection. Click on the first point of the run, which should be indicated by a purple square with an ‘S’ in it for start. At the bottom of the window four buttons should appear, one of which is ‘Insert Node.’ Click on it to turn the first point into a node for the first intersection (Ireland St here). If points need to be trimmed after the last intersection, pan over to the end of the run. Trim those points in groups less than 50 as done for the beginning of the run. Click ‘Save’ and then close this window.



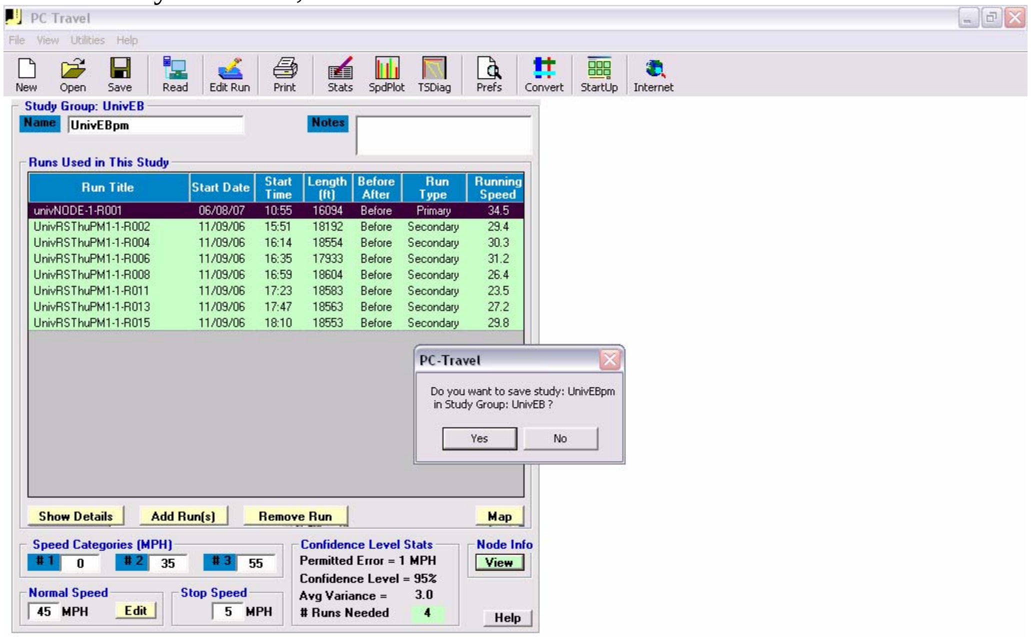
17. Once back at the “Study Group” window it will be necessary to name all of the nodes in the primary run.
    a. Select the primary run that contains the nodes, here univNODE-1-R001, and click on the ‘Show Details’ button. The “Run Details” window will open. Click on ‘Trim Start’ to remove the data recorded before the first node that was created in step 16.



    b. Name all of the nodes in the “Node Names and Distances” pane and click on ‘Save.’

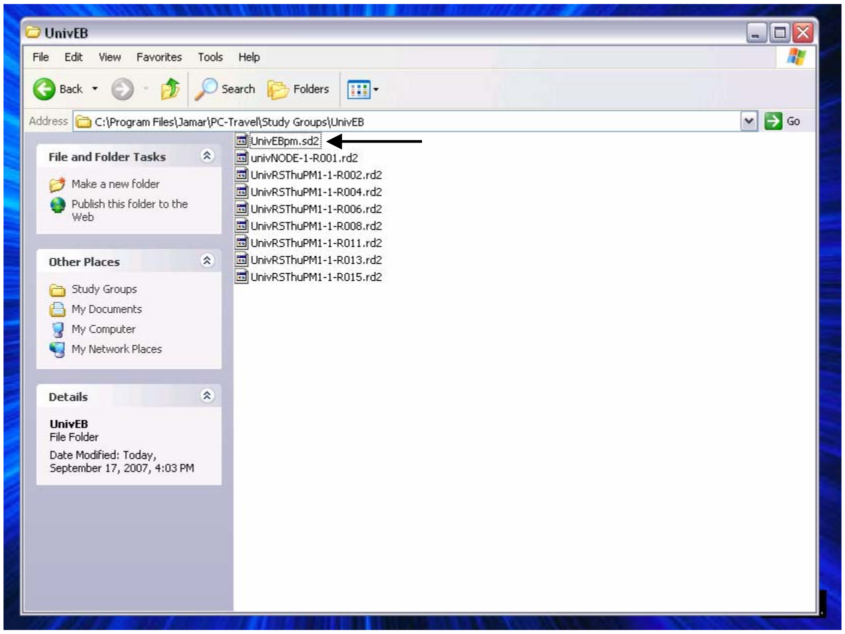


c. Once back at the "Study Group" window, click on 'Save.' A window will pop up asking if you want to save the travel time study in the specified folder. If the travel time study is correct, click 'Yes.'



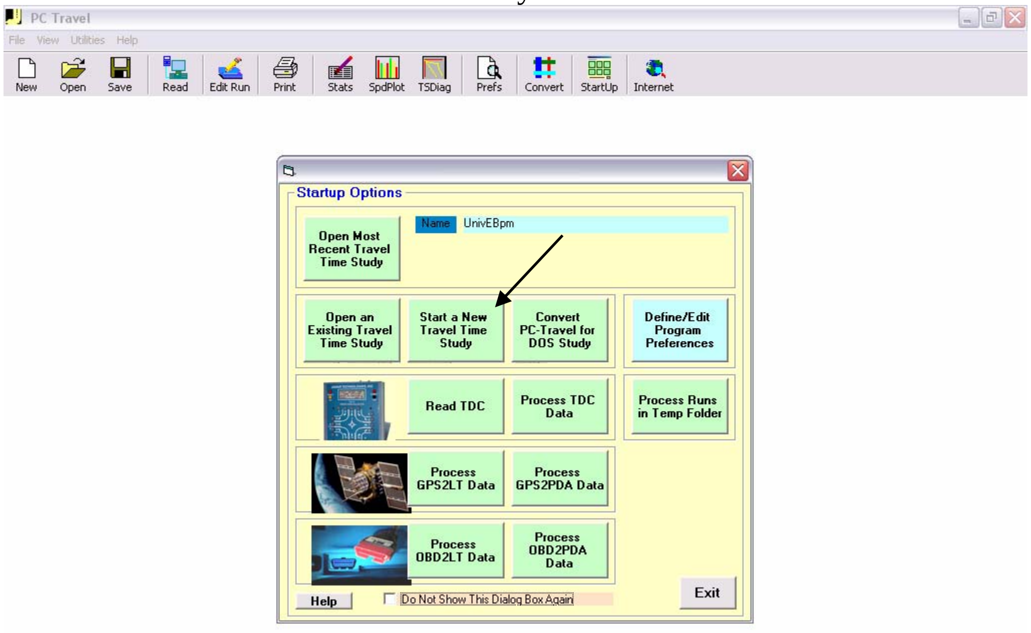
18. In order for the node names to be saved and recognized within PC-Travel, you must exit, delete the travel time study, reopen the program, and recreate the travel time study.
    a. Close PC-Travel by clicking on the red 'X' in the top right-hand corner.

    b. To delete the travel time study navigate to C:\Program Files\Jamar\PC-Travel\Study Groups\UnivEB where 'UnivEB' is the Study Group folder we are working in. UniveEBpm.sd2 is the travel time study created in Steps 7 and 8. Click on that file and delete it.

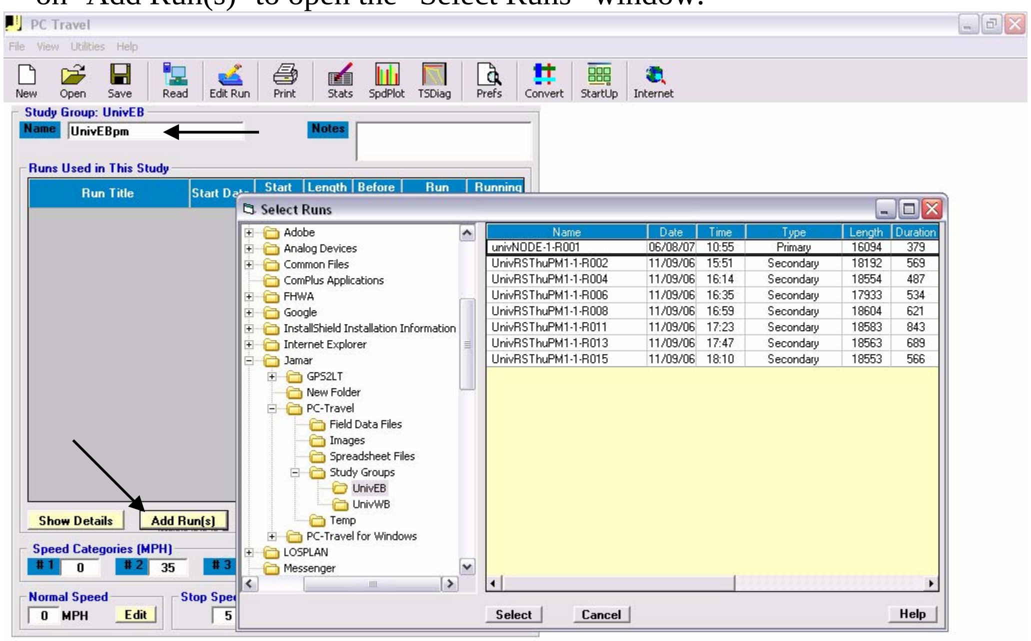


c. Open PC-Travel as in Step 2.

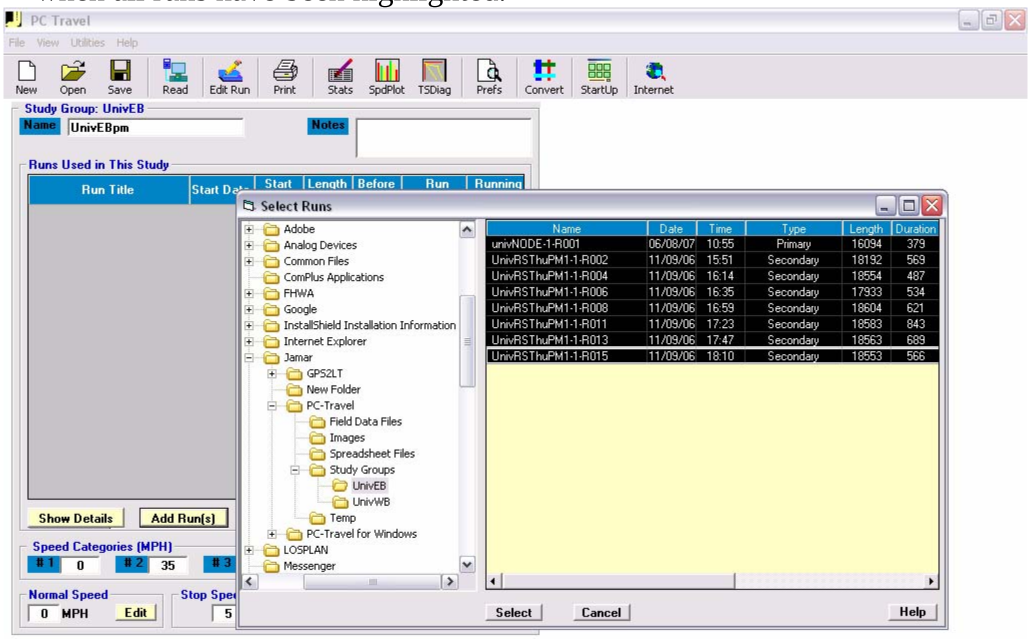
d. Select 'Start a New Travel Time Study.'



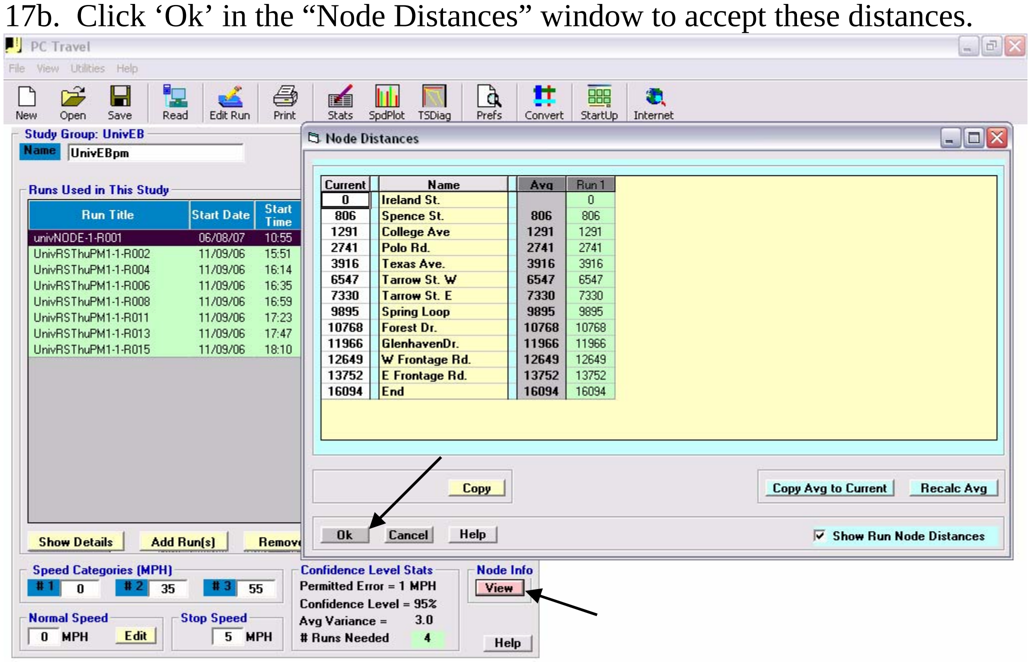
e. Name the travel time study the same name as before. Here UnivEBpm is used. Click on 'Add Run(s)' to open the "Select Runs" window.



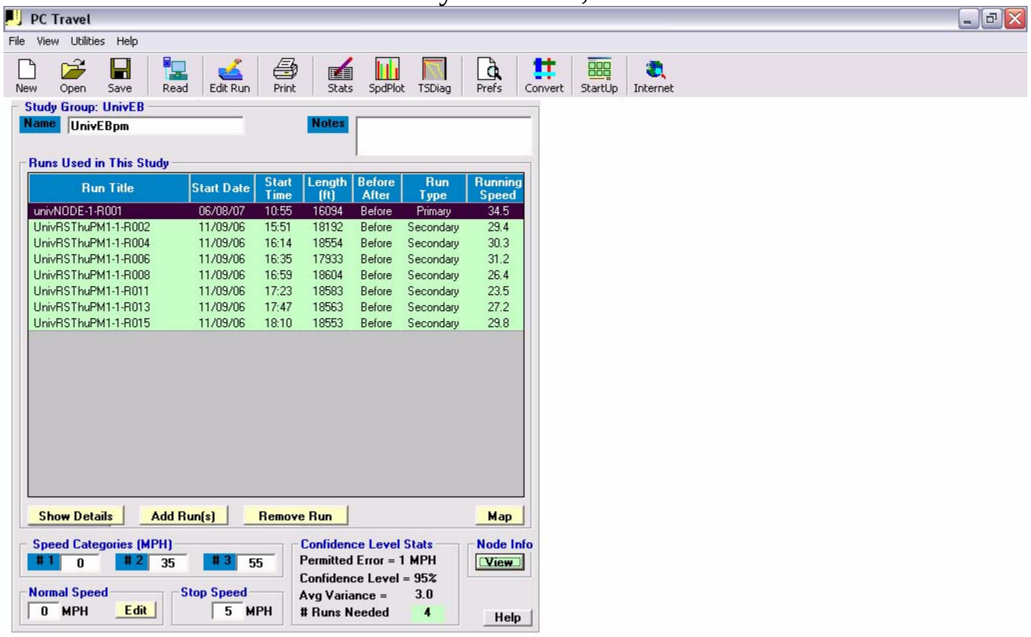
f. Click on each run that was in the travel time study before. This information should come from field data collection sheets as before. The files should include the node run file (univNODE-1-R001) and the actual travel time run files. Click on 'Select' when all runs have been highlighted.



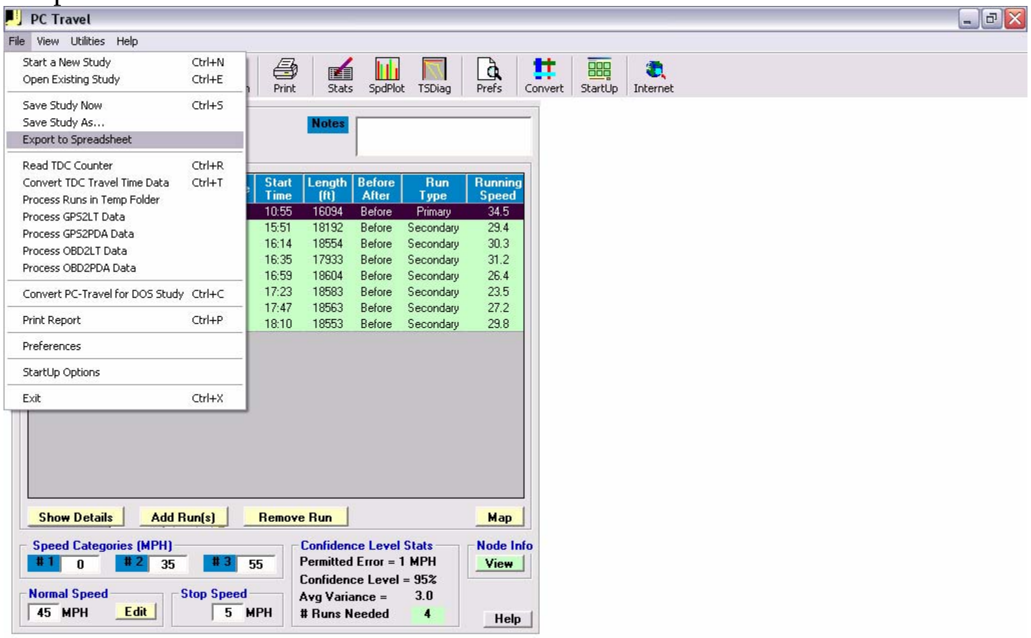
19. This should return to the "Study Group" window. Click on 'View' under Node Info to see the "Node Distances" window. There should only be one green column of distances as shown below. The names of the nodes should also be what were labeled in the node file in Step 17b. Click 'Ok' in the "Node Distances" window to accept these distances.



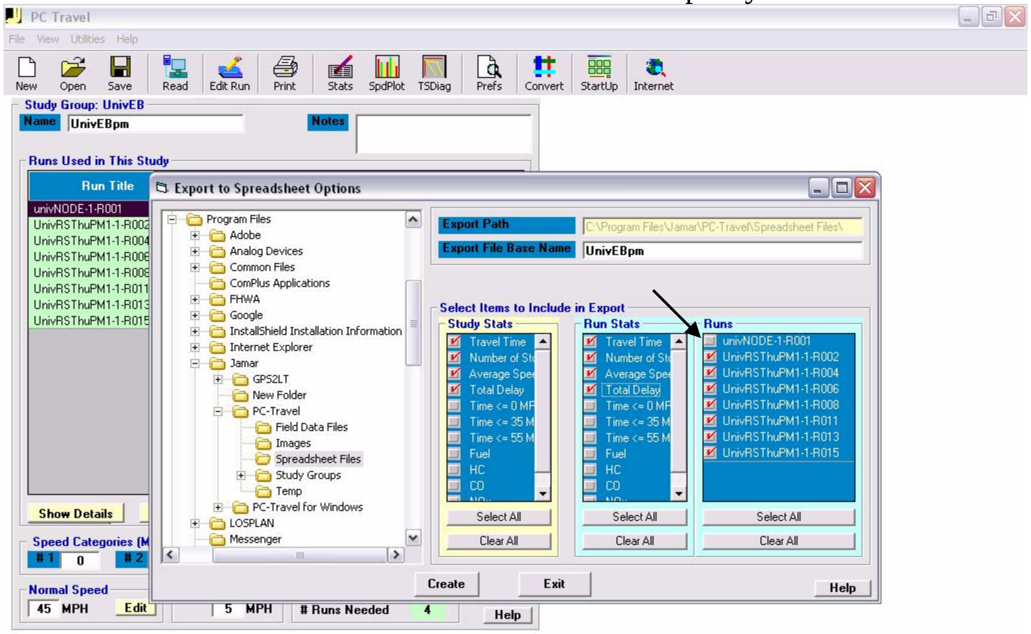
20. Once back at the "Study Group" window the 'View' button under Node Info should be green instead of red. The Normal Speed needs to be changed to a nonzero value for the program to operate. For now 45 mph is used, but during the analysis this value can be changed. Click on 'Save,' and a window will pop up asking if you want to save the travel time study in the specified folder. If the travel time study is correct, click 'Yes.'



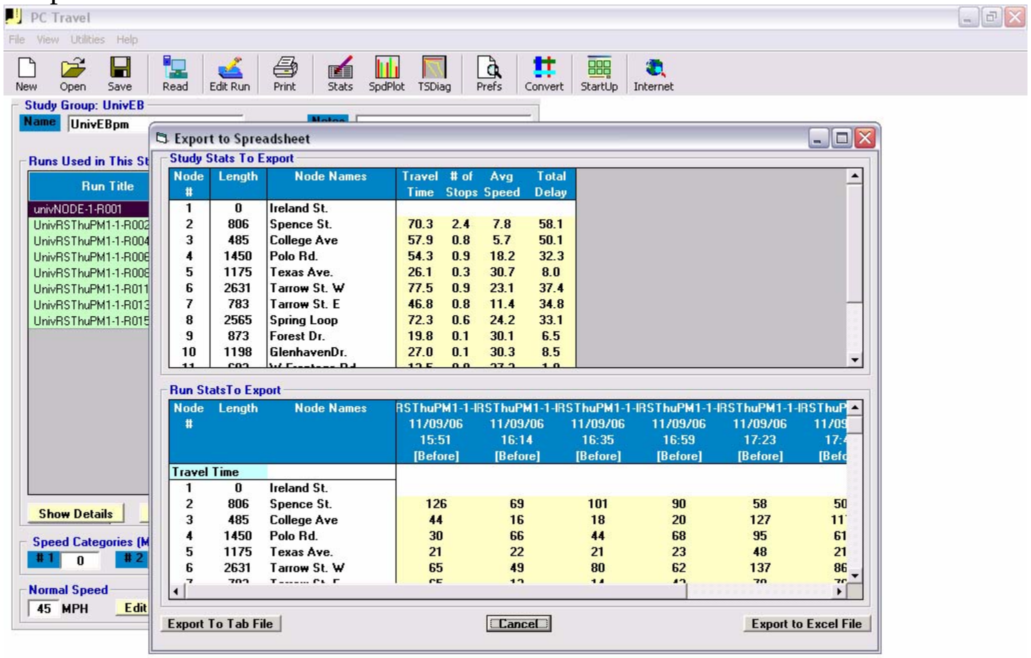
21. Now the Travel Time Study for University Drive in the eastbound direction for the afternoon runs is ready to be analyzed.
    a. If you want to use the analysis done by PC-Travel, go to File → Export to Spreadsheet.



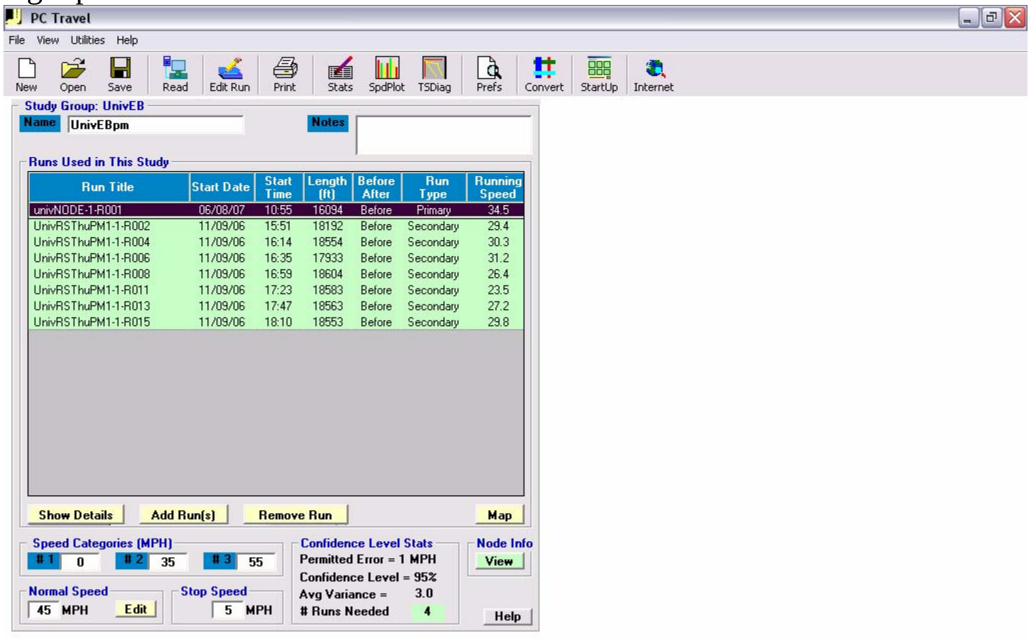
b. In the “Export to Spreadsheet Options” window there are the “Study Stats” and “Run Stats” windows from which you can create a variety of reports. It is important to note that you should deselect the node run file in the “Runs” pane to avoid that travel time to be included in your output. However, the node distance data will still be used for the actual travel time runs. Click on ‘Create’ to export your data to another screen.



22. In the “Export to Spreadsheet” window you have the option to export the data to a tab file or Excel file. If you want to format the data on your own, it is advisable to export to a tab file and open it with Excel. If you export directly to Excel, the formatting cannot be changed. The files created by PC-Travel will be stored in: C:\Program Files\Jamar\PC-Travel\Spreadsheet Files.



23. Close the "Export to Spreadsheet" window by clicking on 'Cancel' when you are finished creating reports. Click on 'Save' and exit PC-Travel.



APPENDIX D

Travel Rate Index Graphs and
Average Speed and Cumulative Average Travel Time Graphs
(Note: Electronic Files in Attached CD)

The Microsoft Excel files located in the directory "Appendix D" of the CD at the end of this report contain the data used to create the graphics in Appendix D.

Each file represents analysis for a given roadway in a given peak direction. Therefore, there are four files per roadway (Morning Peak and Afternoon Peak time periods and two directions). The roadway, direction, and time period are included in the file name.

The Study Stats worksheet includes the data used to create the figure in the Speed & TT worksheet/tab. The Run Stats worksheet includes the data used to create the figure in the TRI worksheet/tab.

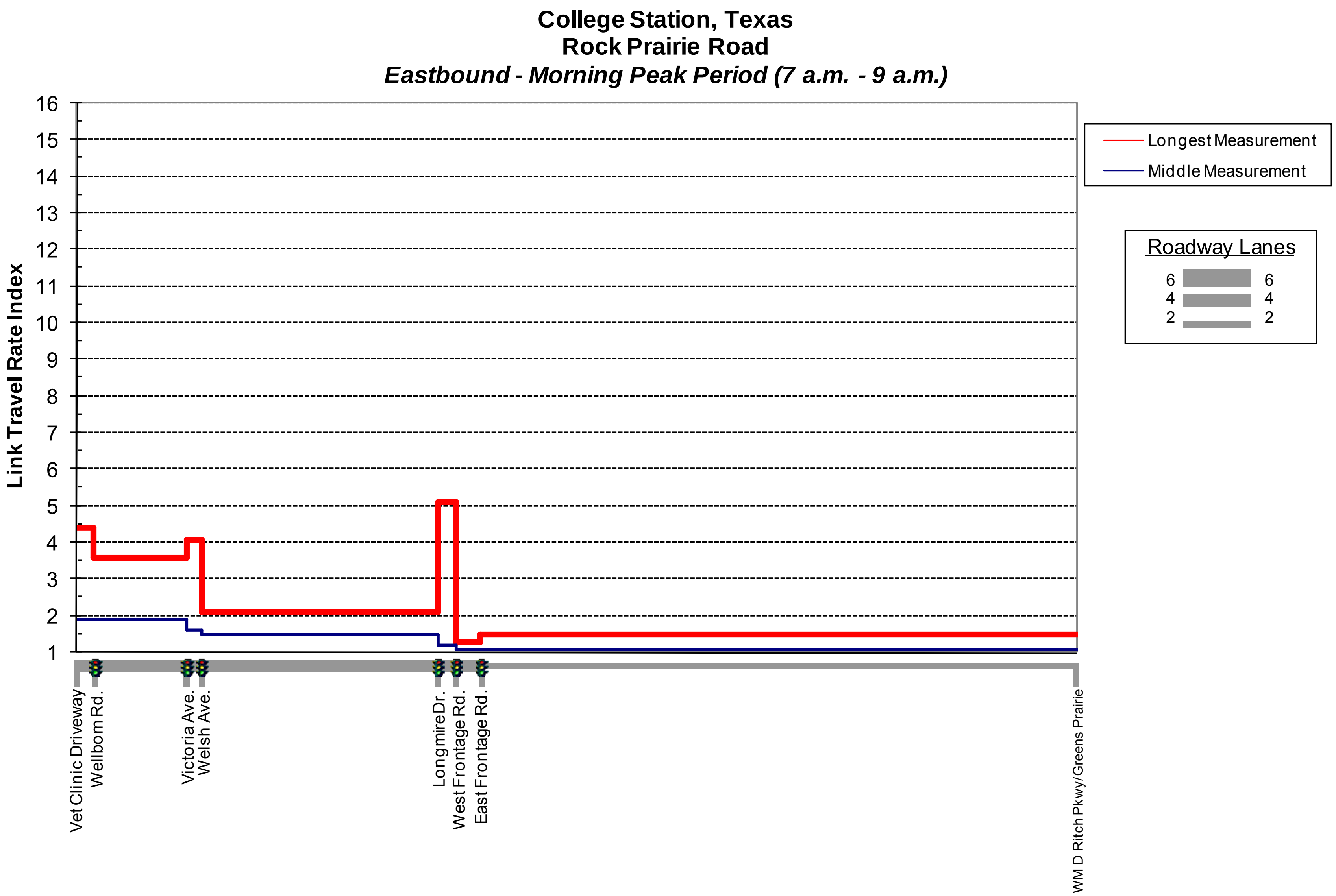


Figure D-1. Link Travel Rate Index for Rock Prairie Road, Eastbound - Morning

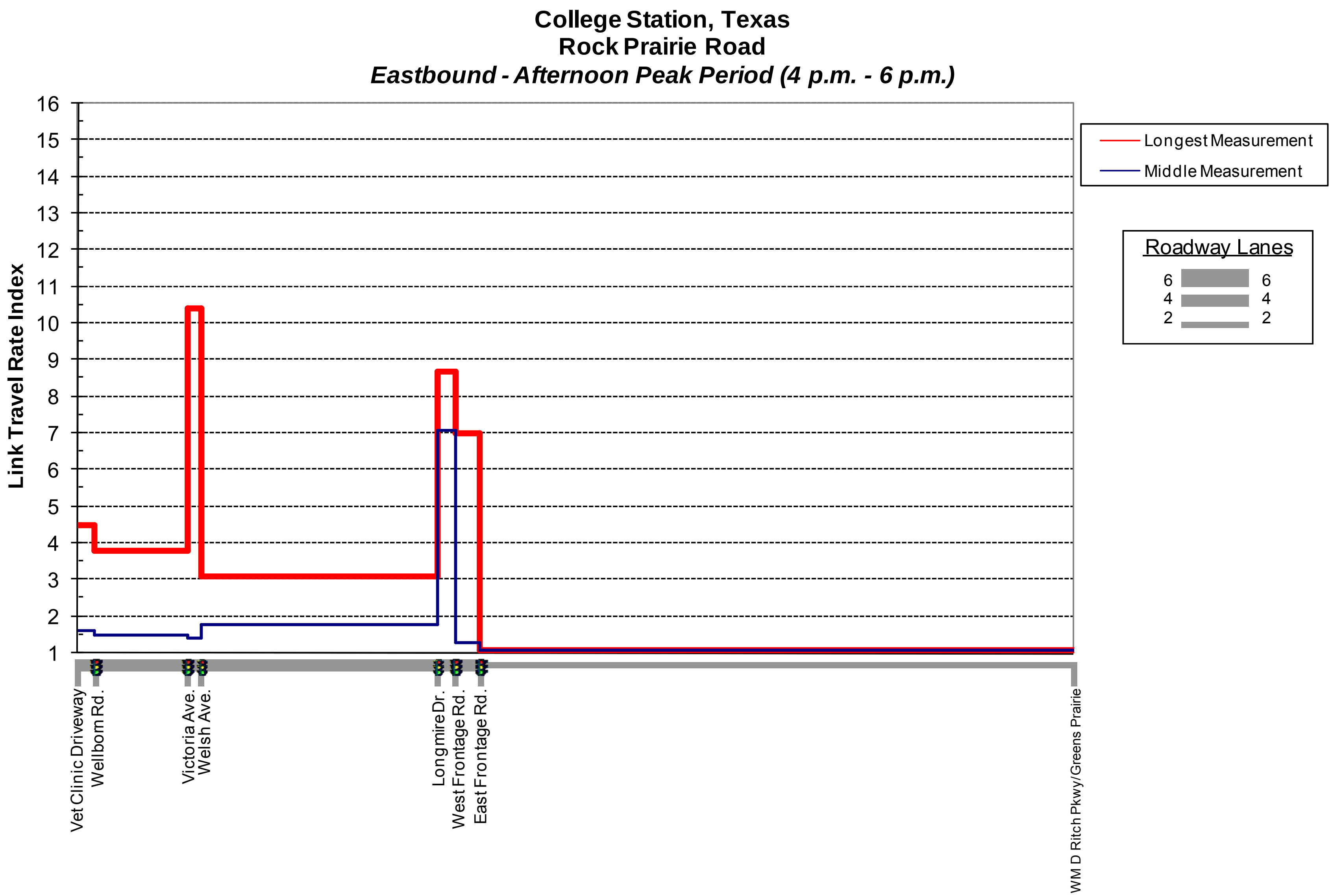


Figure D-2. Link Travel Rate Index for Rock Prairie Road, Eastbound - Afternoon.

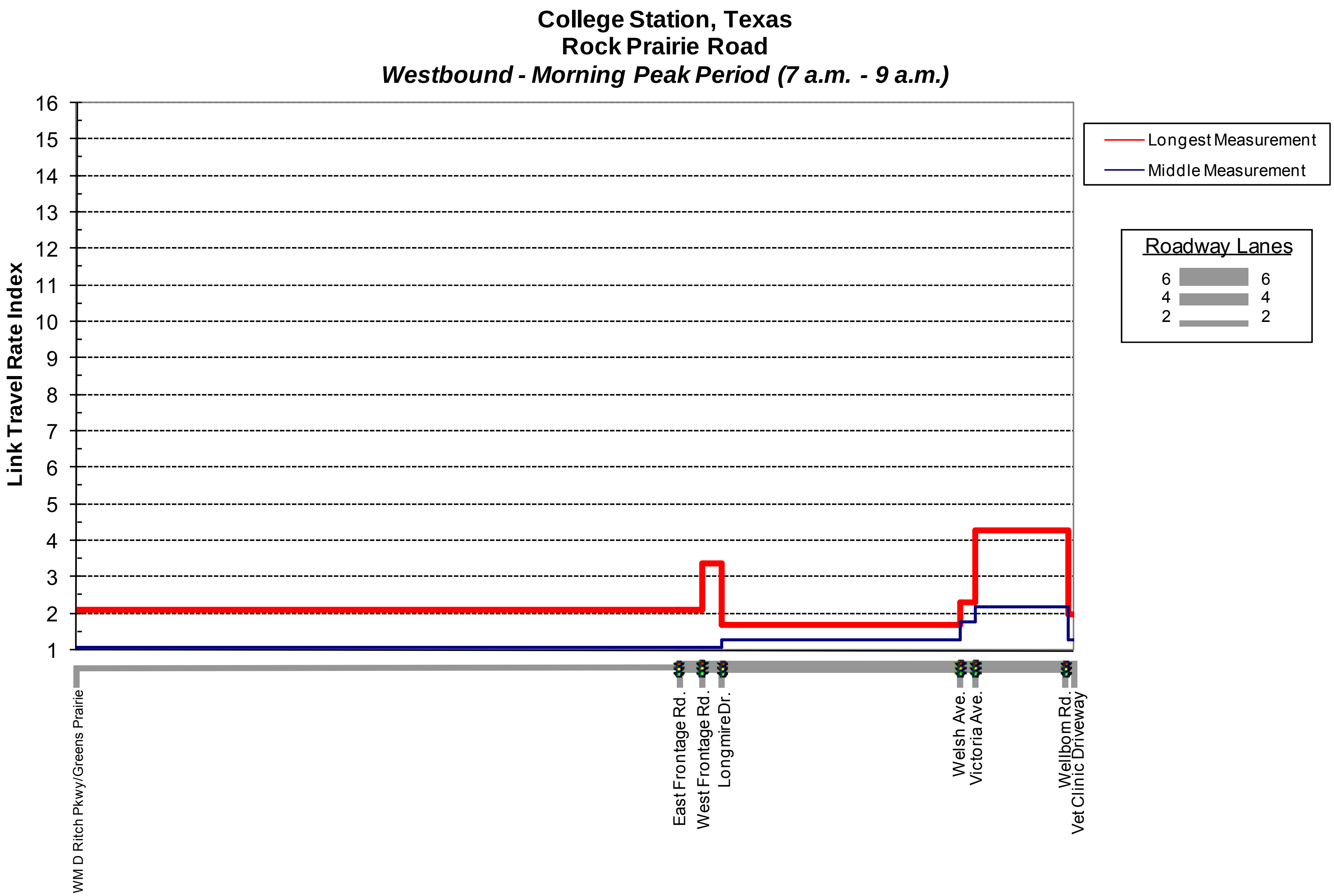


Figure D-3. Link Travel Rate Index for Rock Prairie Road, Westbound - Morning

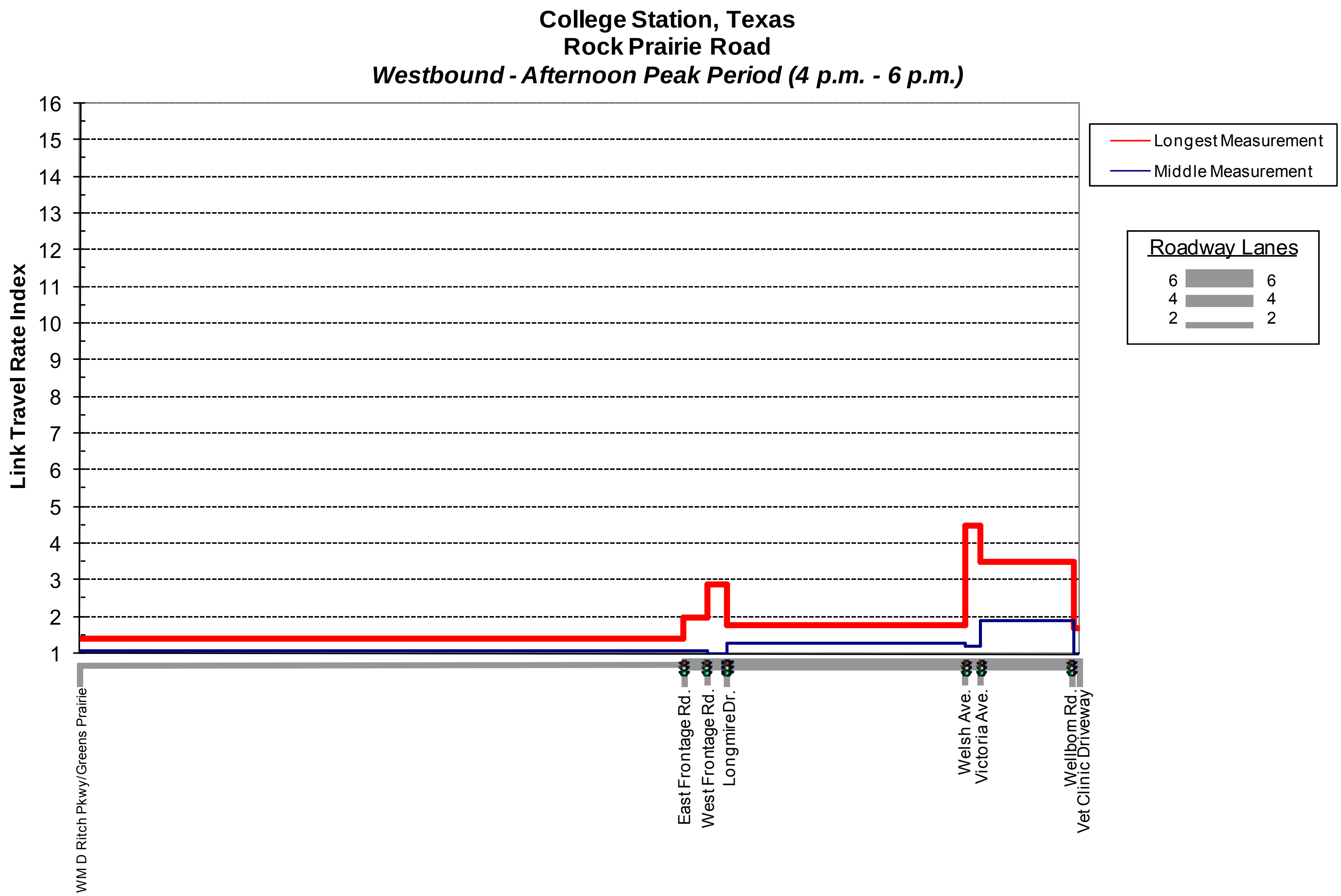


Figure D-4. Link Travel Rate Index for Rock Prairie Road, Westbound - Afternoon.

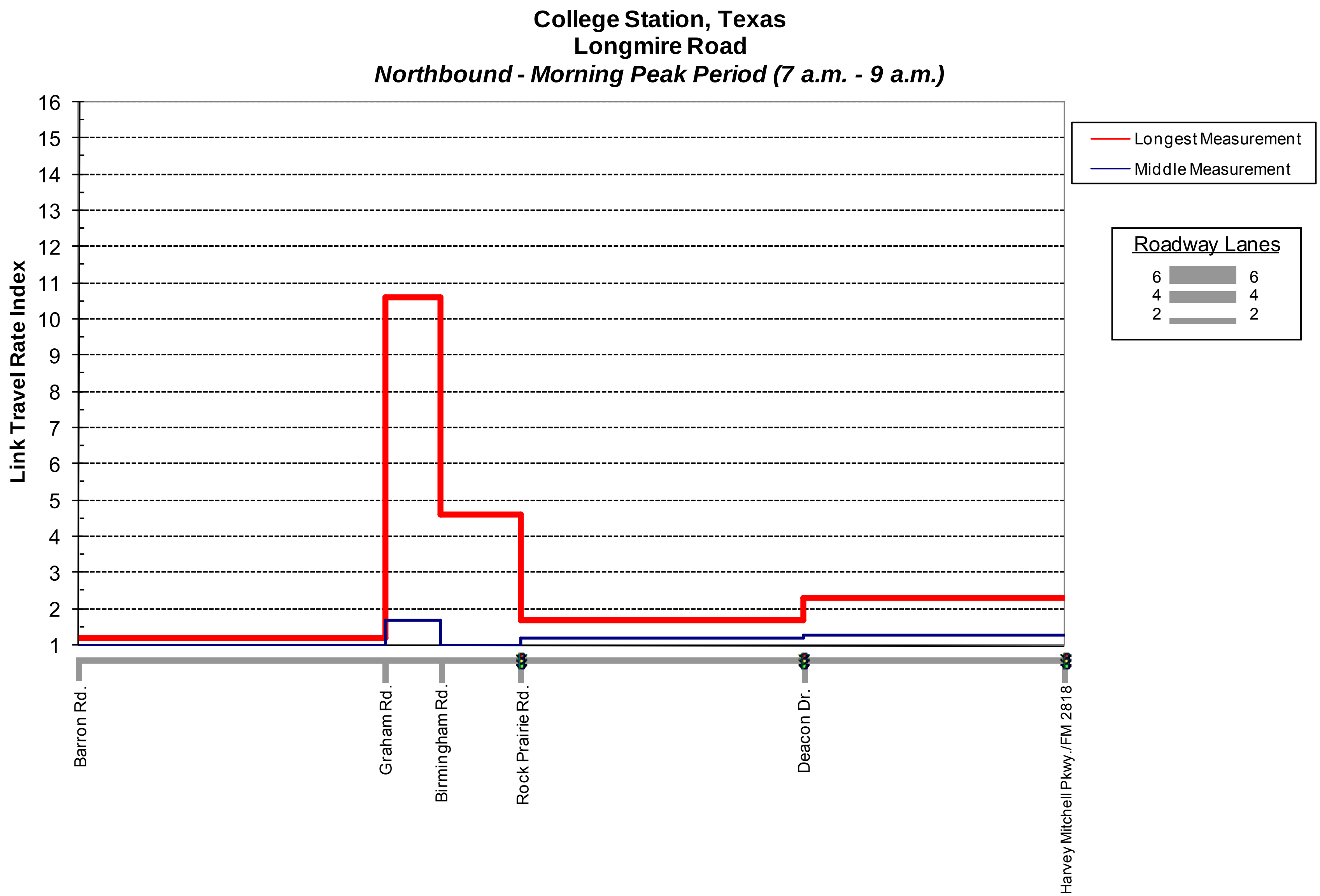


Figure D-5. Link Travel Rate Index for Longmire Road, Northbound - Morning

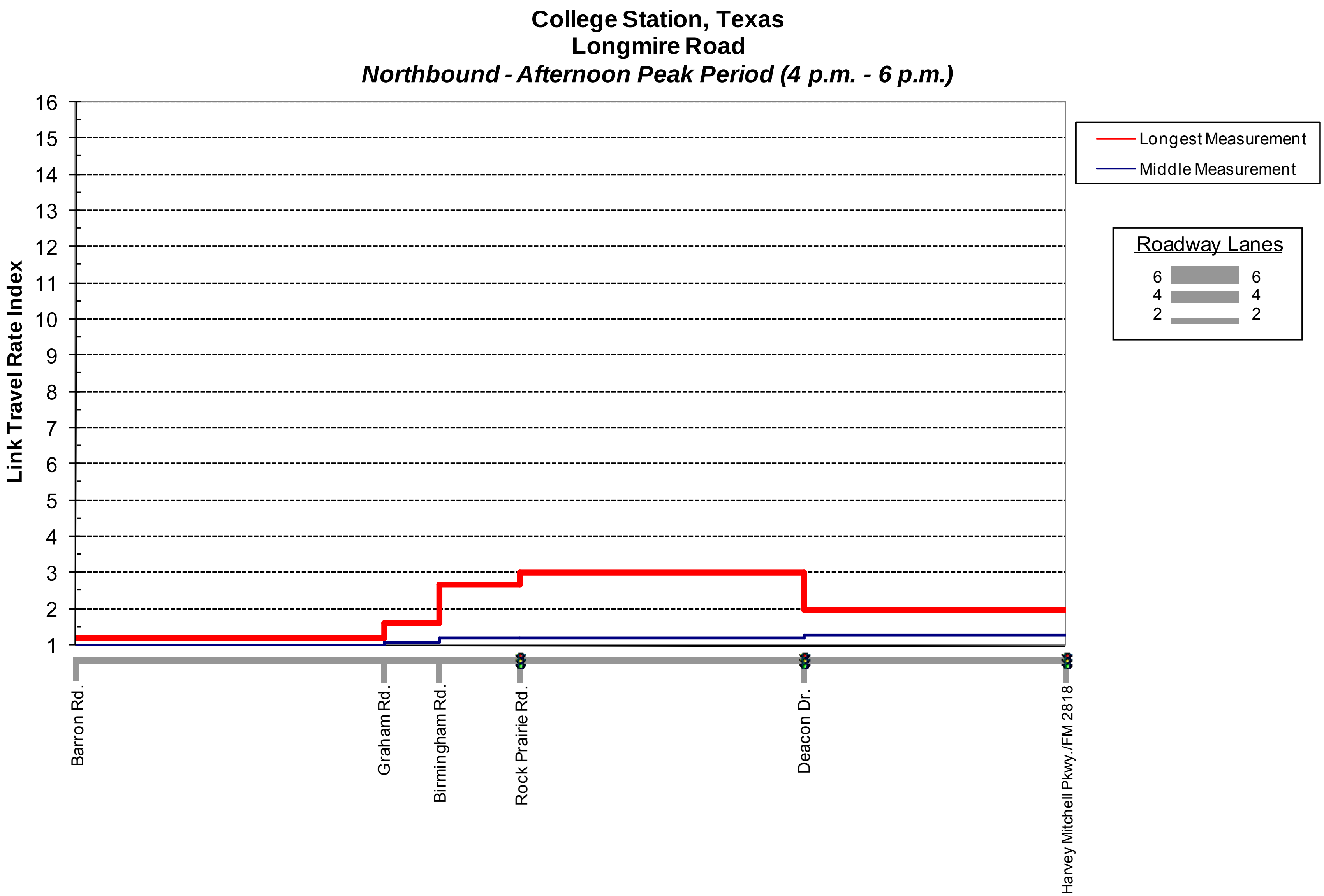


Figure D-6. Link Travel Rate Index for Longmire Road, Northbound - Afternoon.

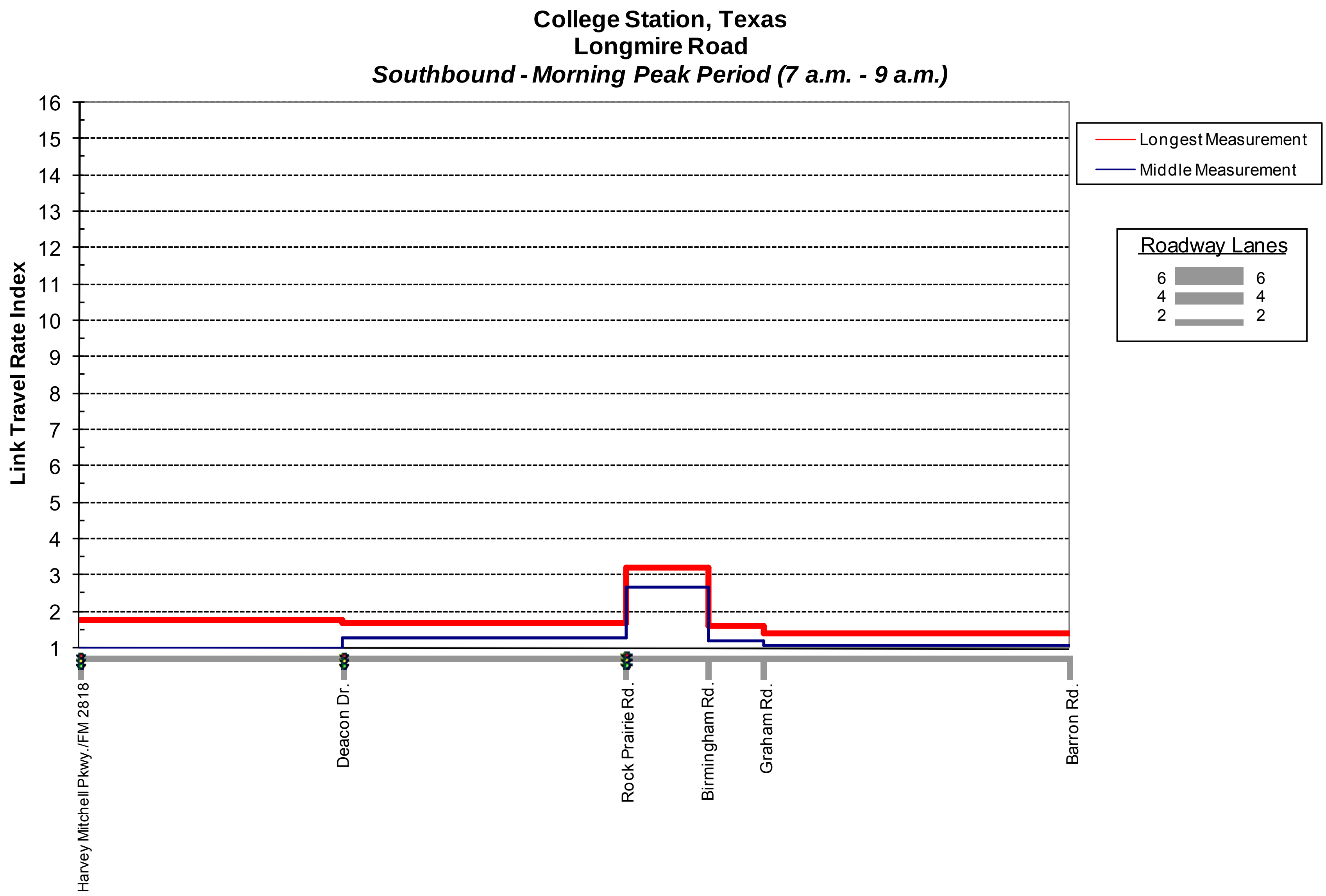


Figure D-7. Link Travel Rate Index for Longmire Road, Southbound - Morning

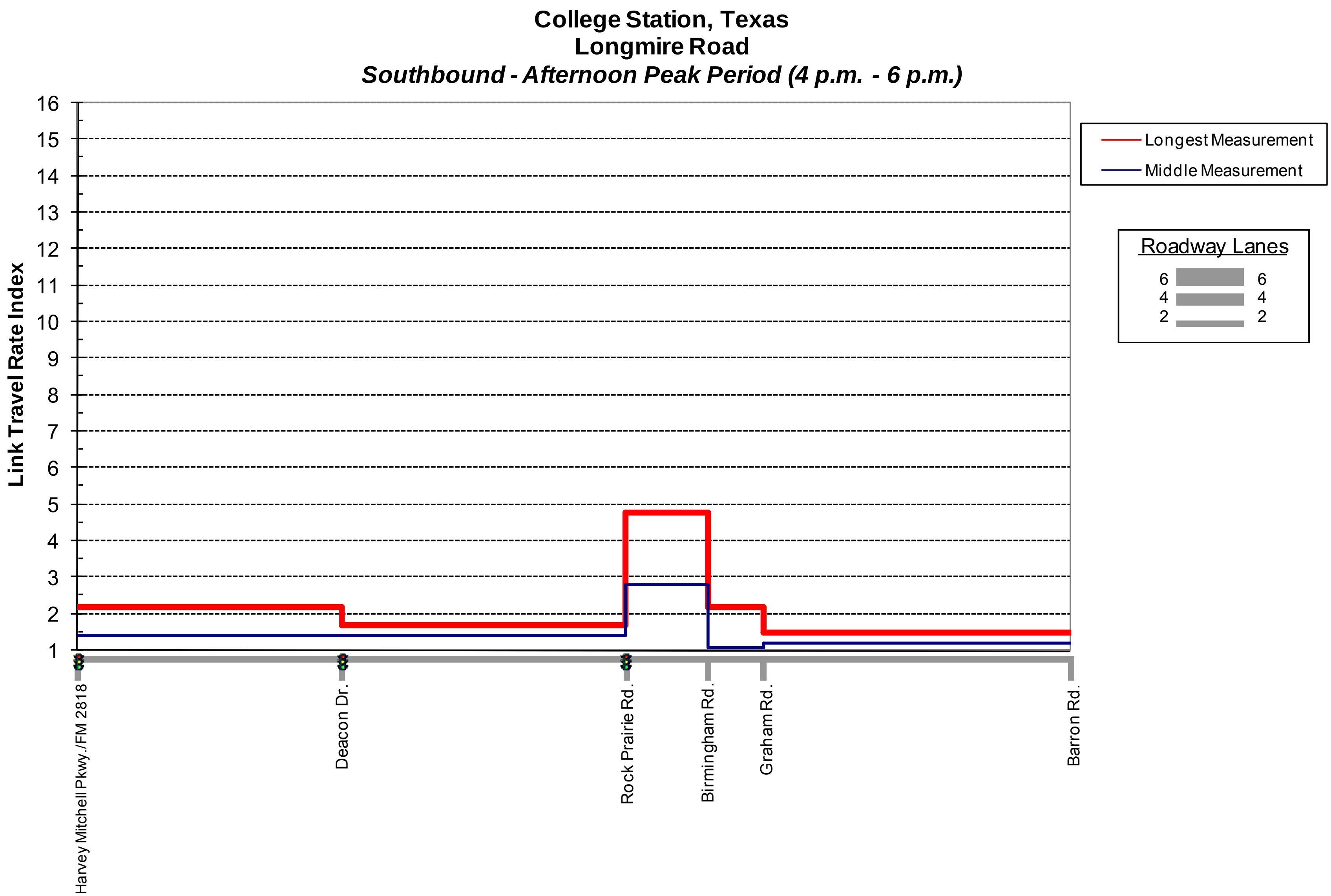


Figure D-8. Link Travel Rate Index for Longmire Road, Southbound - Afternoon.

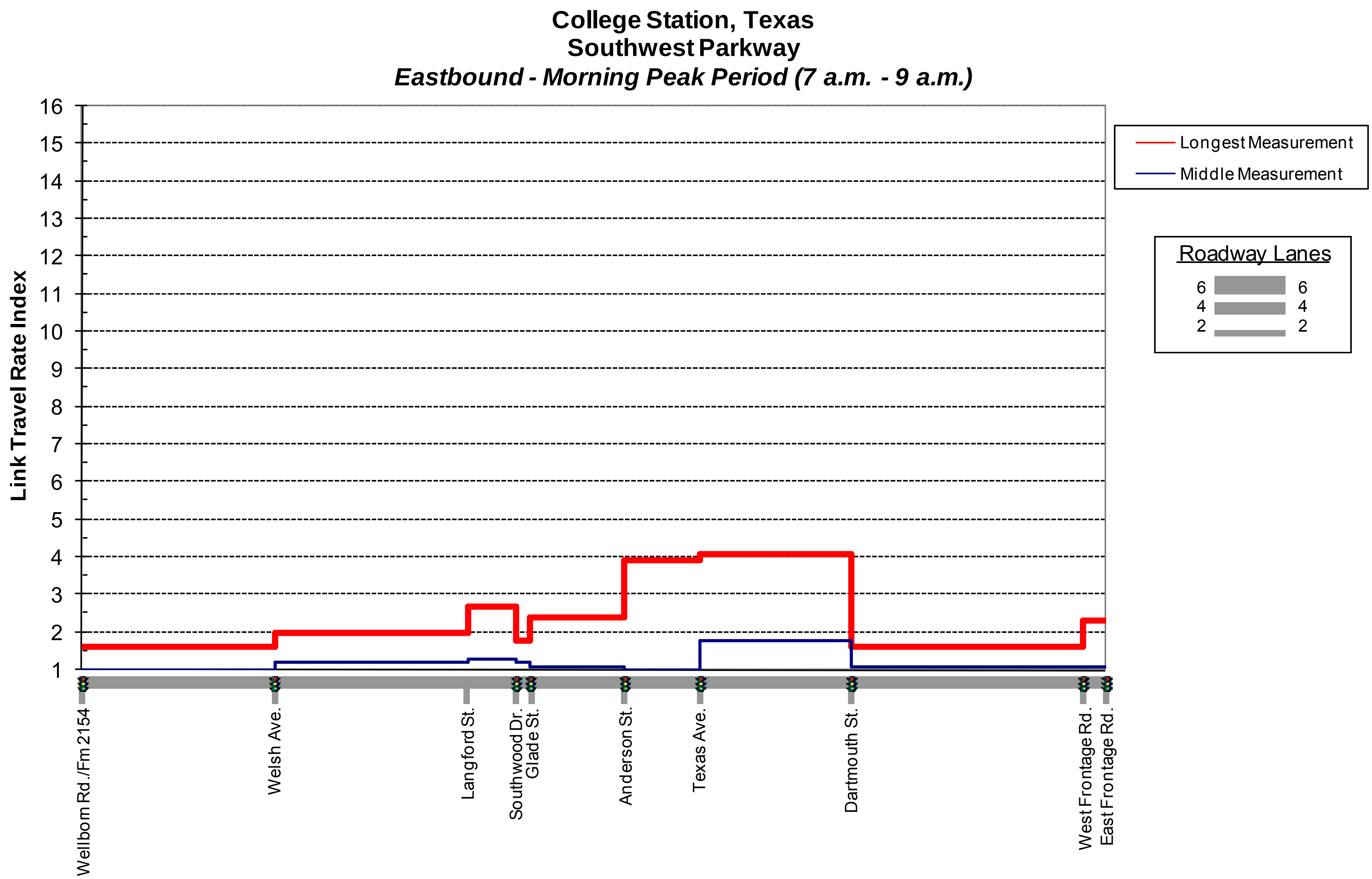


Figure D-9. Link Travel Rate Index for Southwest Parkway, Eastbound - Morning

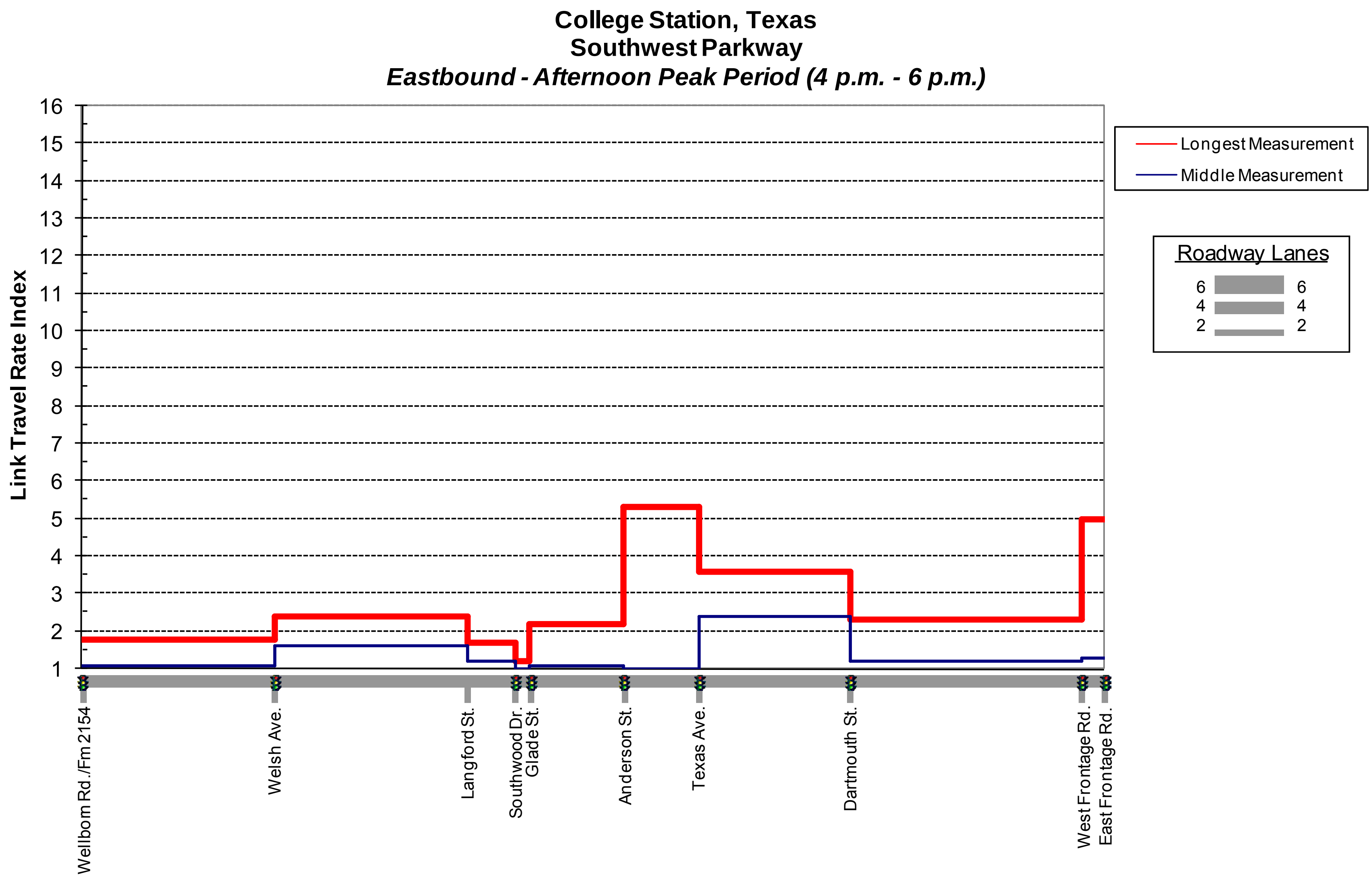


Figure D-10. Link Travel Rate Index for Southwest Parkway, Eastbound - Afternoon.

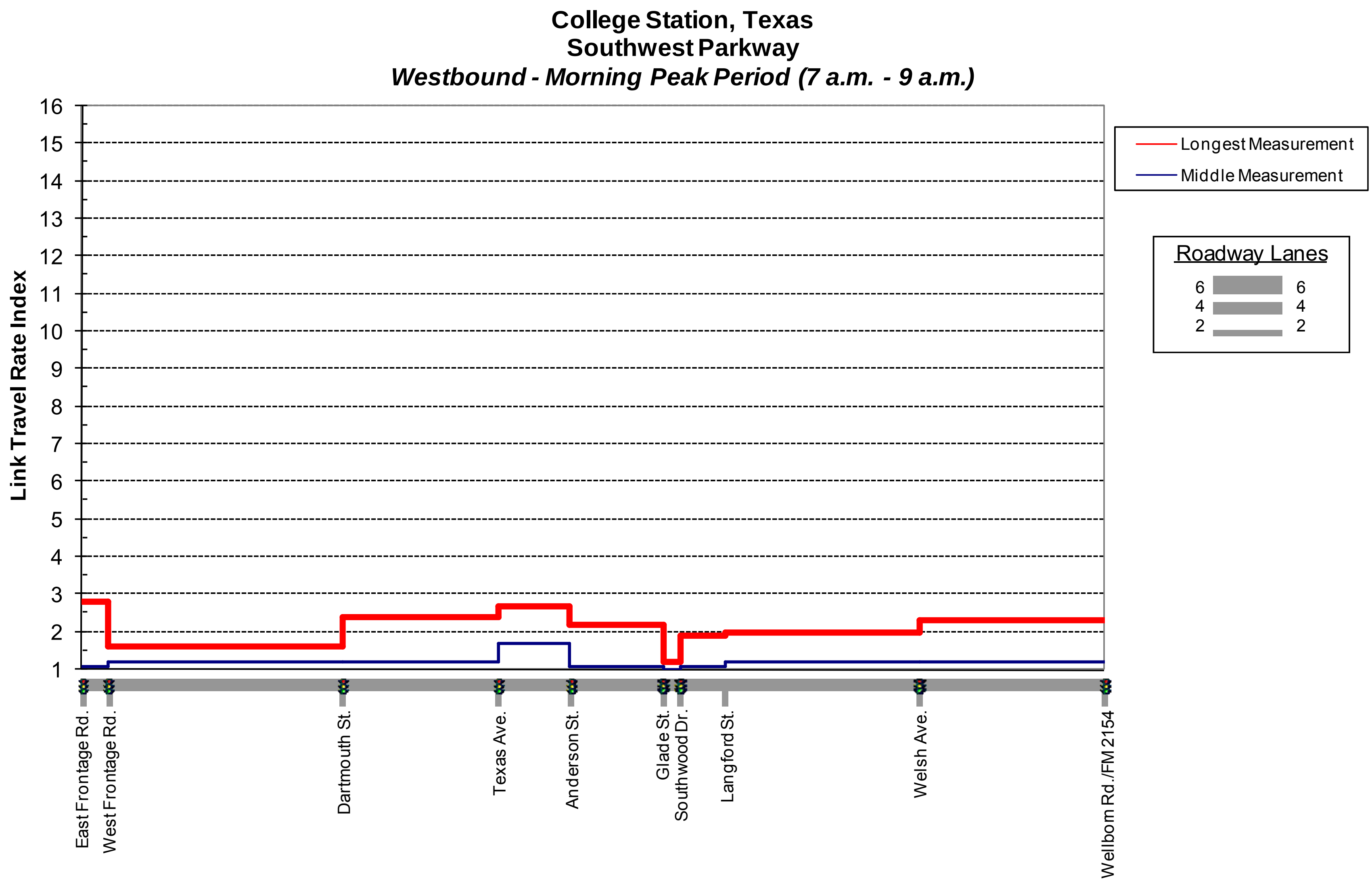


Figure D-11. Link Travel Rate Index for Southwest Parkway, Westbound - Morning

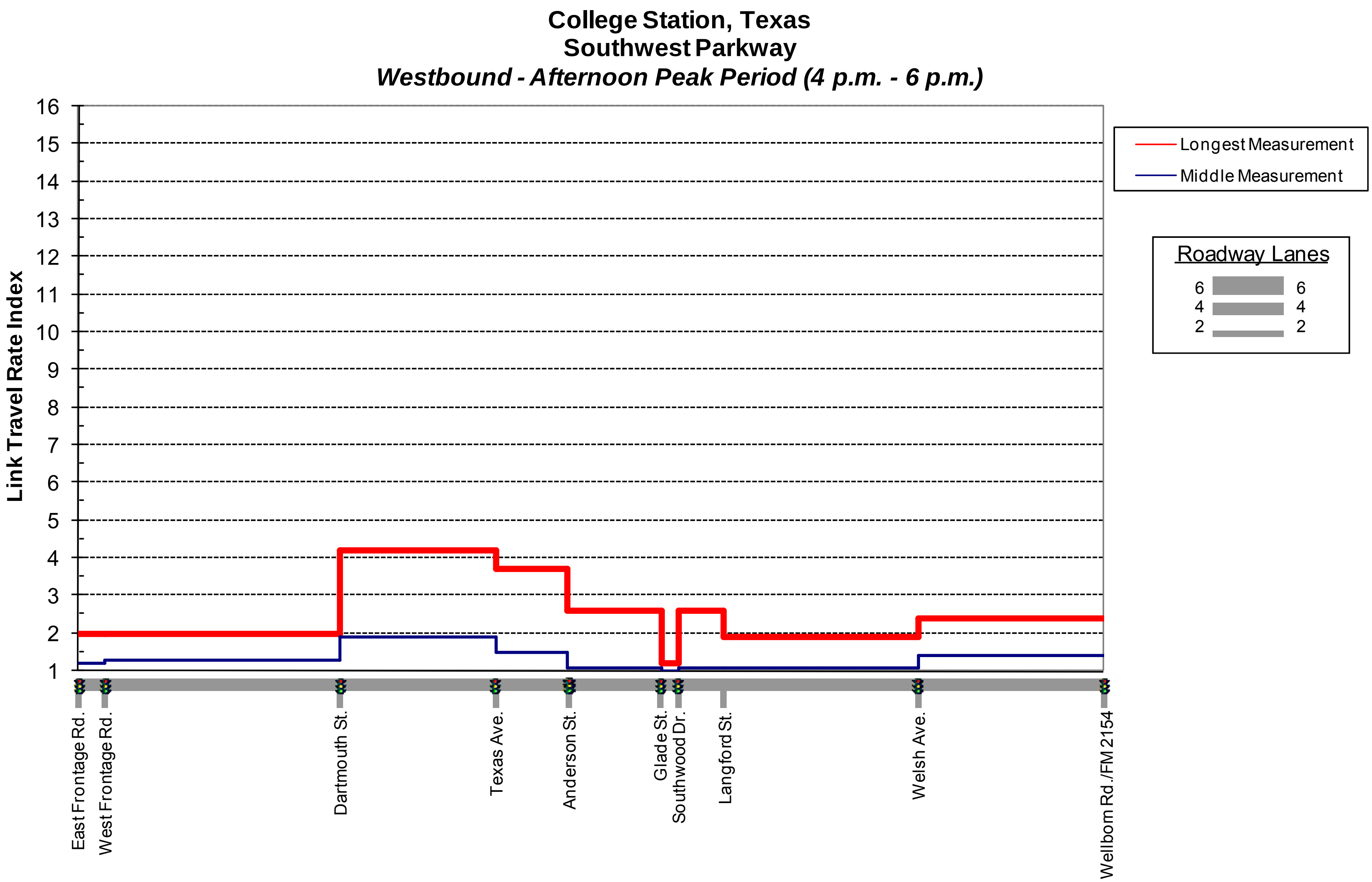


Figure D-12. Link Travel Rate Index for Southwest Parkway, Westbound - Afternoon.

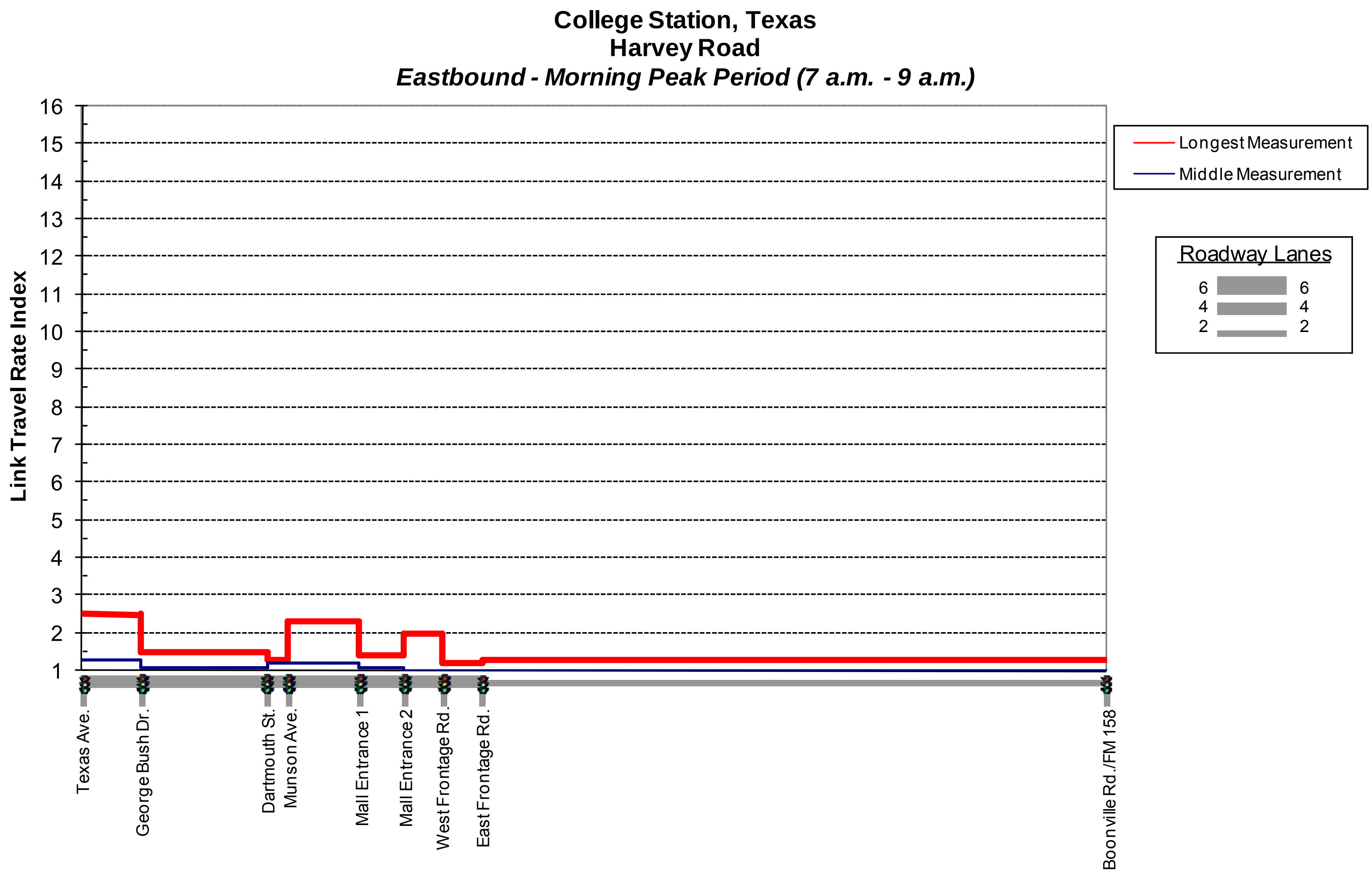


Figure D-13. Link Travel Rate Index for Harvey Road, Eastbound - Morning

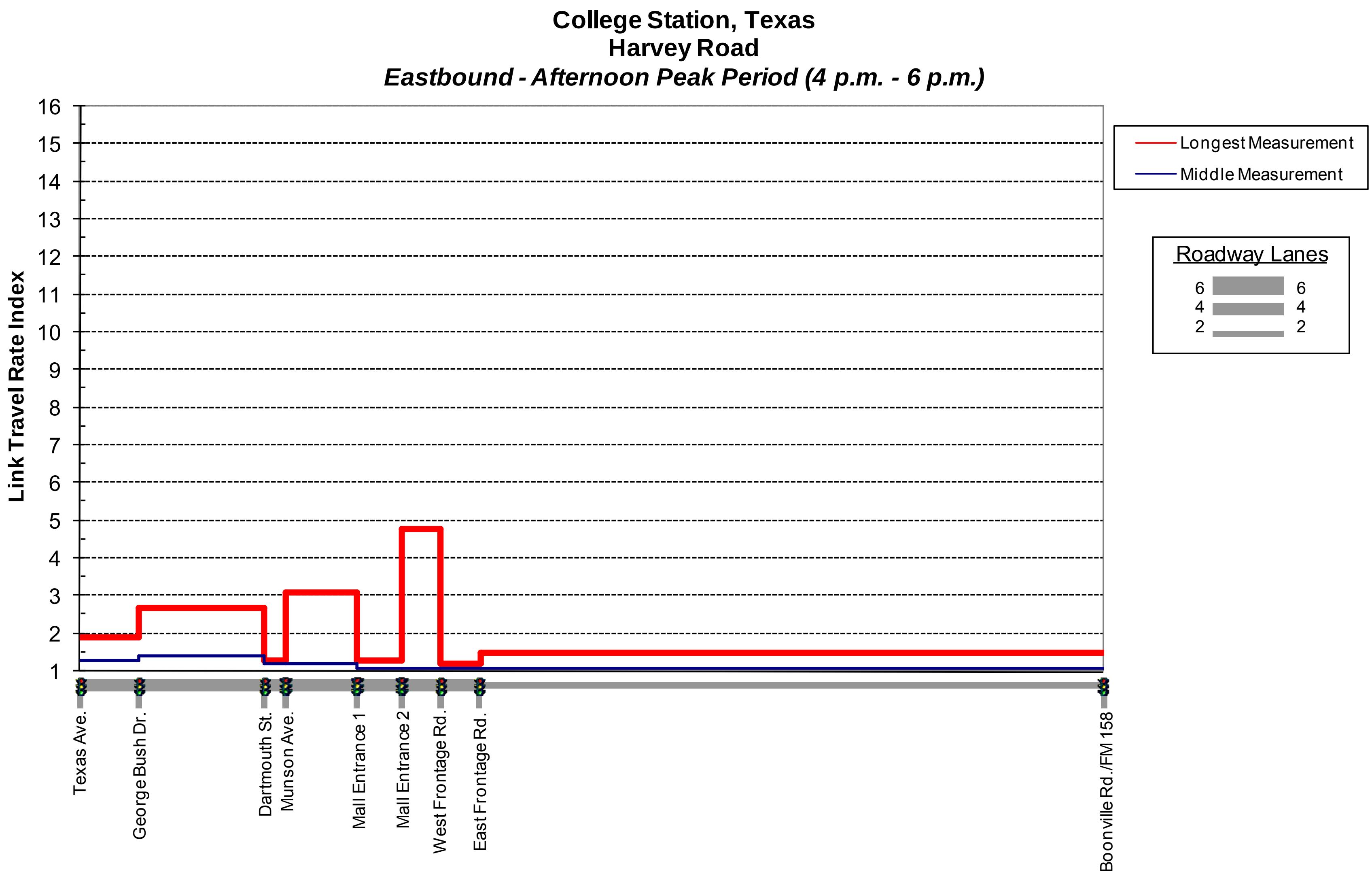


Figure D-14. Link Travel Rate Index for Harvey Road, Eastbound - Afternoon.

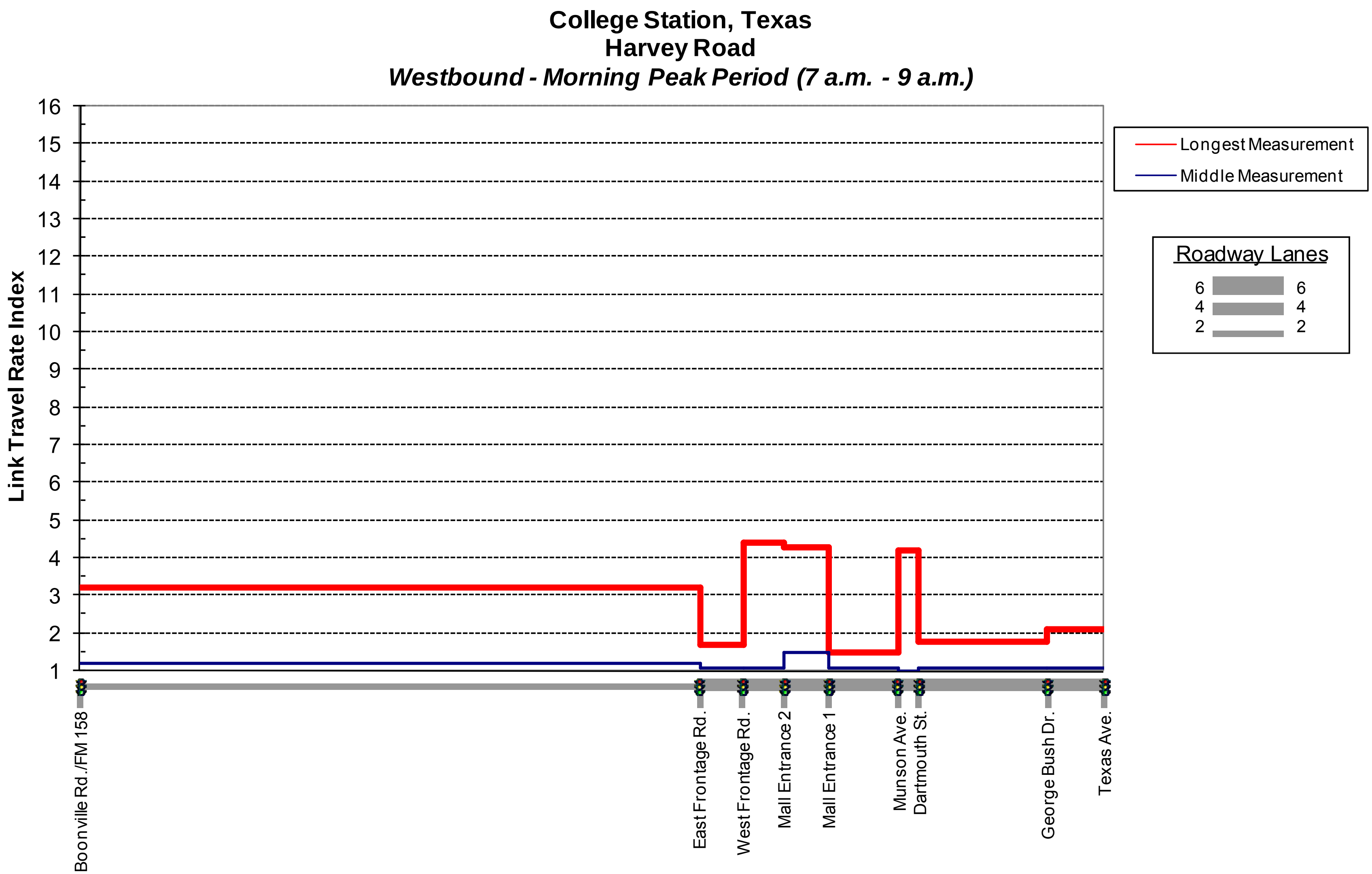


Figure D-15. Link Travel Rate Index for Harvey Road, Westbound - Morning

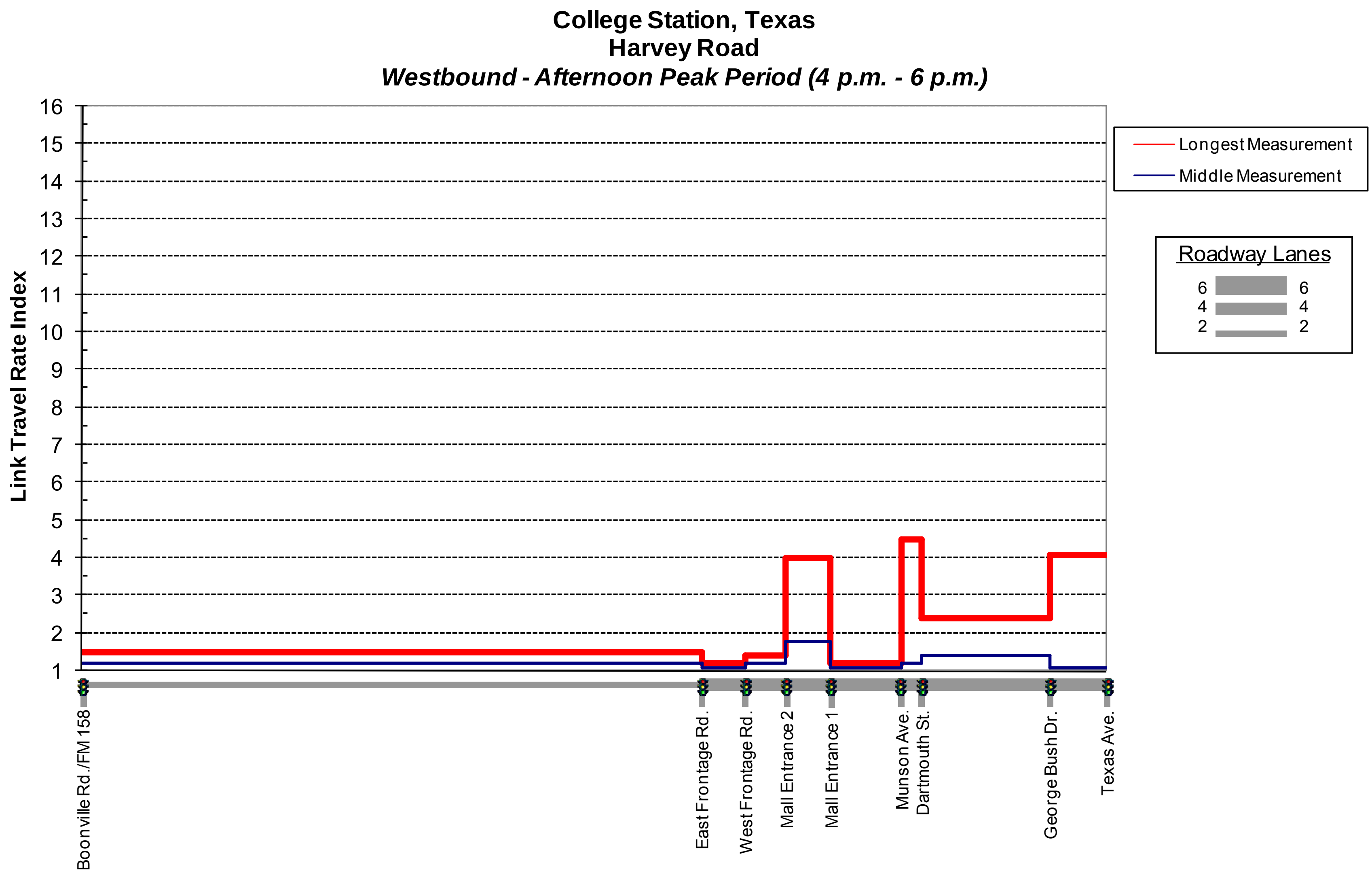


Figure D-16. Link Travel Rate Index for Harvey Road, Westbound - Afternoon.

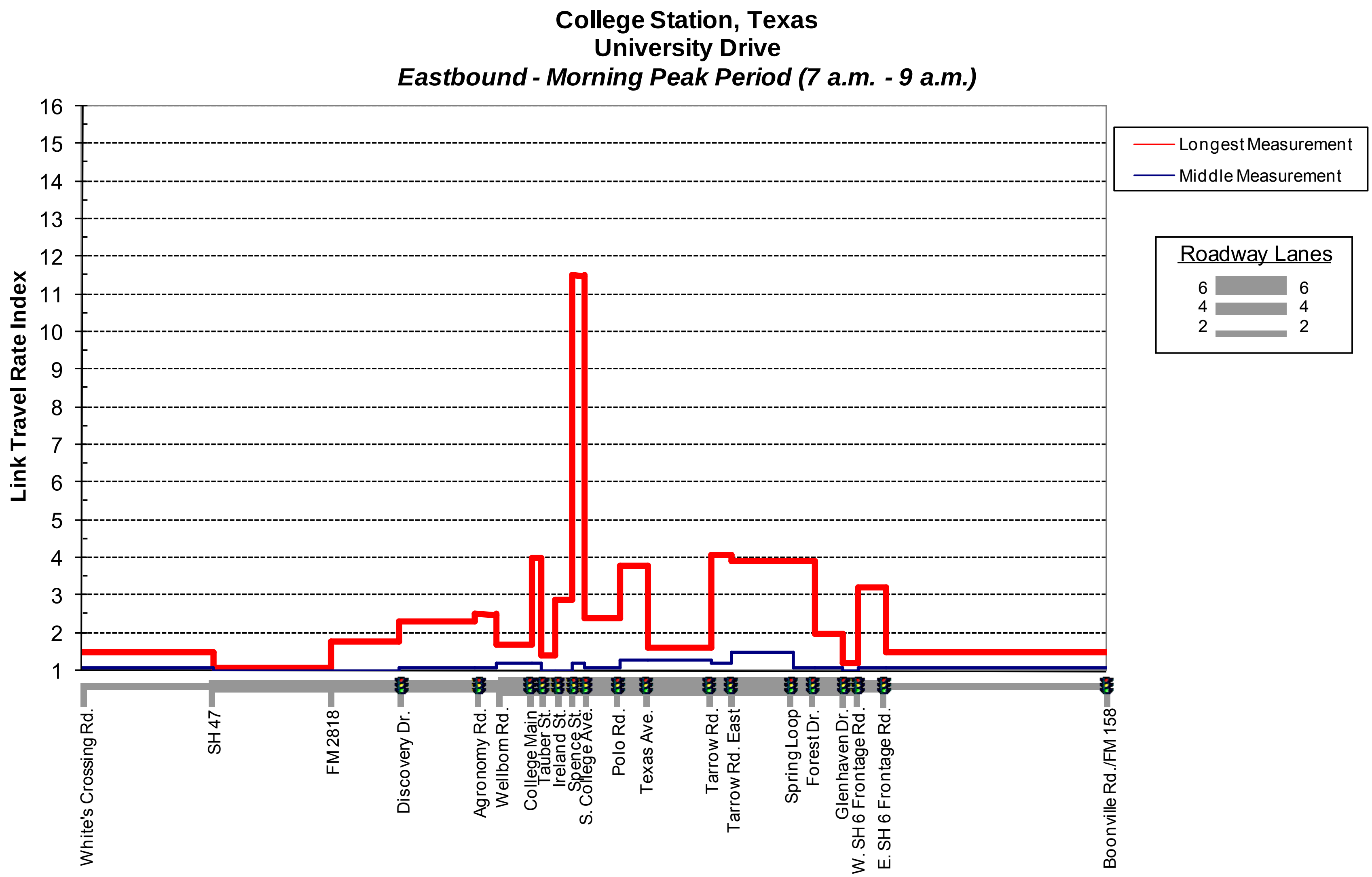


Figure D-17. Link Travel Rate Index for University Drive, Eastbound - Morning

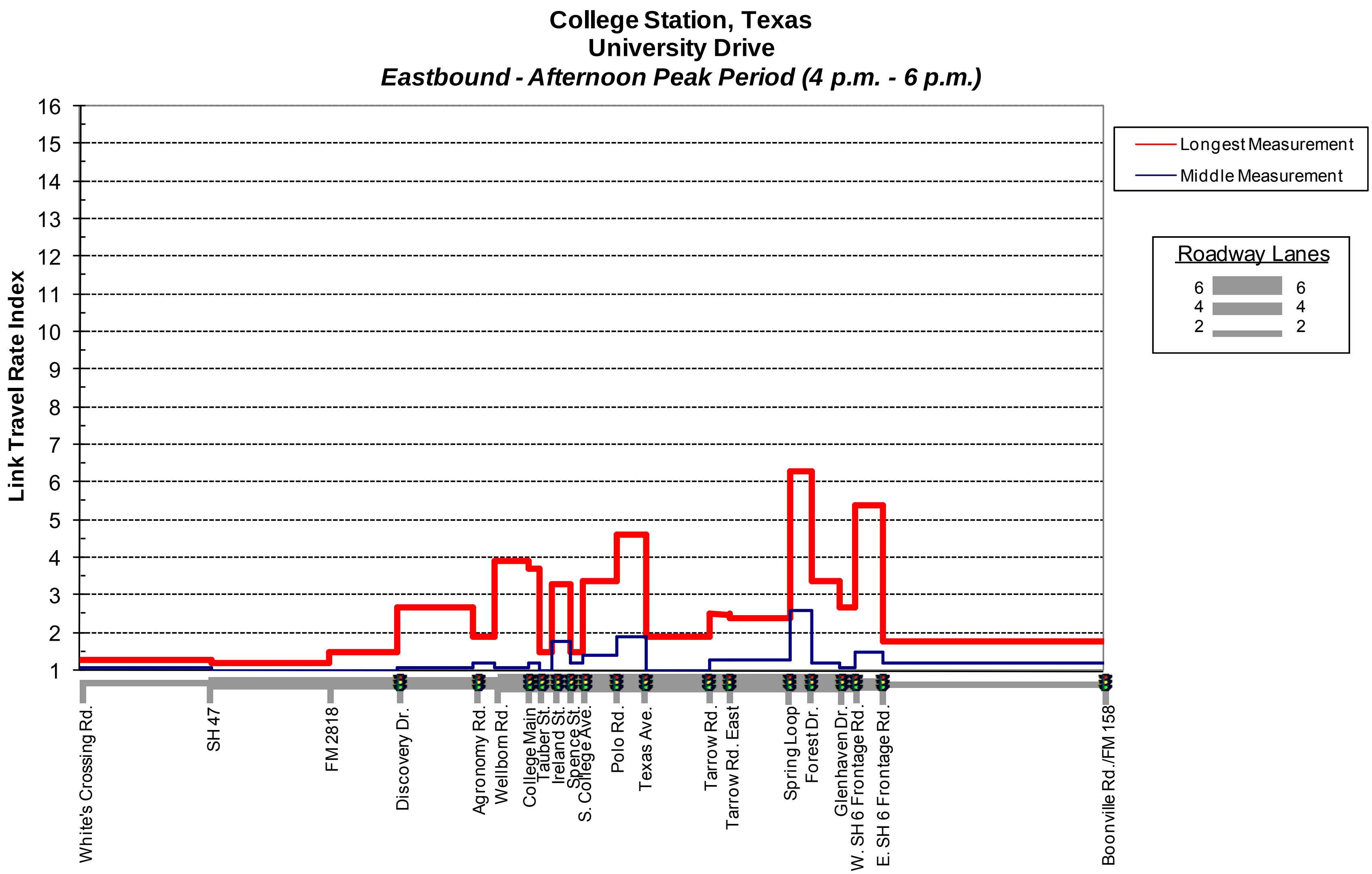


Figure D-18. Link Travel Rate Index for University Drive, Eastbound - Afternoon.

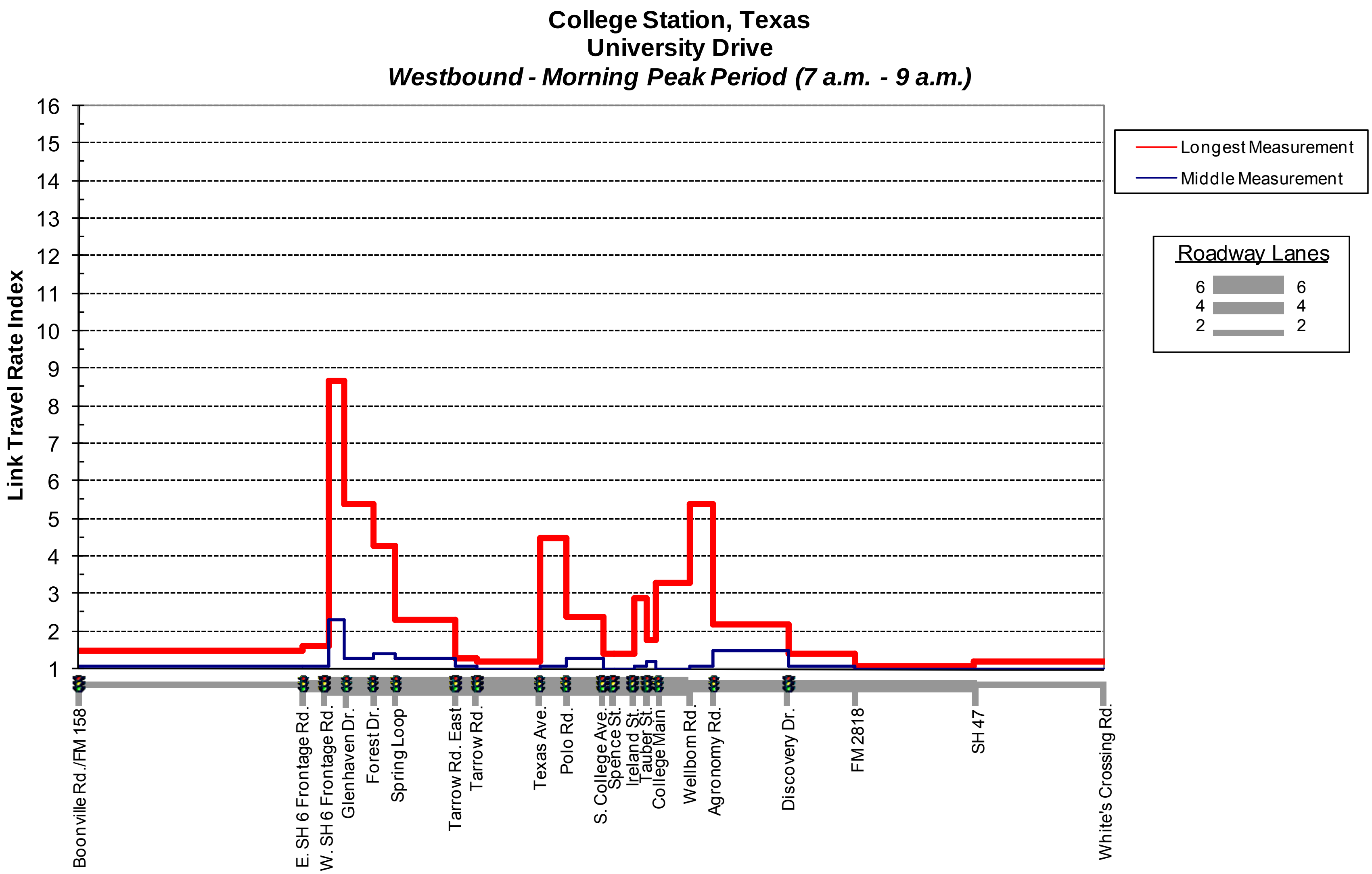


Figure D-19. Link Travel Rate Index for University Drive, Westbound - Morning

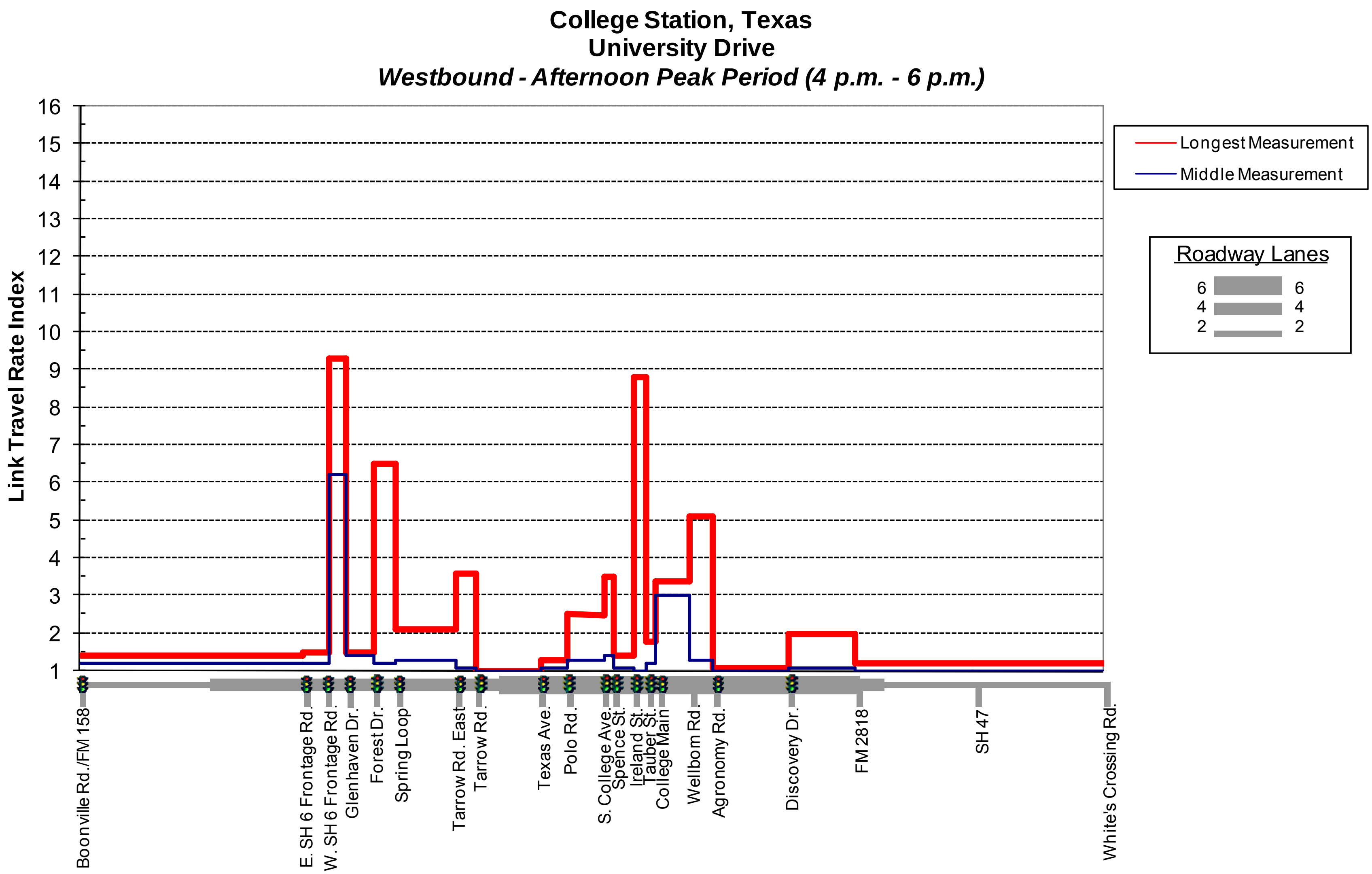


Figure D-20. Link Travel Rate Index for University Drive, Westbound - Afternoon.

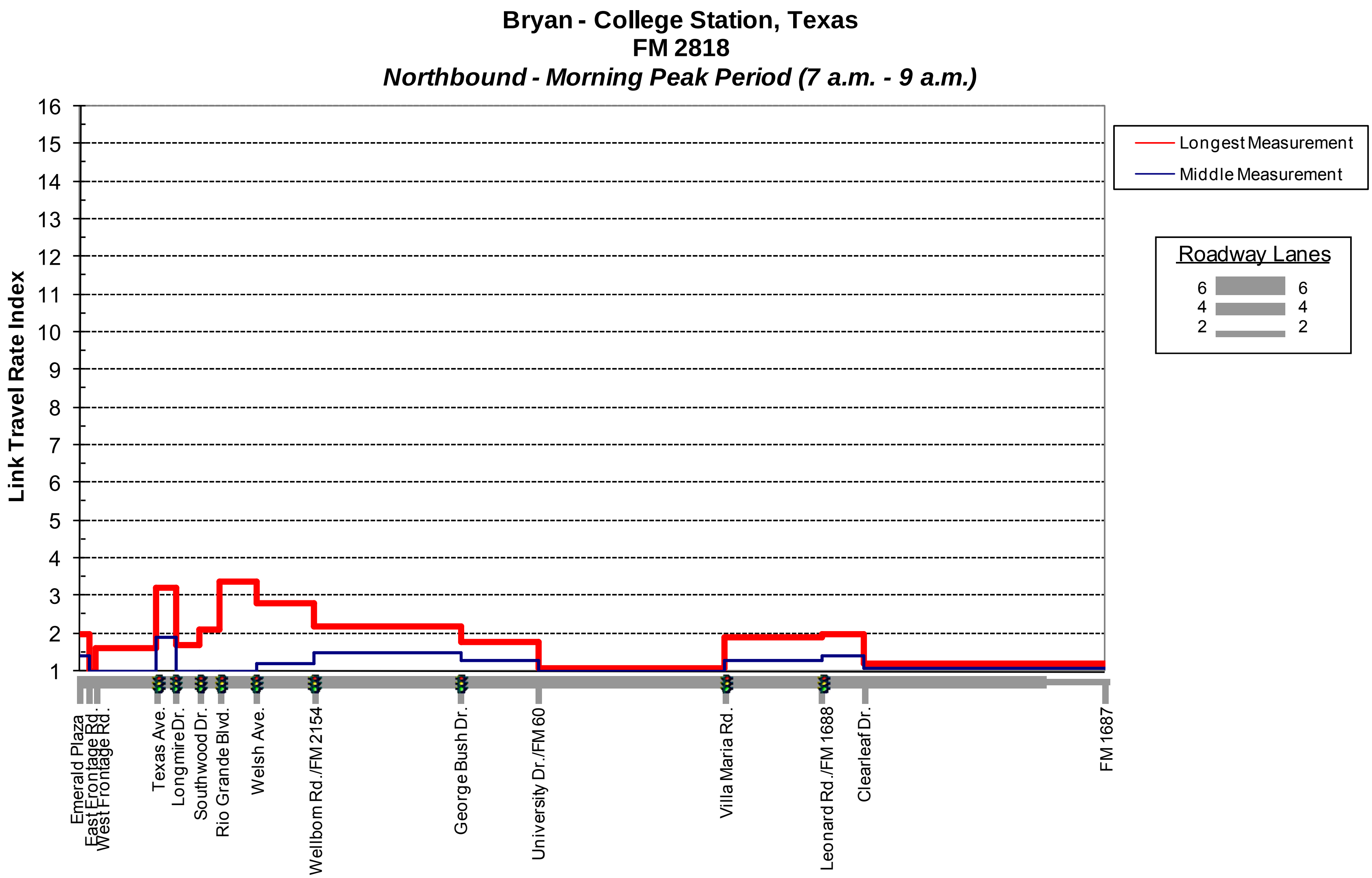


Figure D-21. Link Travel Rate Index for FM 2818, Northbound - Morning

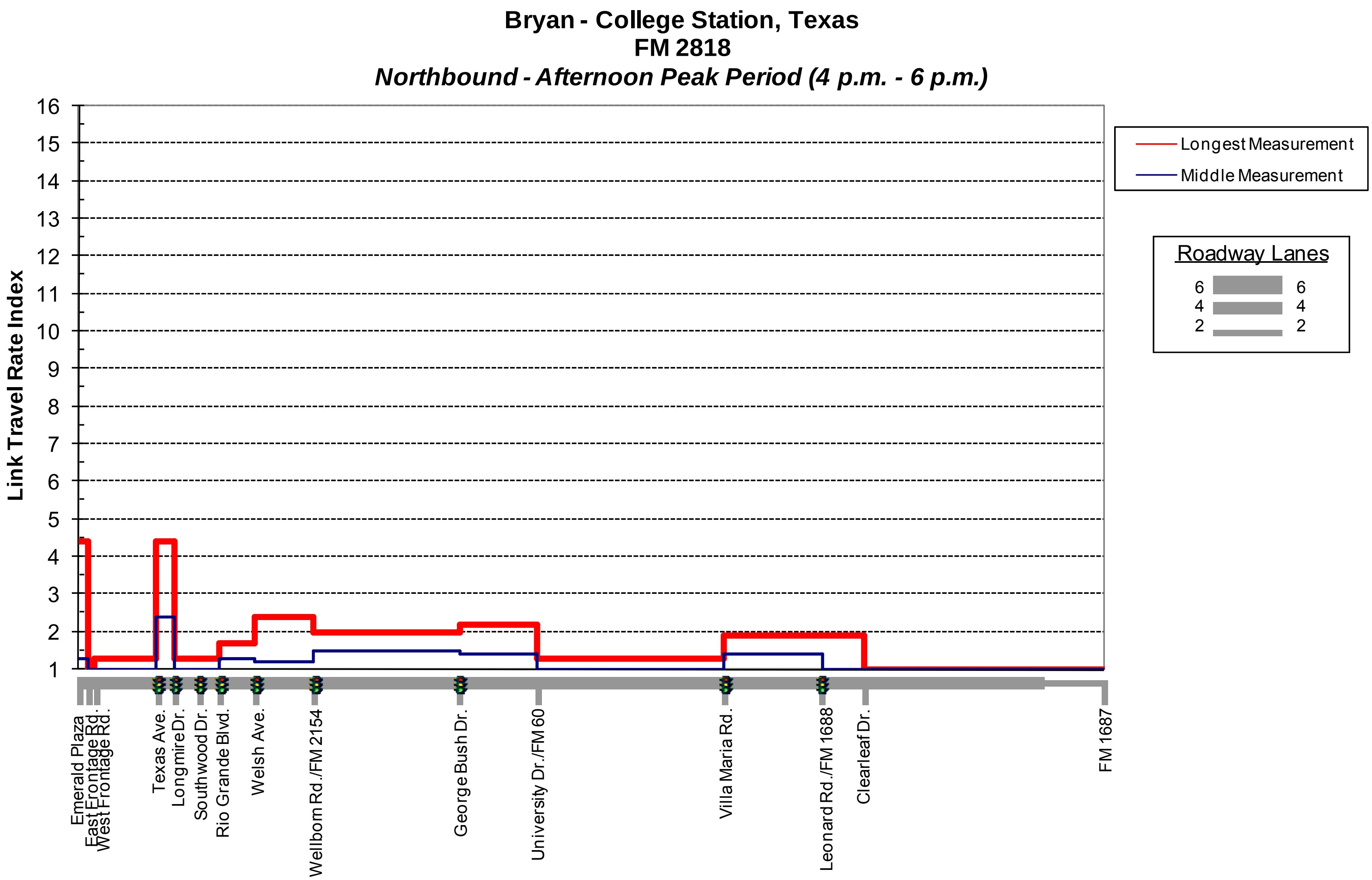


Figure D-22. Link Travel Rate Index for FM 2818, Northbound - Afternoon.

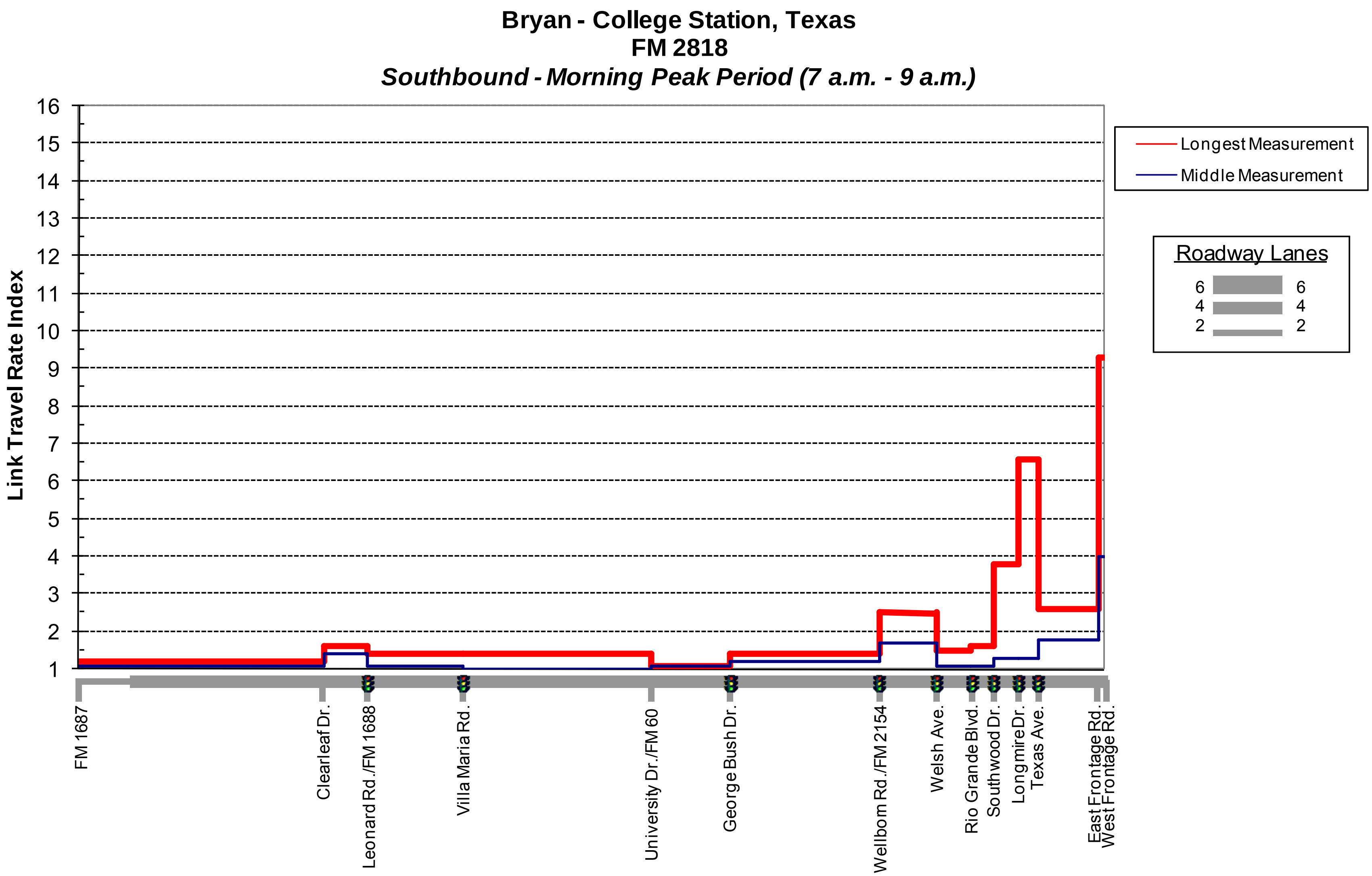


Figure D-23. Link Travel Rate Index for FM 2818, Southbound - Morning

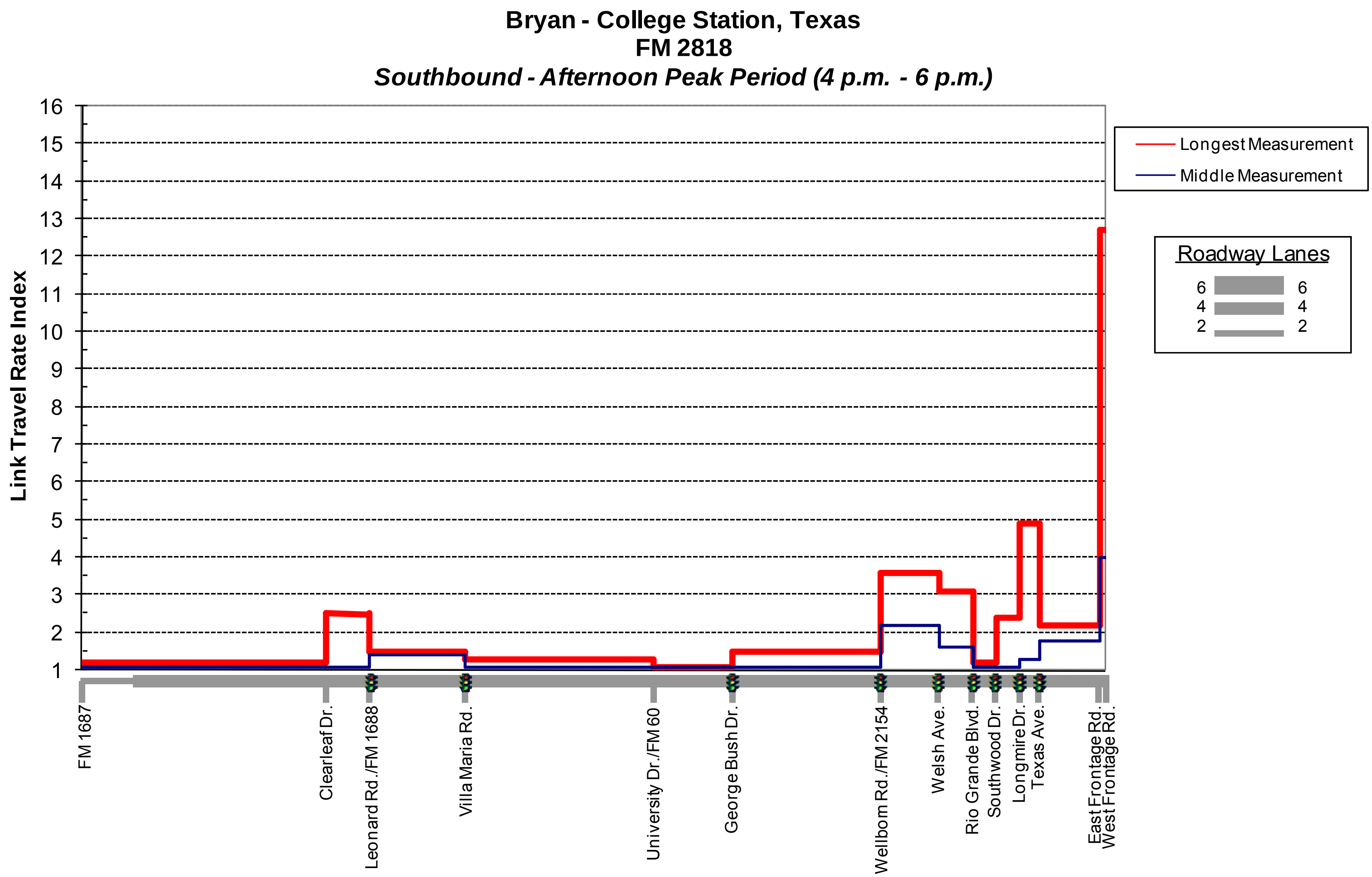


Figure D-24. Link Travel Rate Index for FM 2818, Southbound - Afternoon.

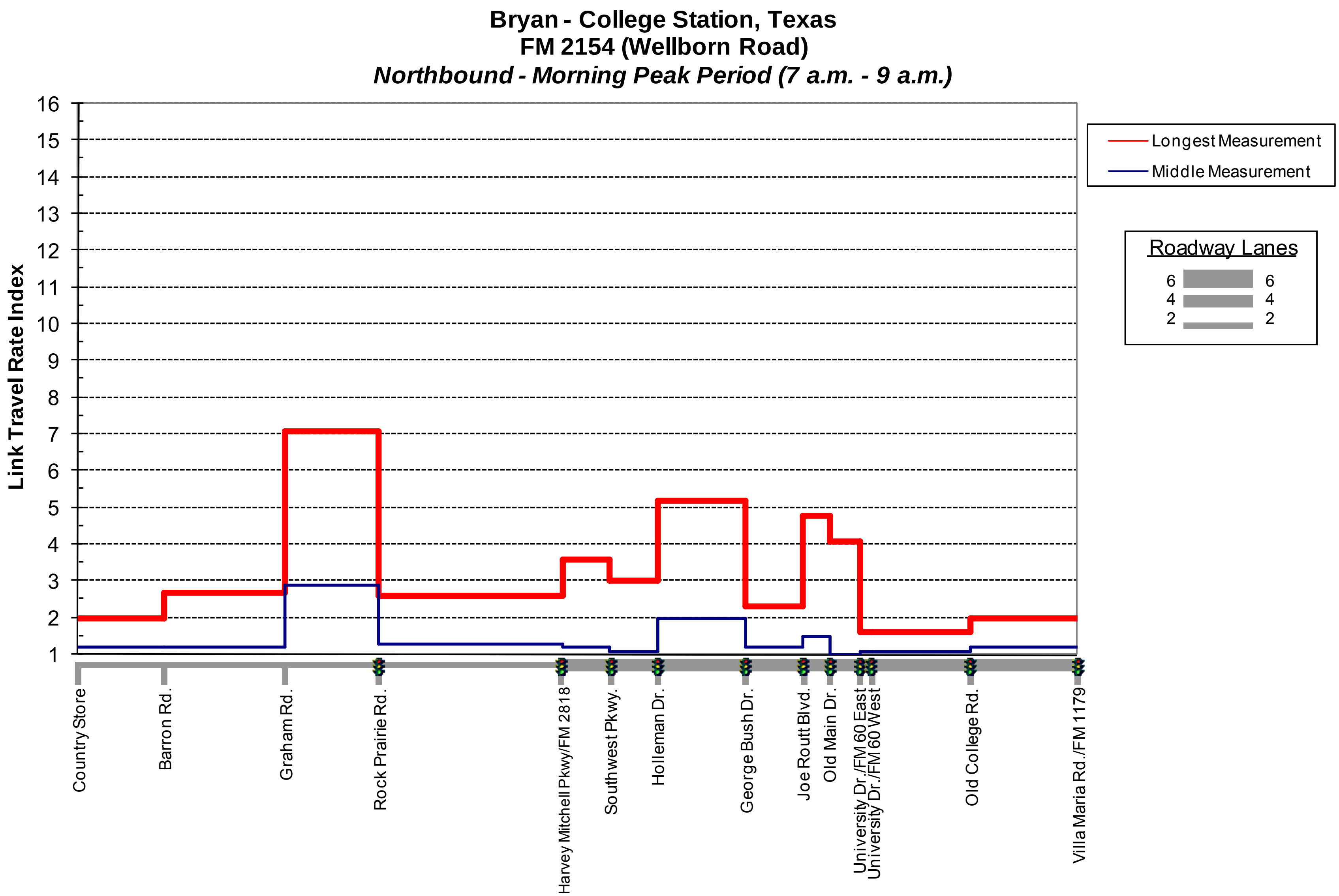


Figure D-25. Link Travel Rate Index for FM 2154 (Wellborn Road), Northbound - Morning

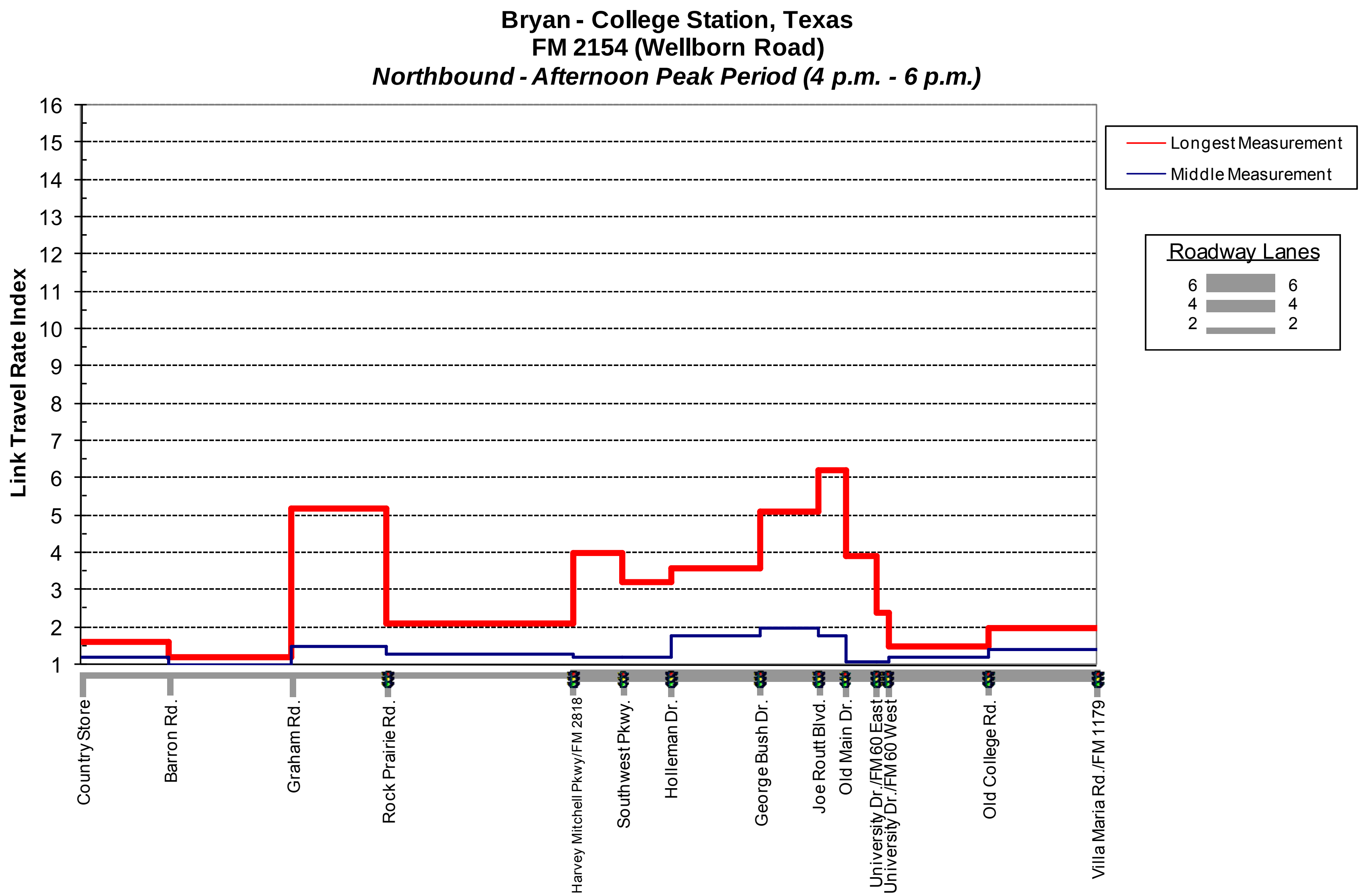


Figure D-26. Link Travel Rate Index for FM 2154 (Wellborn Road), Northbound - Afternoon.

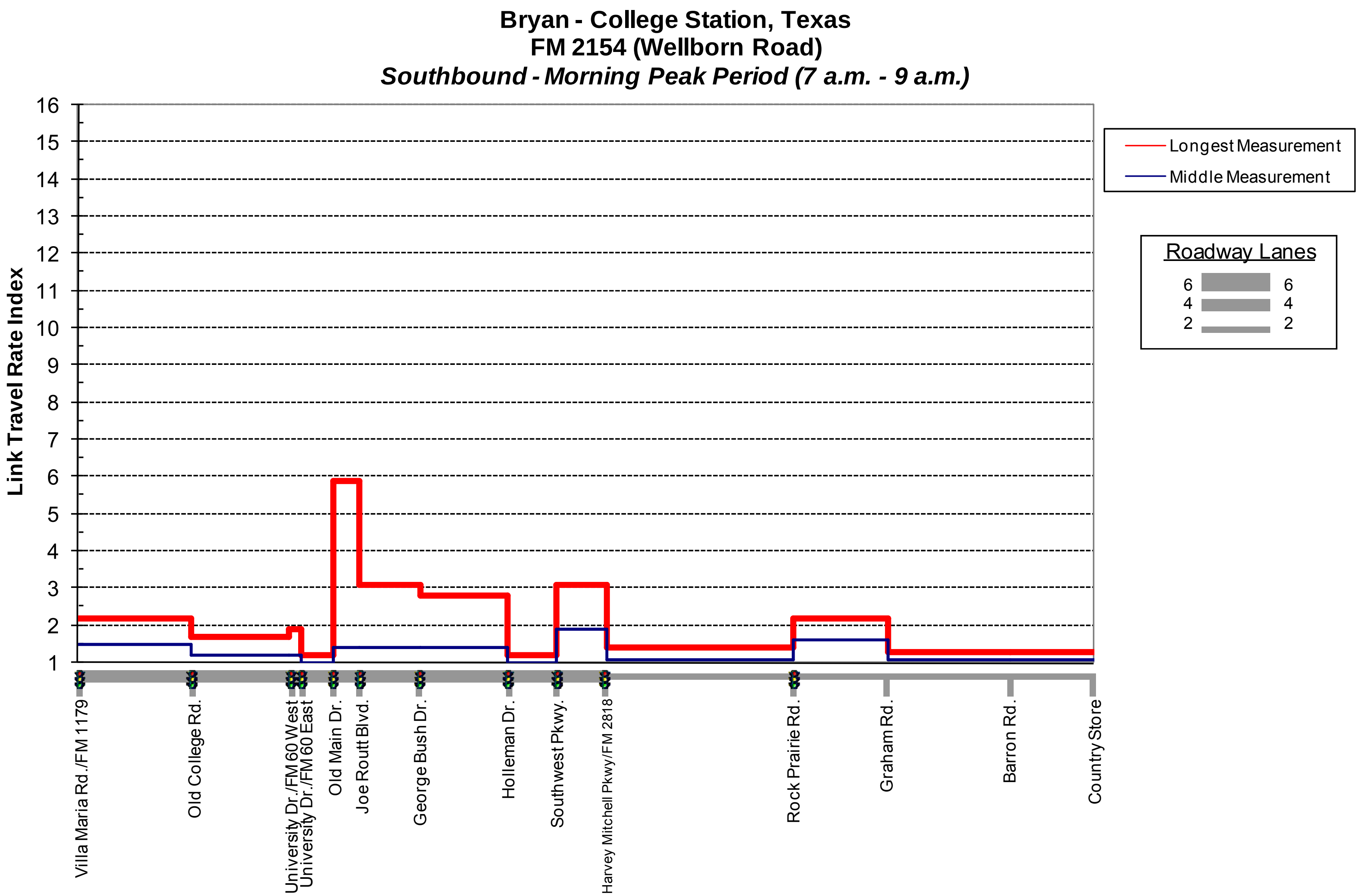


Figure D-27. Link Travel Rate Index for FM 2154 (Wellborn Road), Southbound - Morning

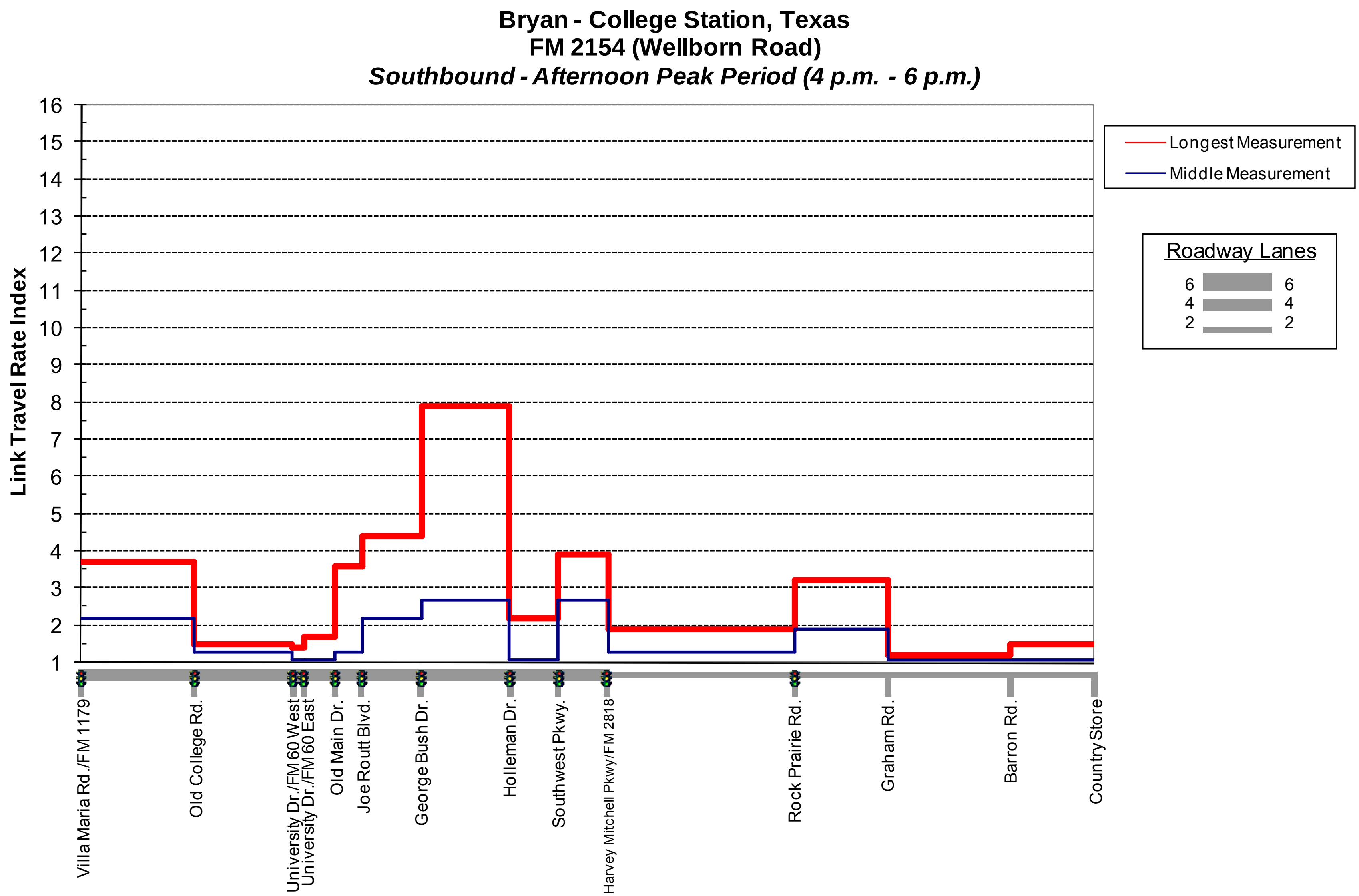


Figure D-28. Link Travel Rate Index for FM 2154 (Wellborn Road), Southbound - Afternoon.

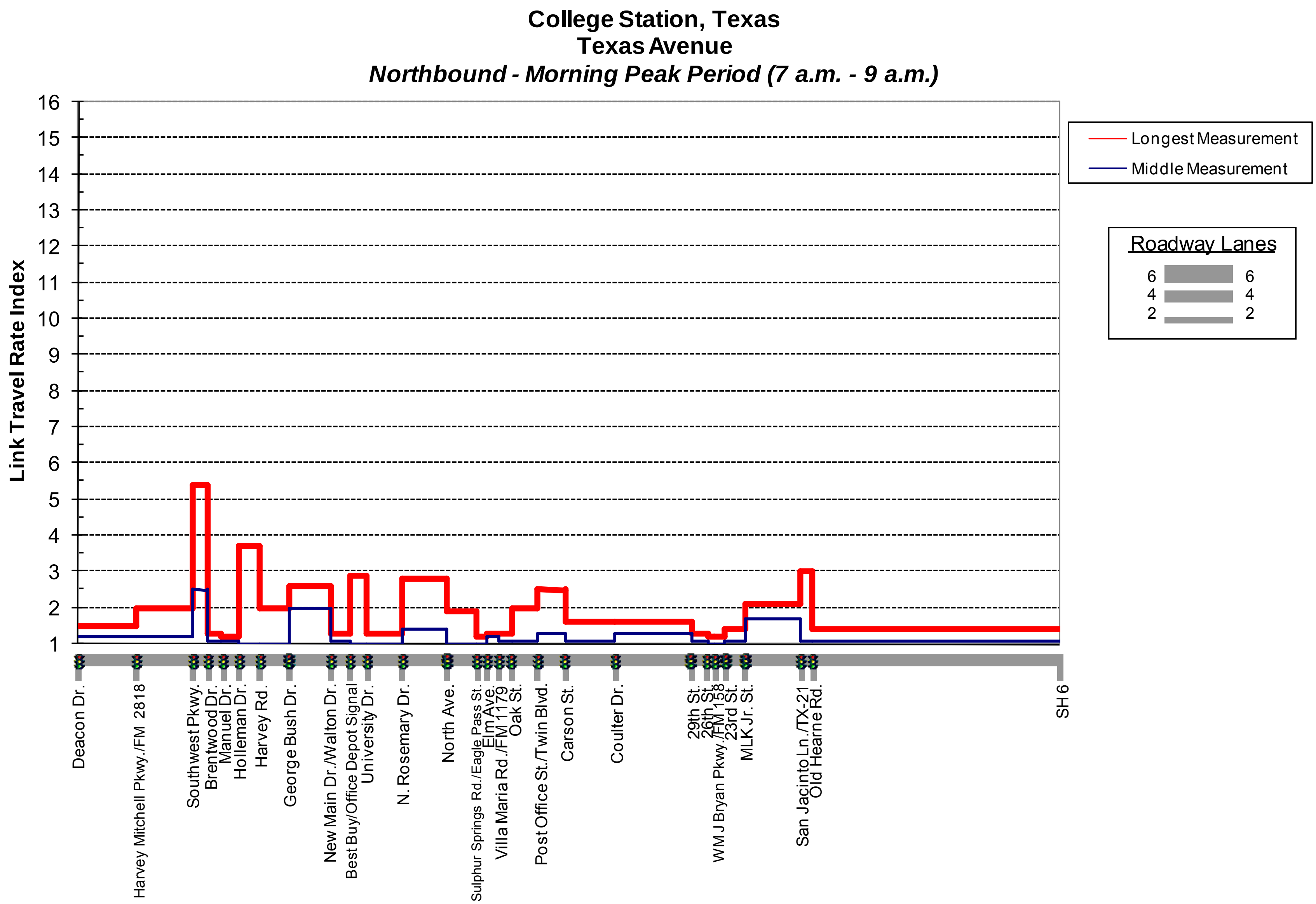


Figure D-29. Link Travel Rate Index for Texas Avenue, Northbound - Morning

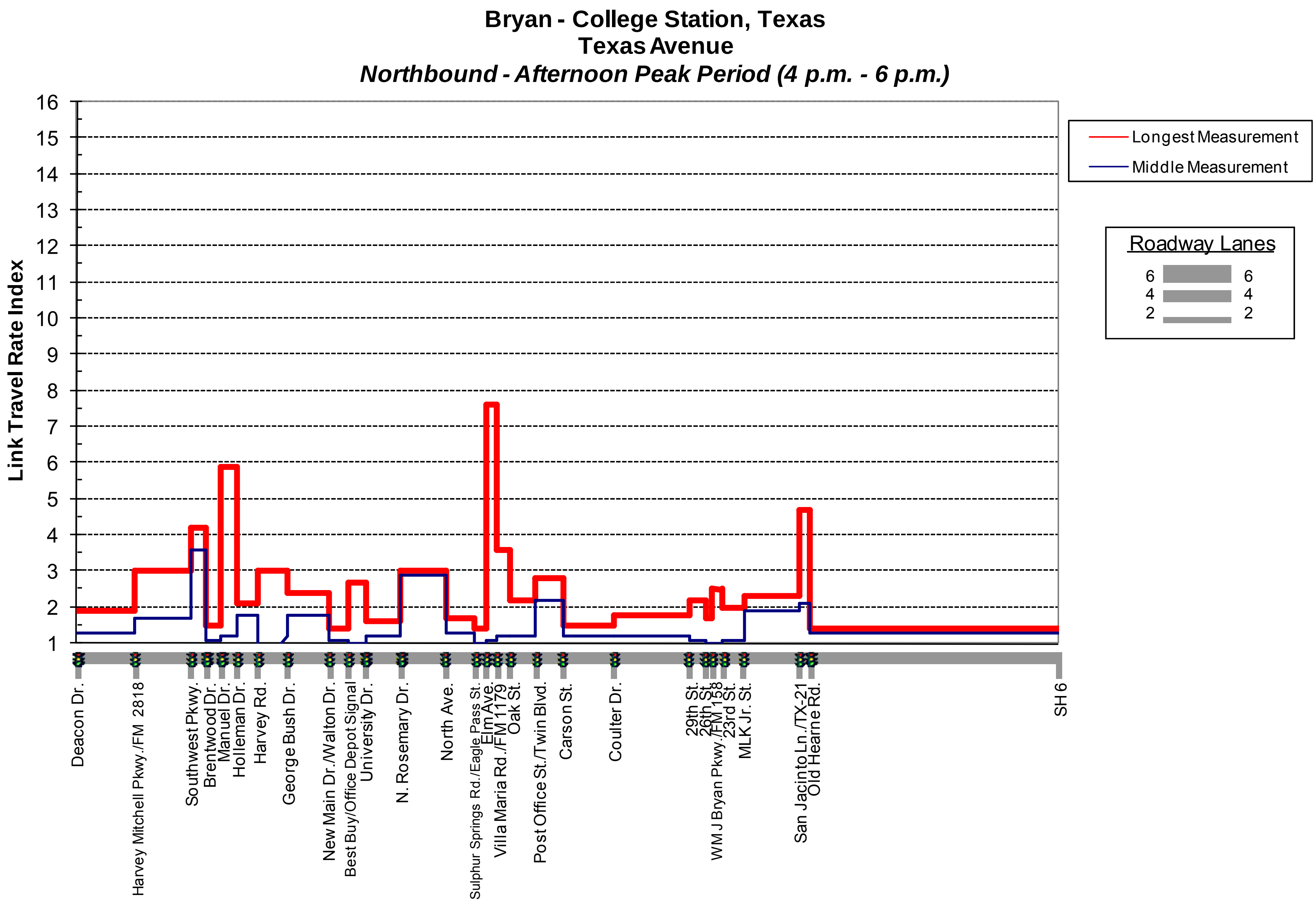


Figure D-30. Link Travel Rate Index for Texas Avenue, Northbound - Afternoon.

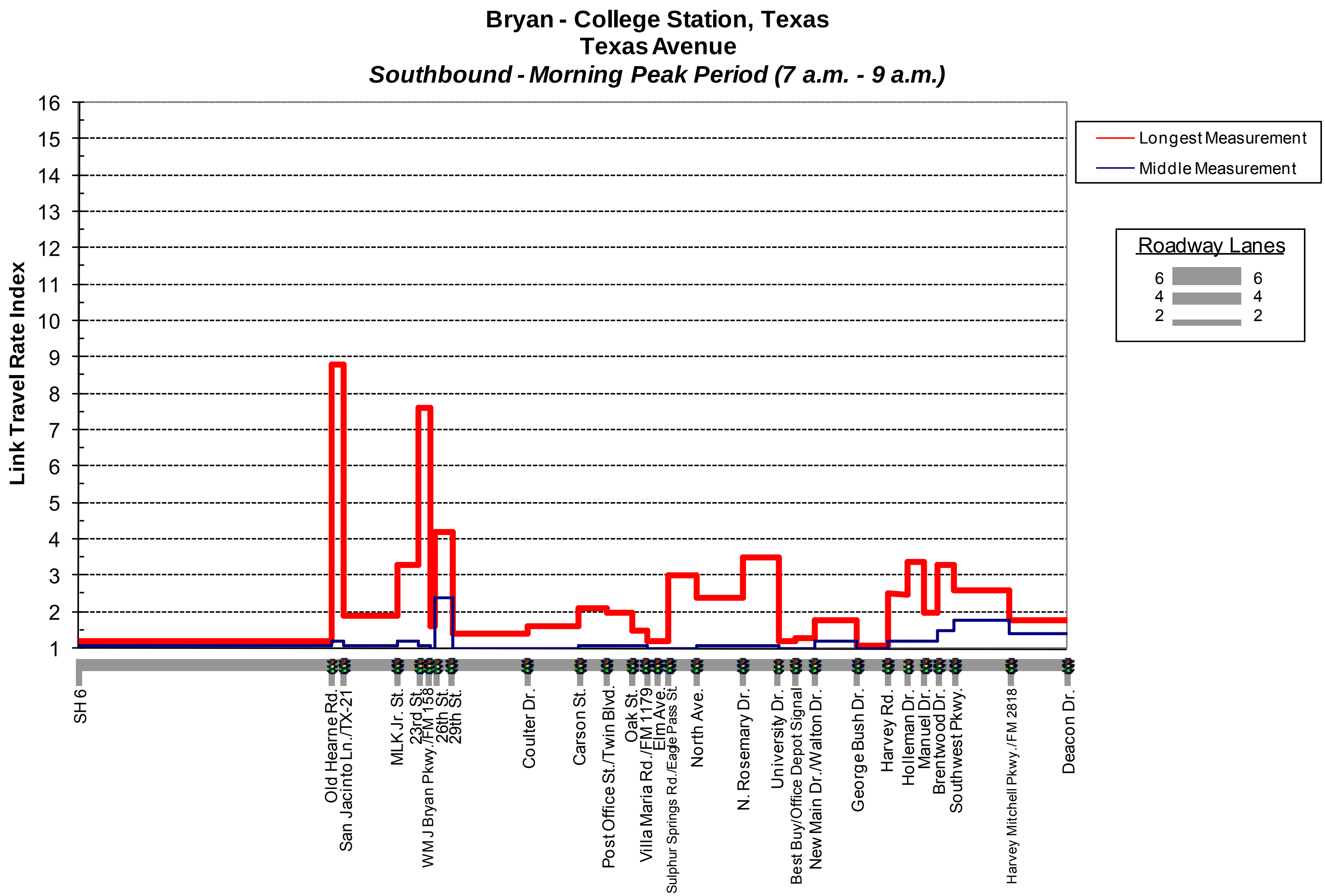


Figure D-31. Link Travel Rate Index for Texas Avenue, Southbound - Morning

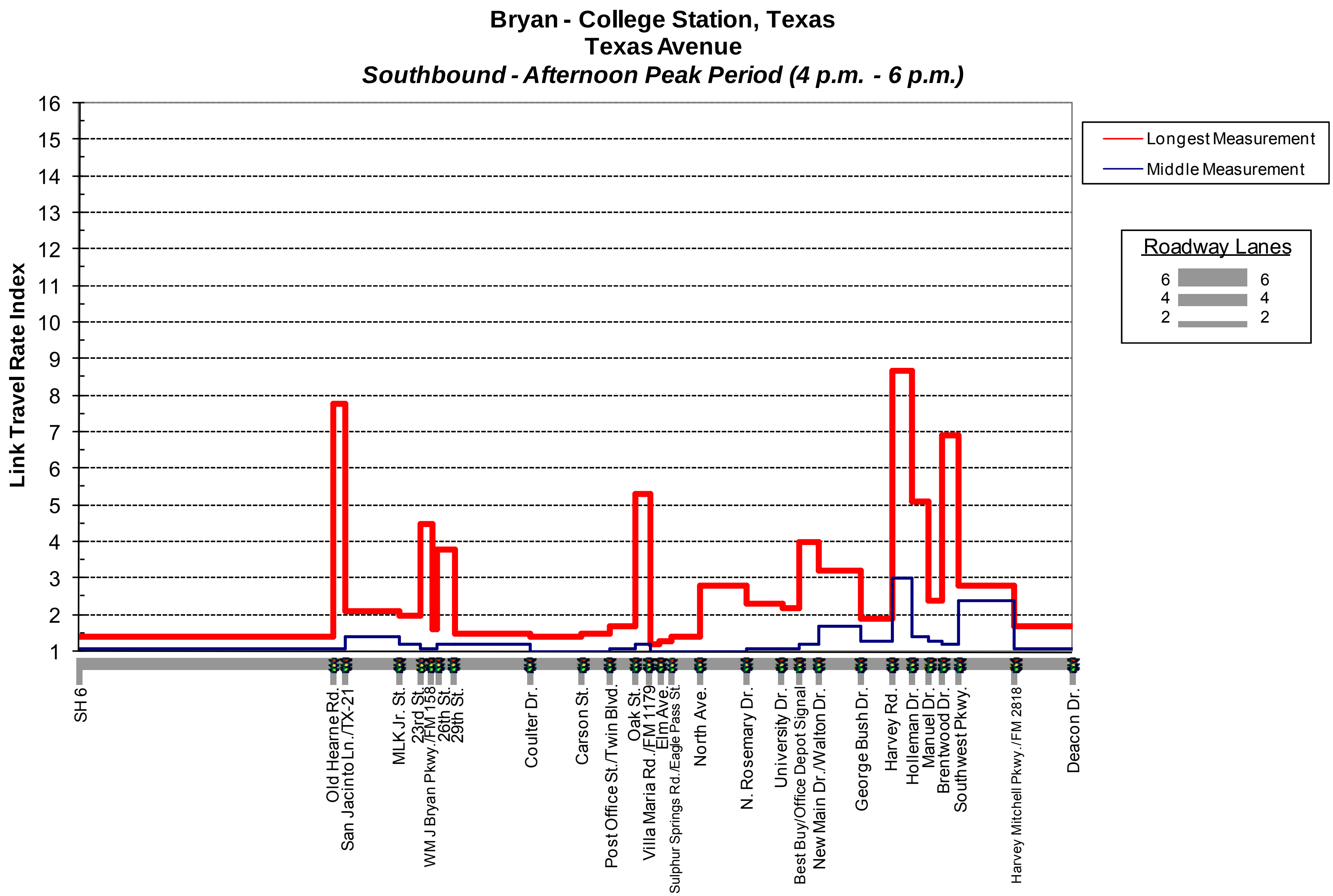


Figure D-32. Link Travel Rate Index for Texas Avenue, Southbound - Afternoon.

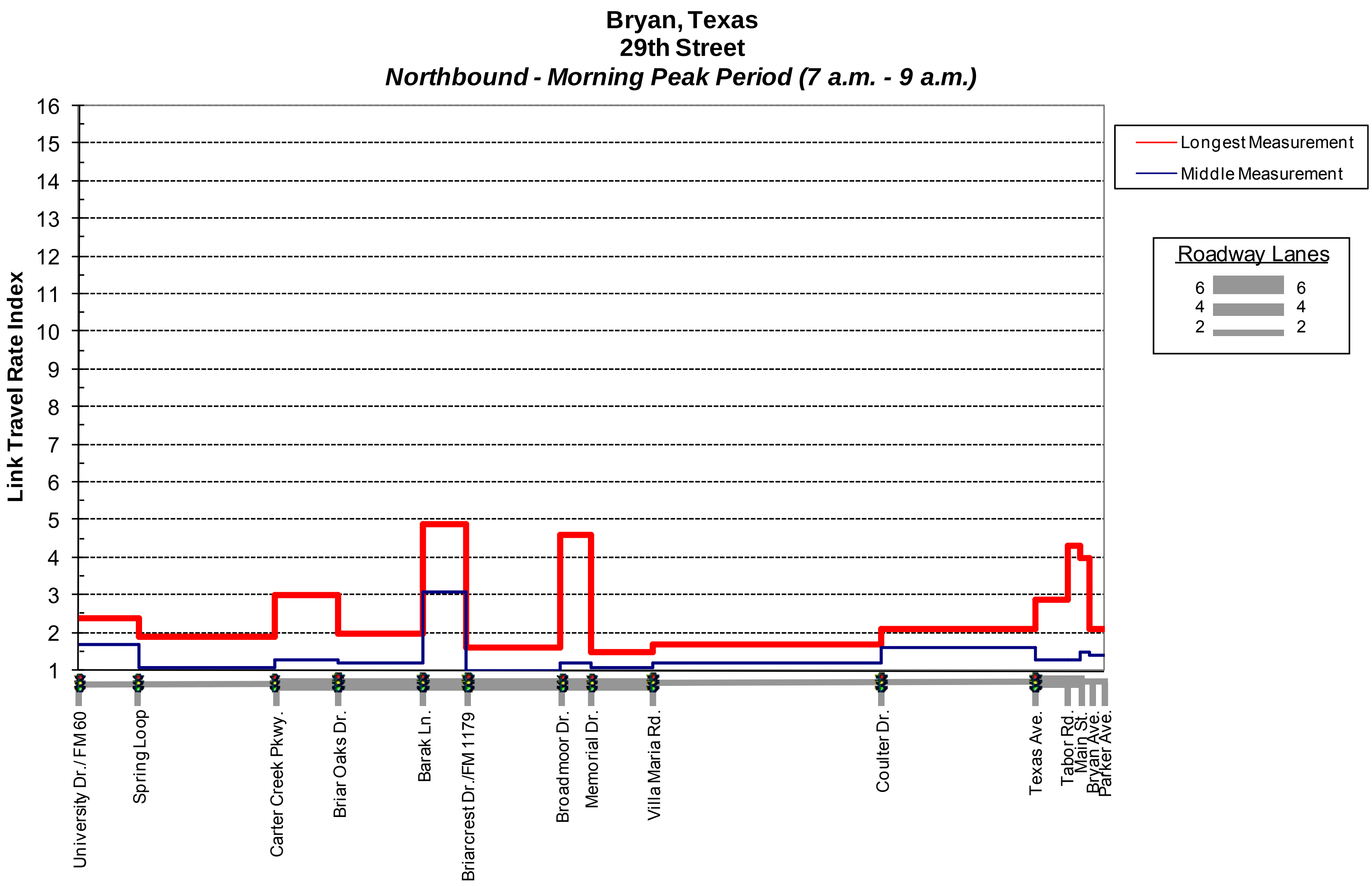


Figure D-33. Link Travel Rate Index for 29th Street, Northbound - Morning

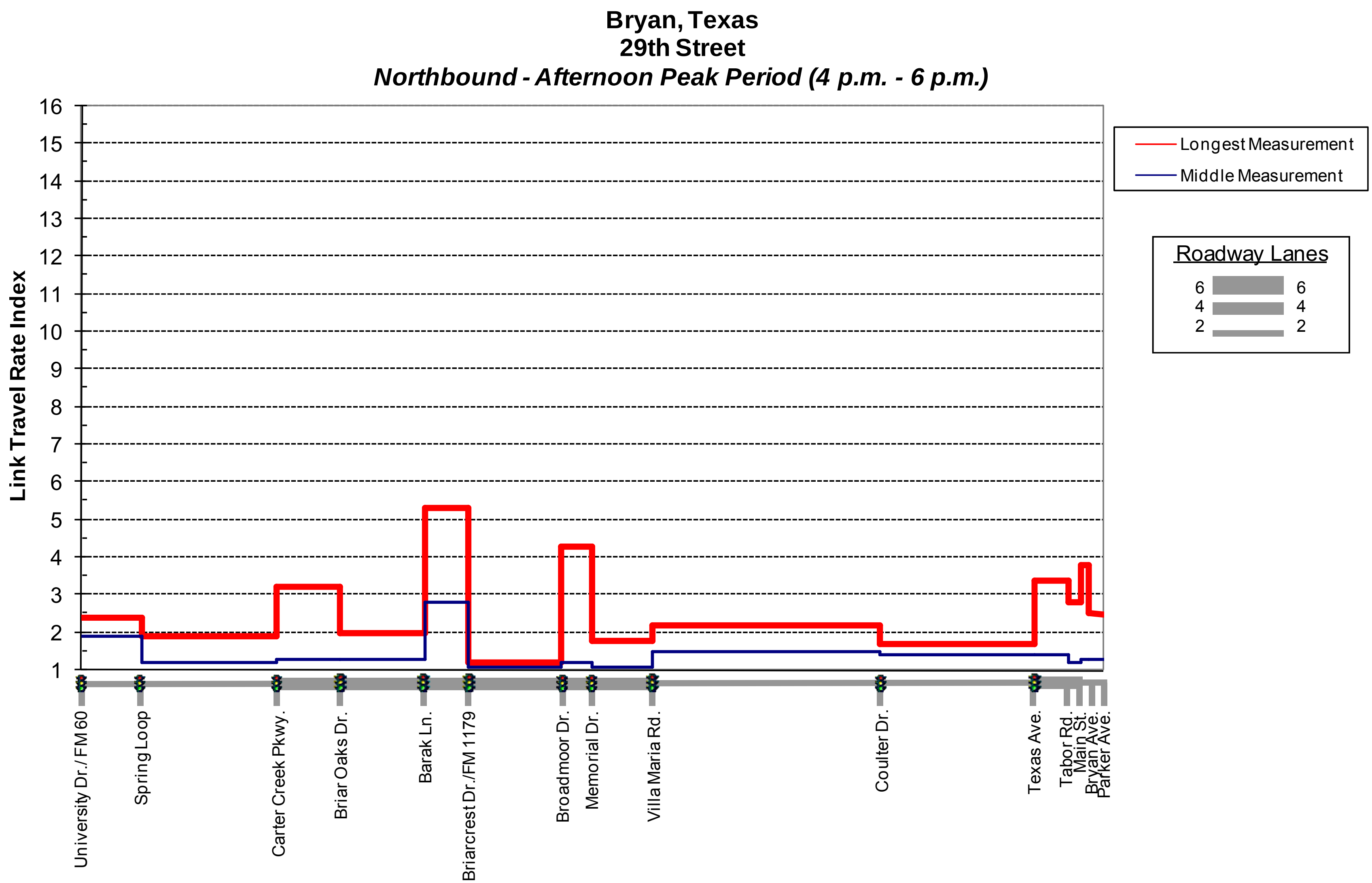


Figure D-34. Link Travel Rate Index for 29th Street, Northbound - Afternoon.

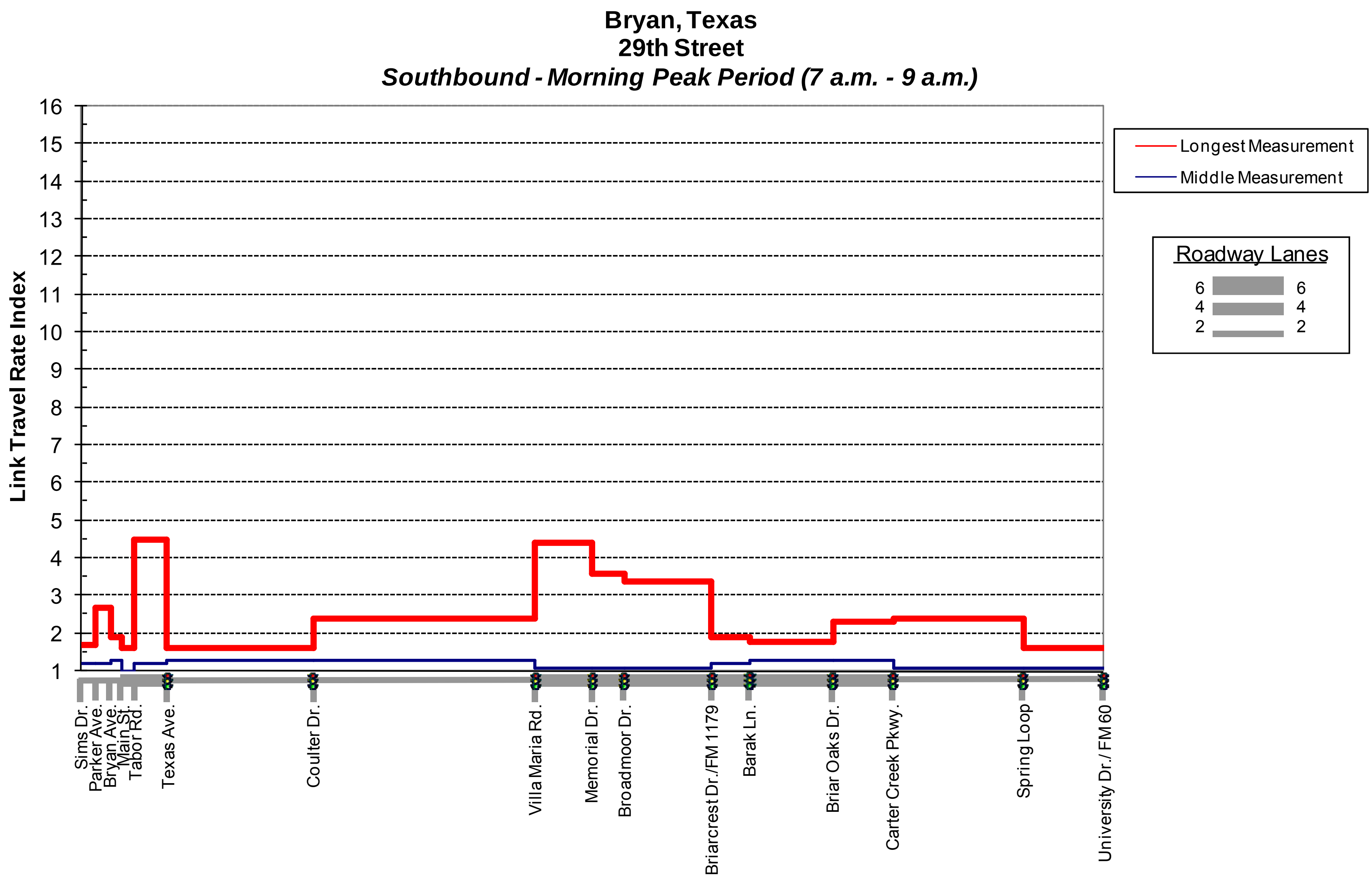


Figure D-35. Link Travel Rate Index for 29th Street, Southbound - Morning

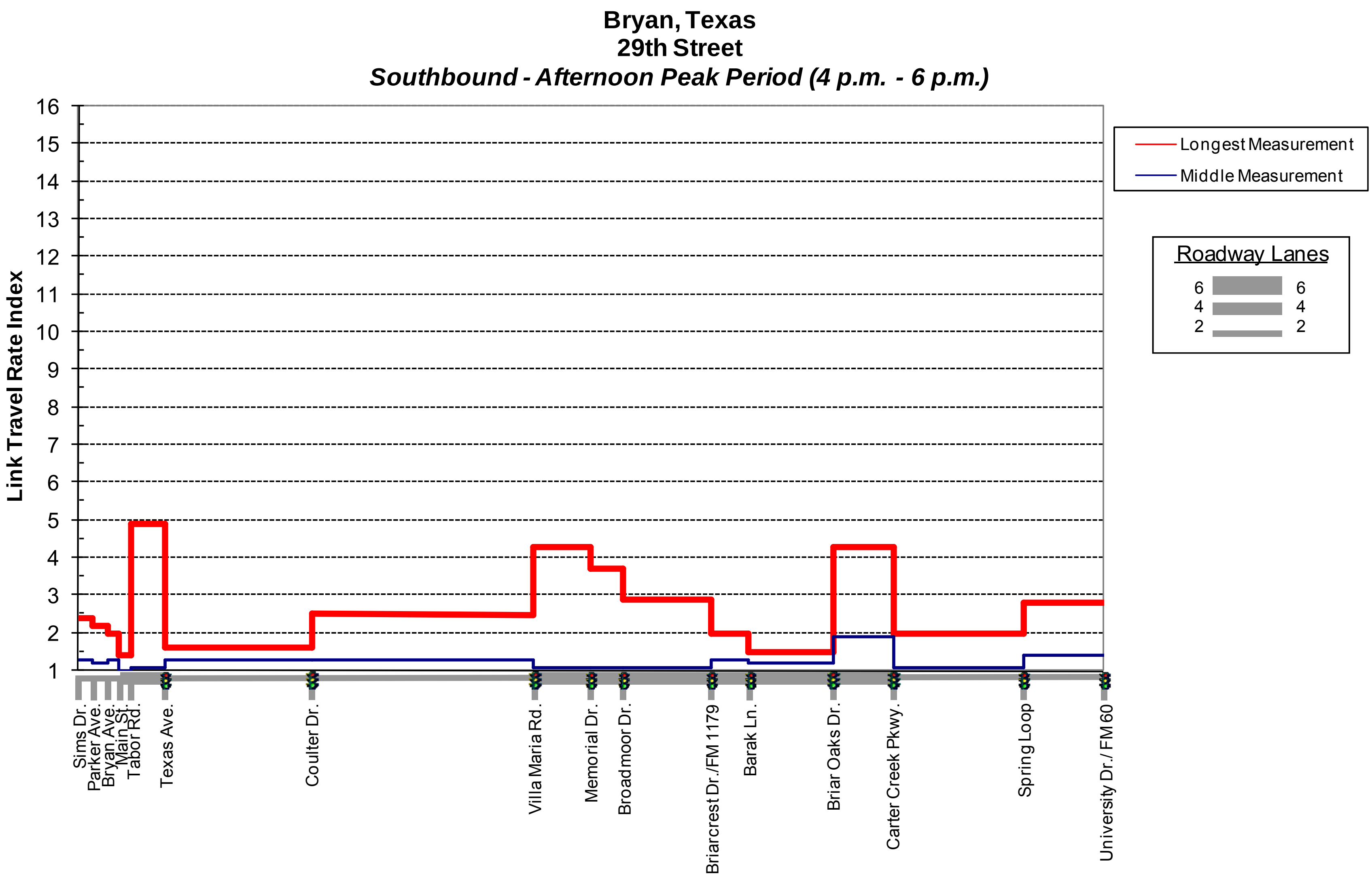


Figure D-36. Link Travel Rate Index for 29th Street, Southbound - Afternoon.

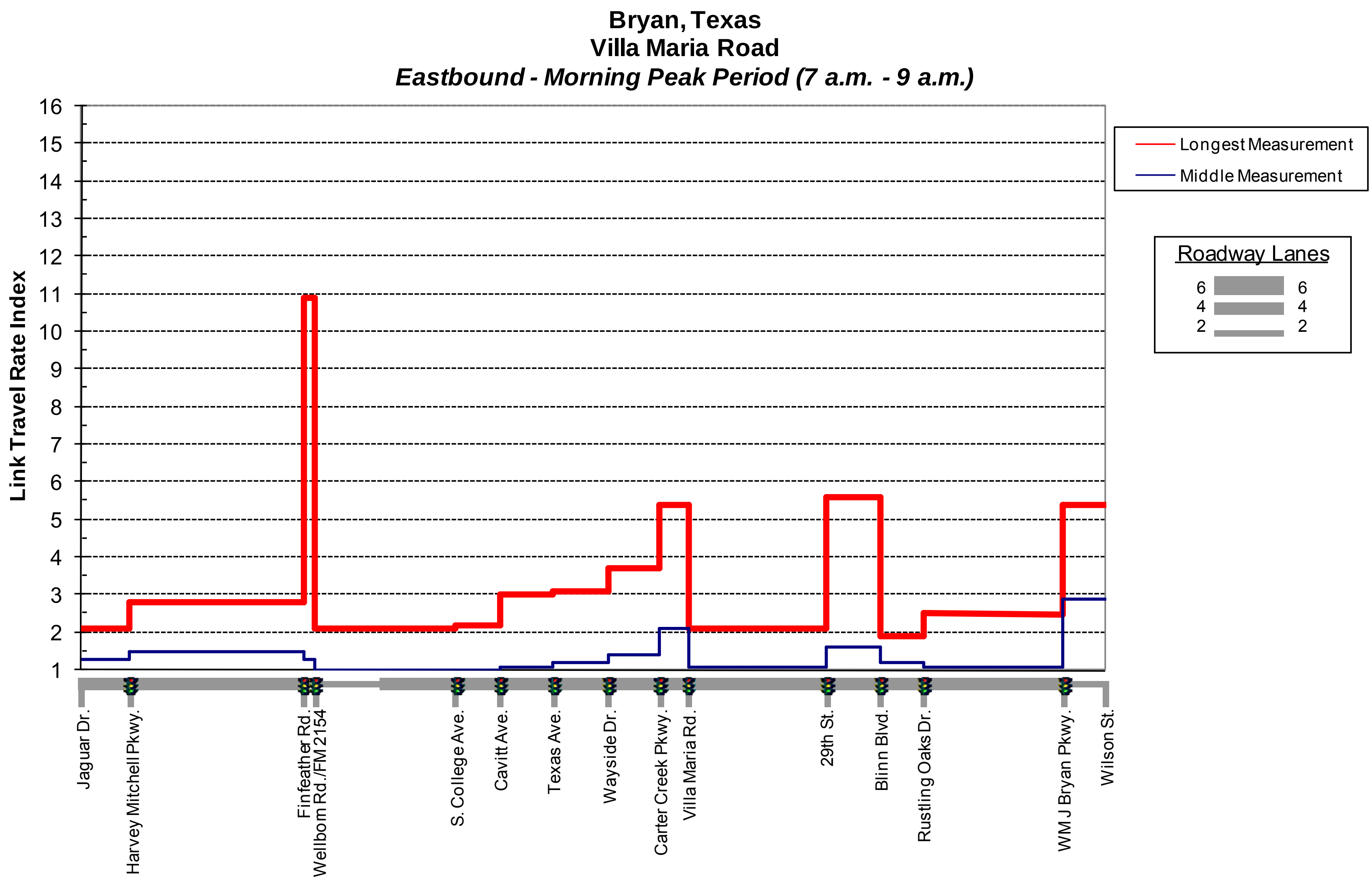


Figure D-37. Link Travel Rate Index for Villa Maria Road, Eastbound - Morning

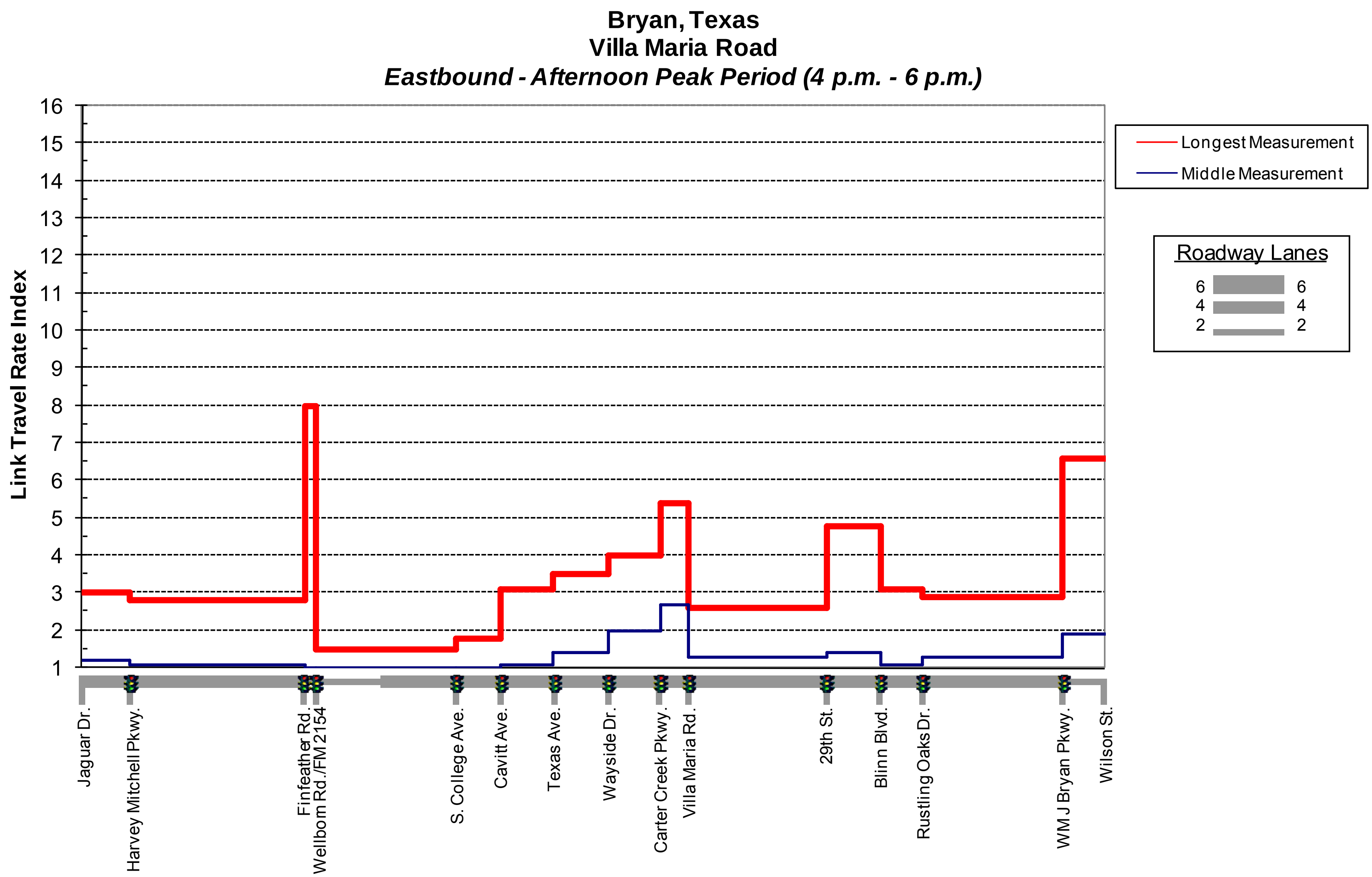


Figure D-38. Link Travel Rate Index for Villa Maria Road, Eastbound - Afternoon.

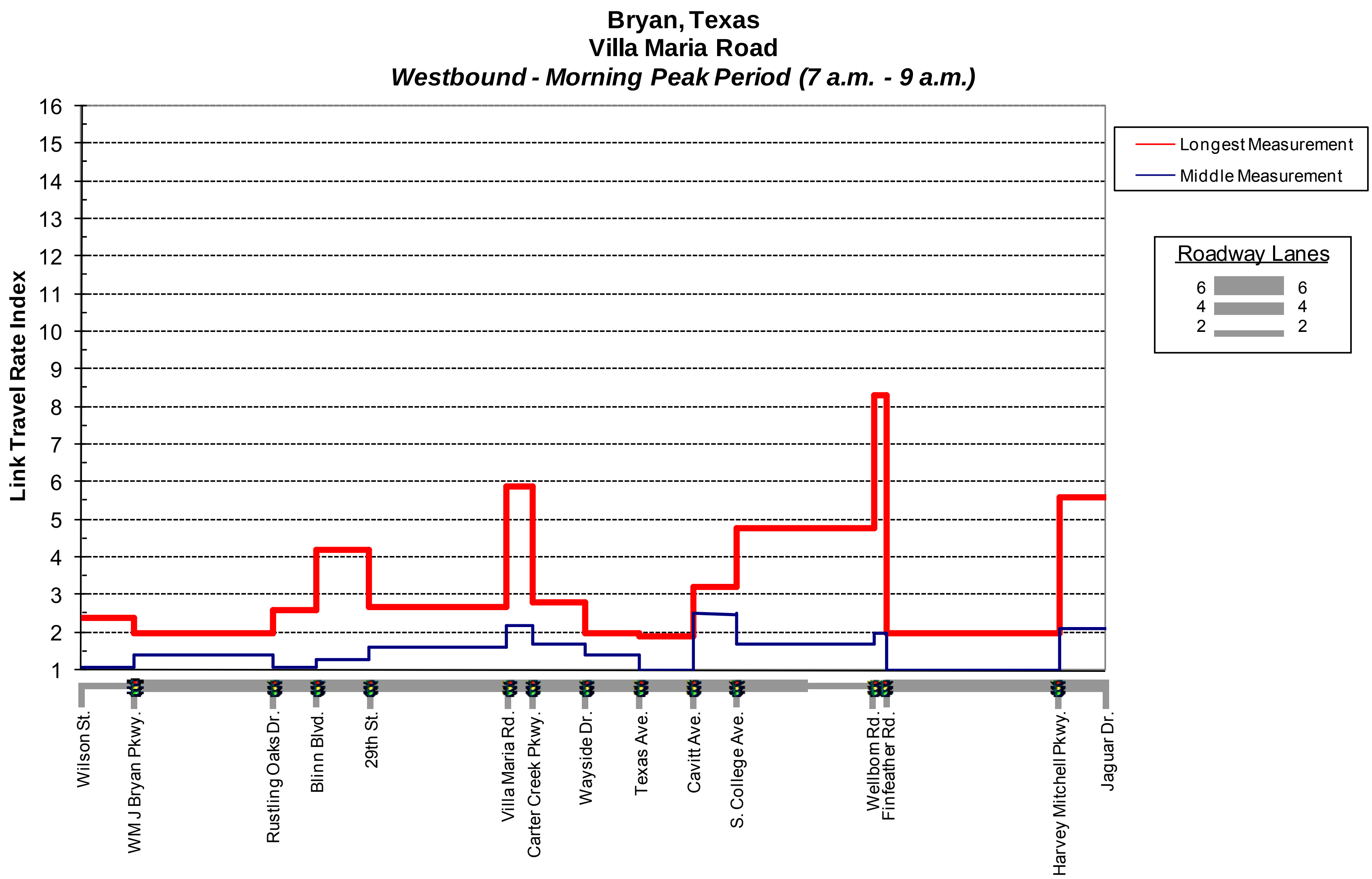


Figure D-39. Link Travel Rate Index for Villa Maria Road, Westbound - Morning

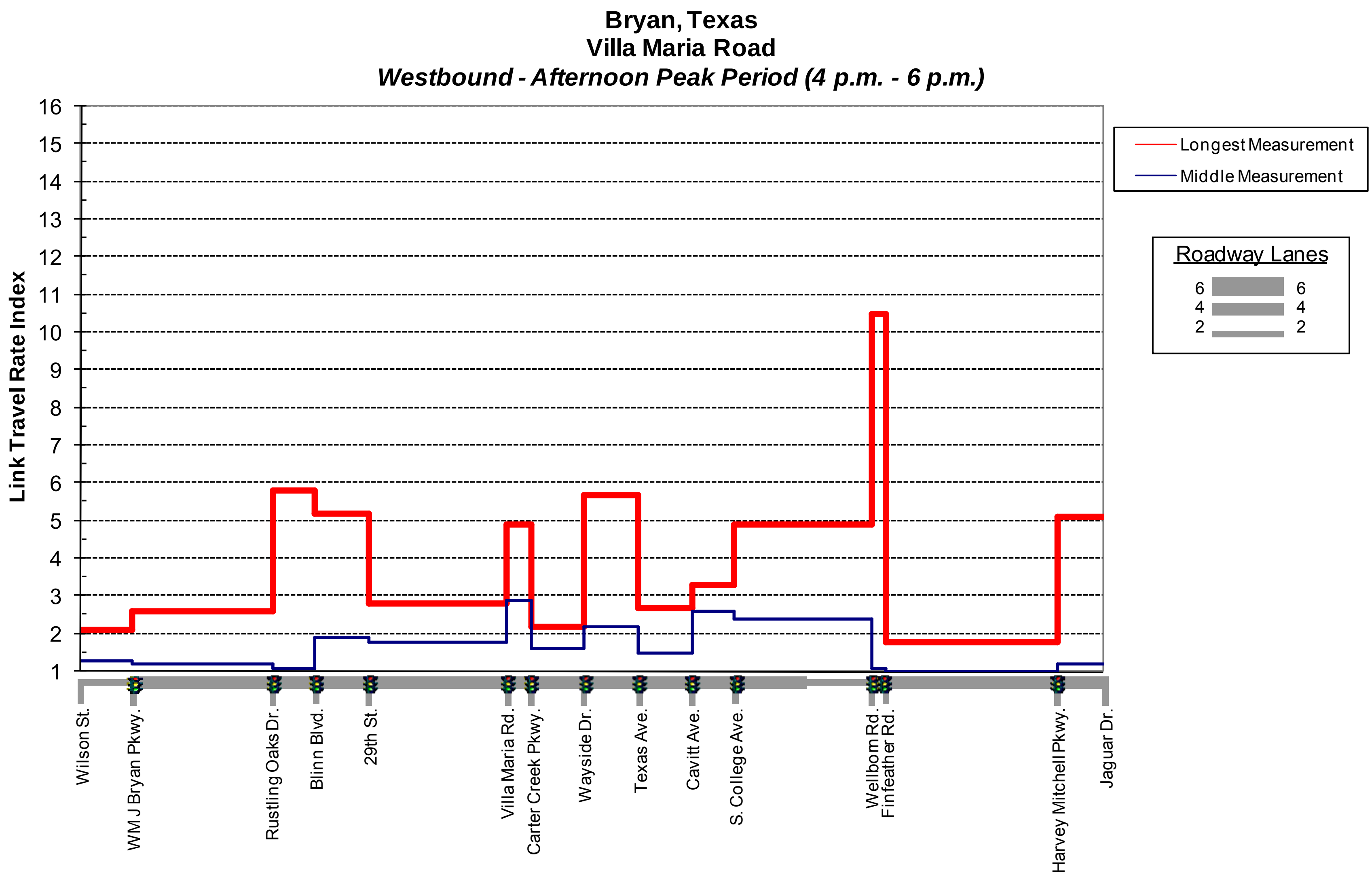


Figure D-40. Link Travel Rate Index for Villa Maria Road, Westbound - Afternoon.

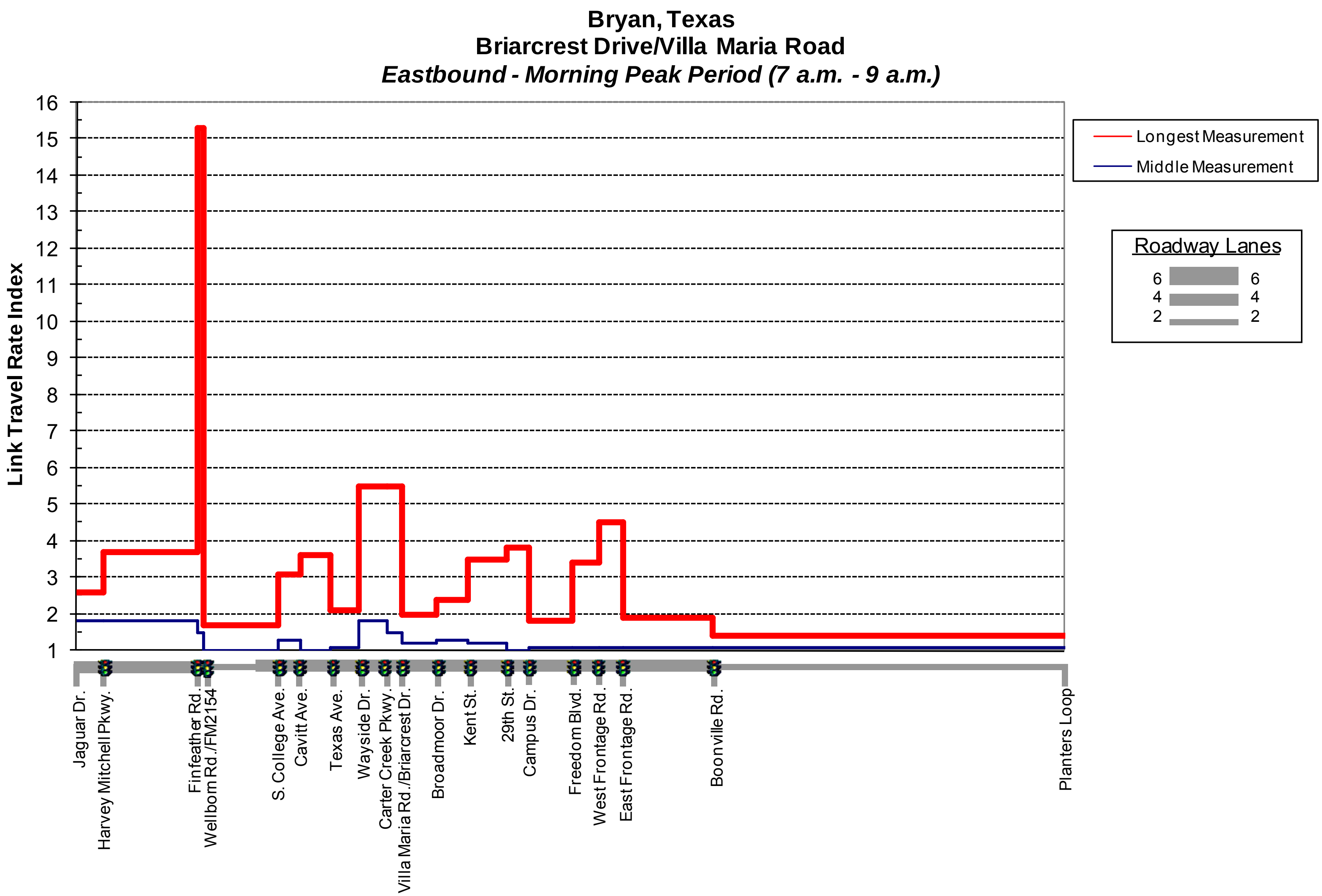


Figure D-41. Link Travel Rate Index for Briarcrest Drive/Villa Maria Road, Eastbound - Morning

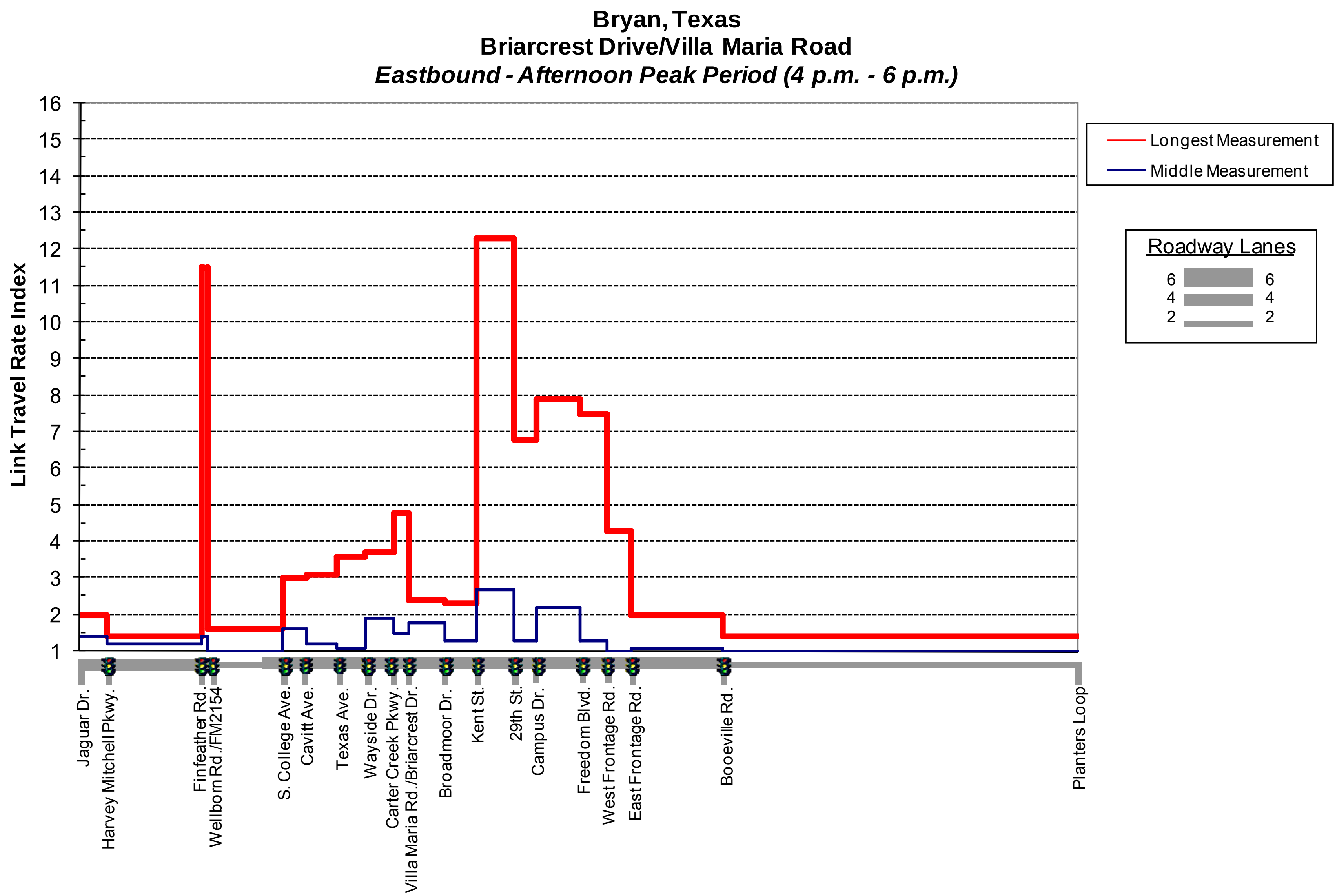


Figure D-42. Link Travel Rate Index for Briarcrest Drive/Villa Maria Road, Eastbound - Afternoon.

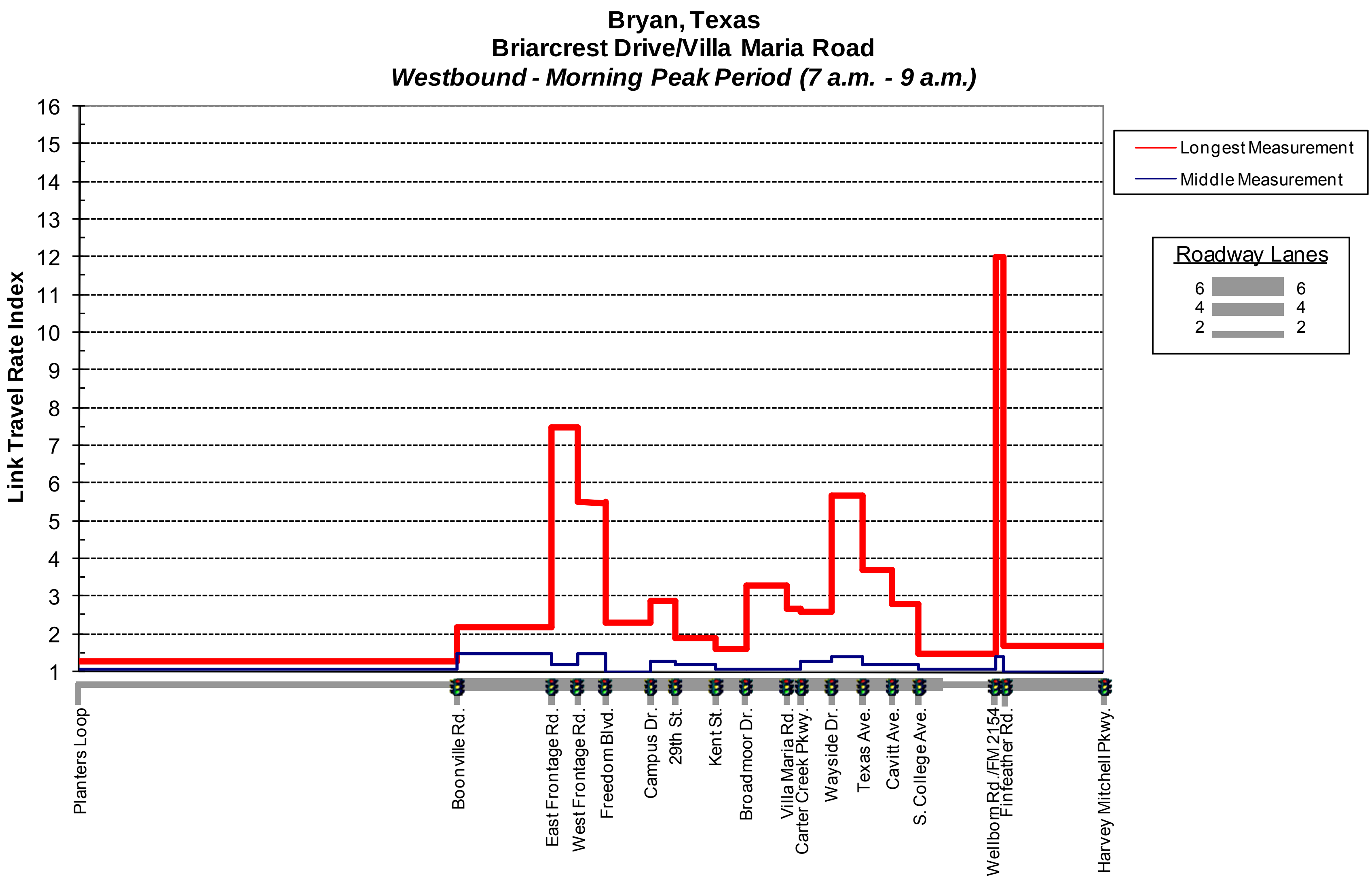


Figure D-43. Link Travel Rate Index for Briarcrest Drive/Villa Maria Road, Westbound - Morning

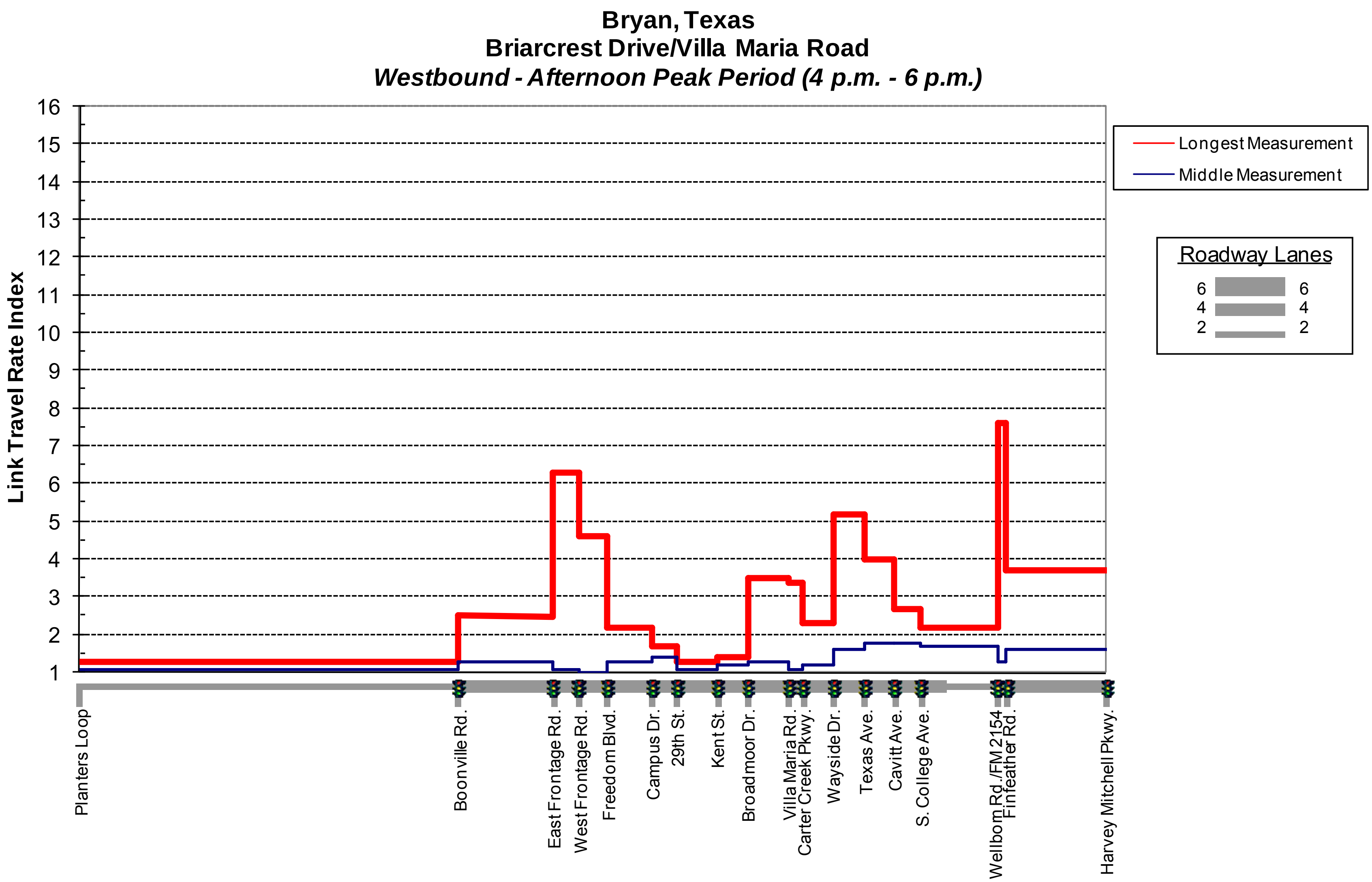


Figure D-44. Link Travel Rate Index for Briarcrest Drive/Villa Maria Road, Westbound - Afternoon.

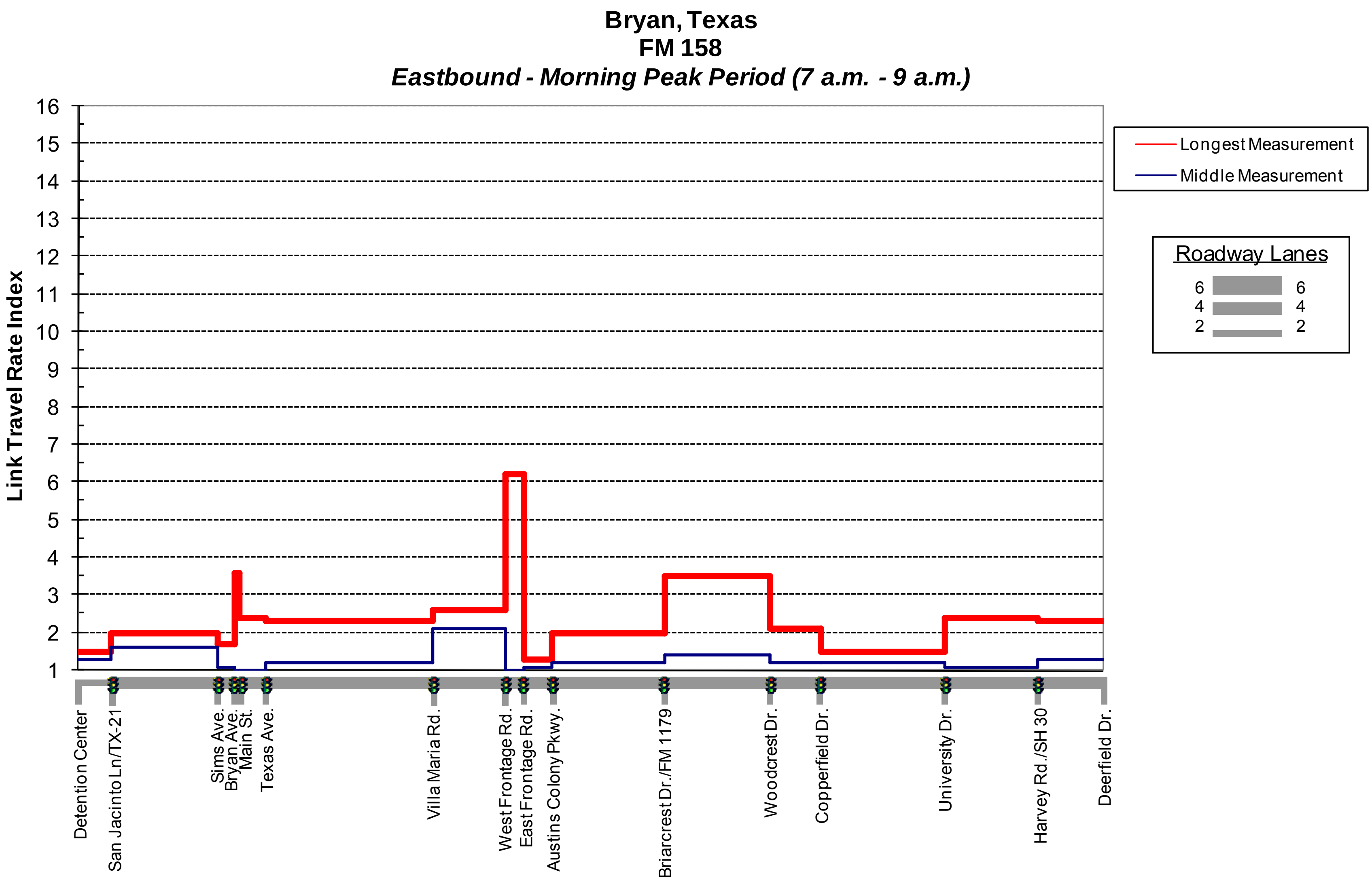


Figure D-45. Link Travel Rate Index for FM 158, Eastbound - Morning

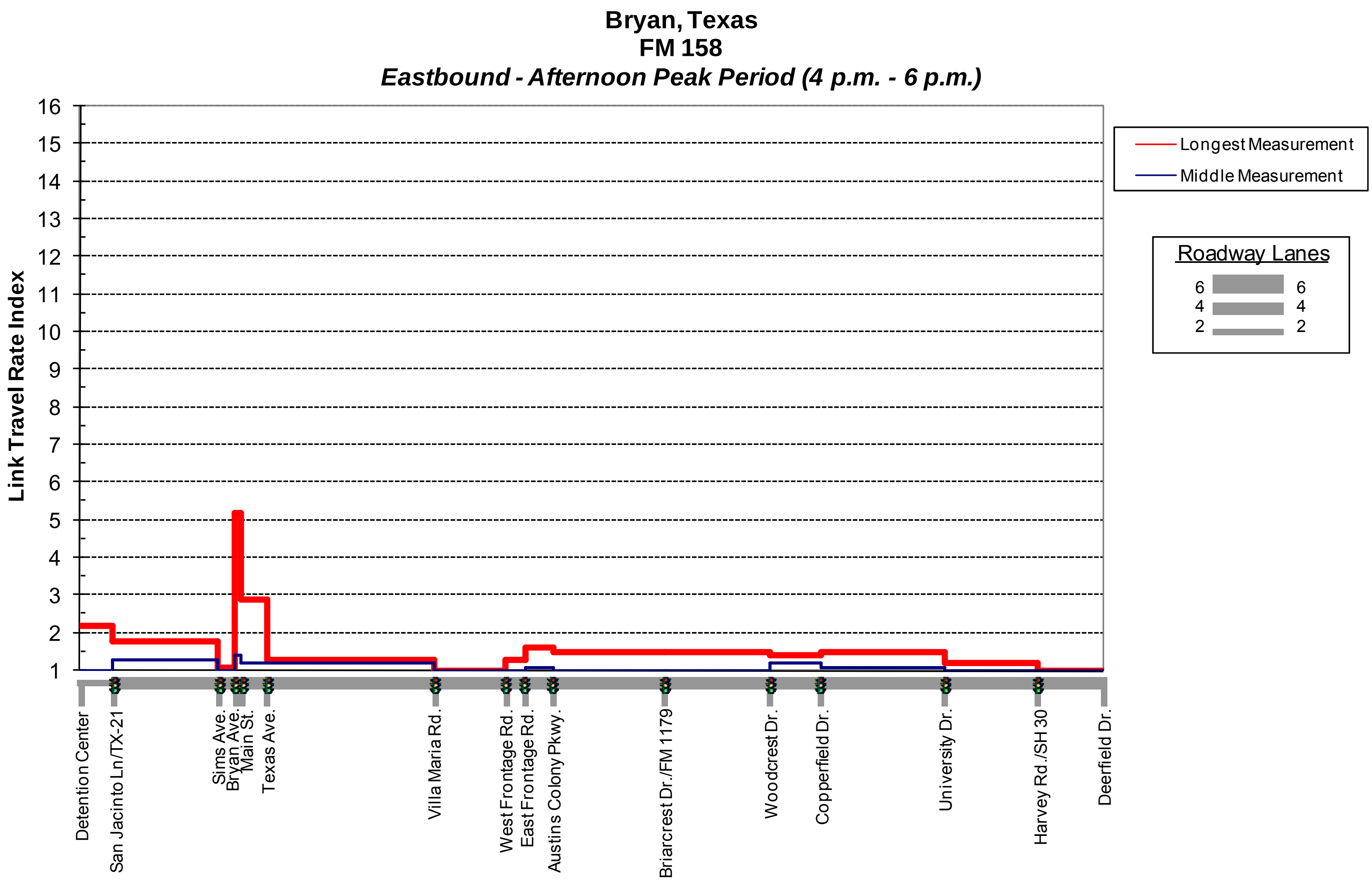


Figure D-46. Link Travel Rate Index for FM 158, Eastbound - Afternoon.

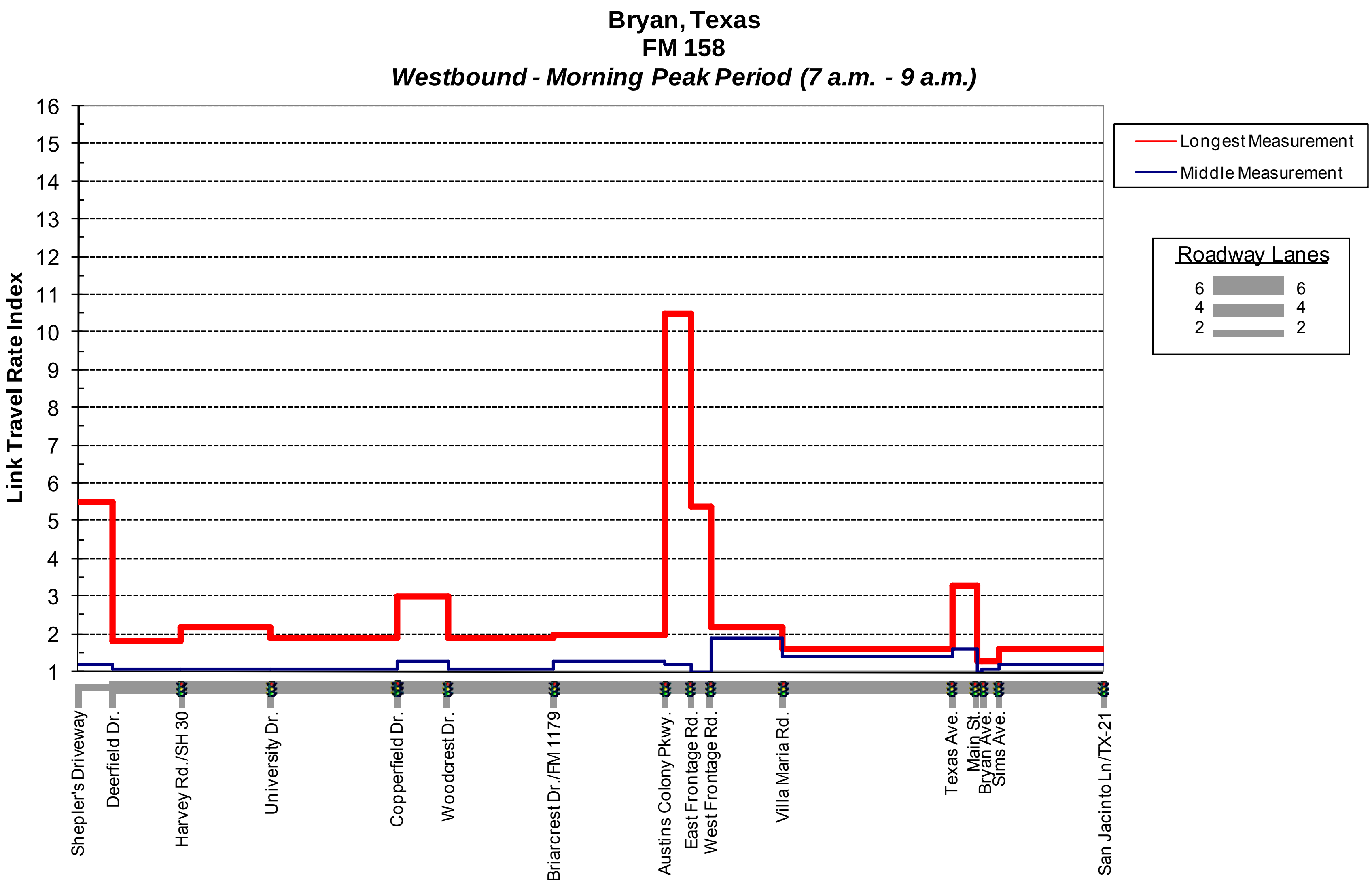


Figure D-47. Link Travel Rate Index for FM 158, Westbound - Morning

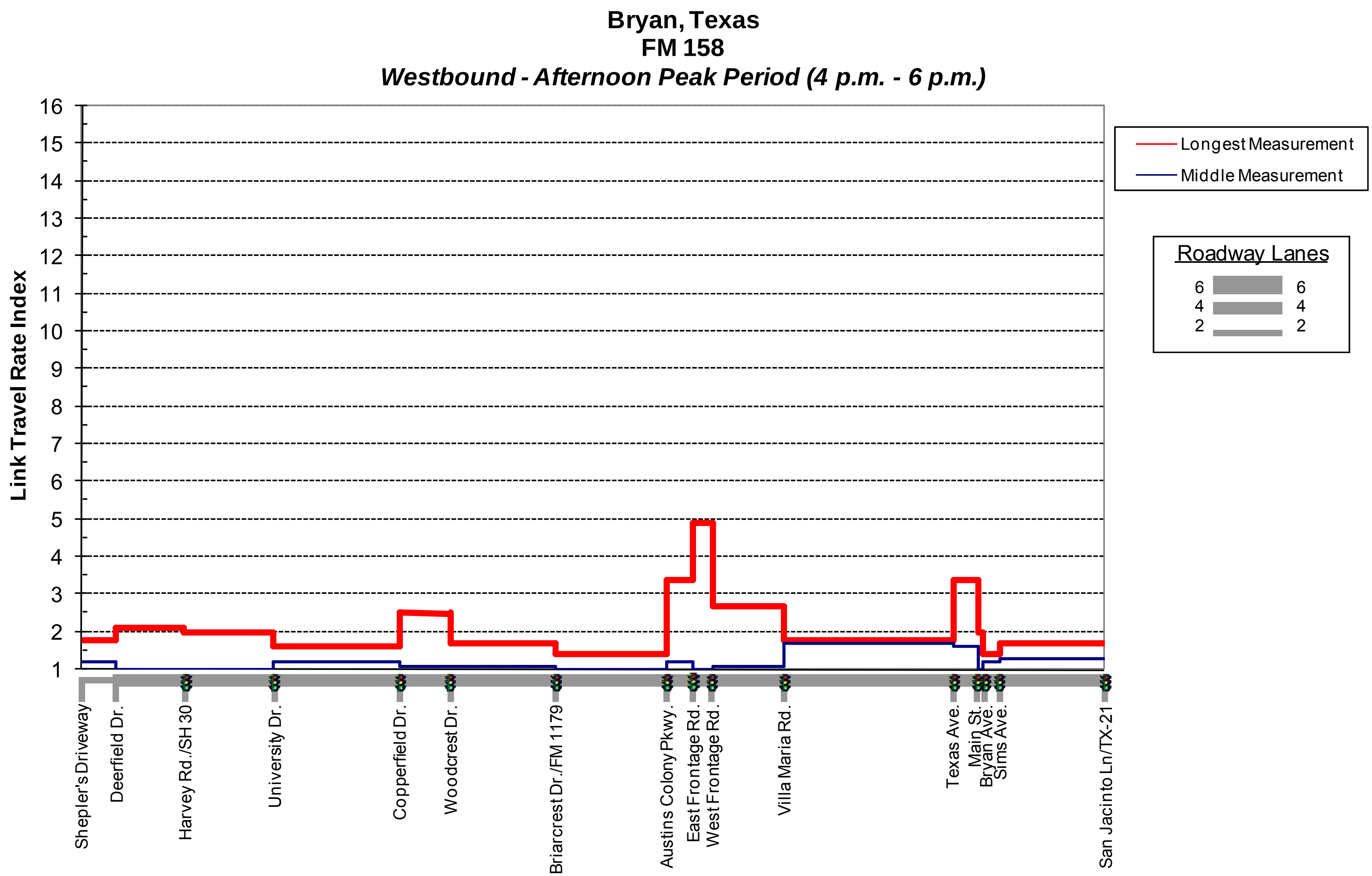


Figure D-48. Link Travel Rate Index for FM 158, Westbound - Afternoon.

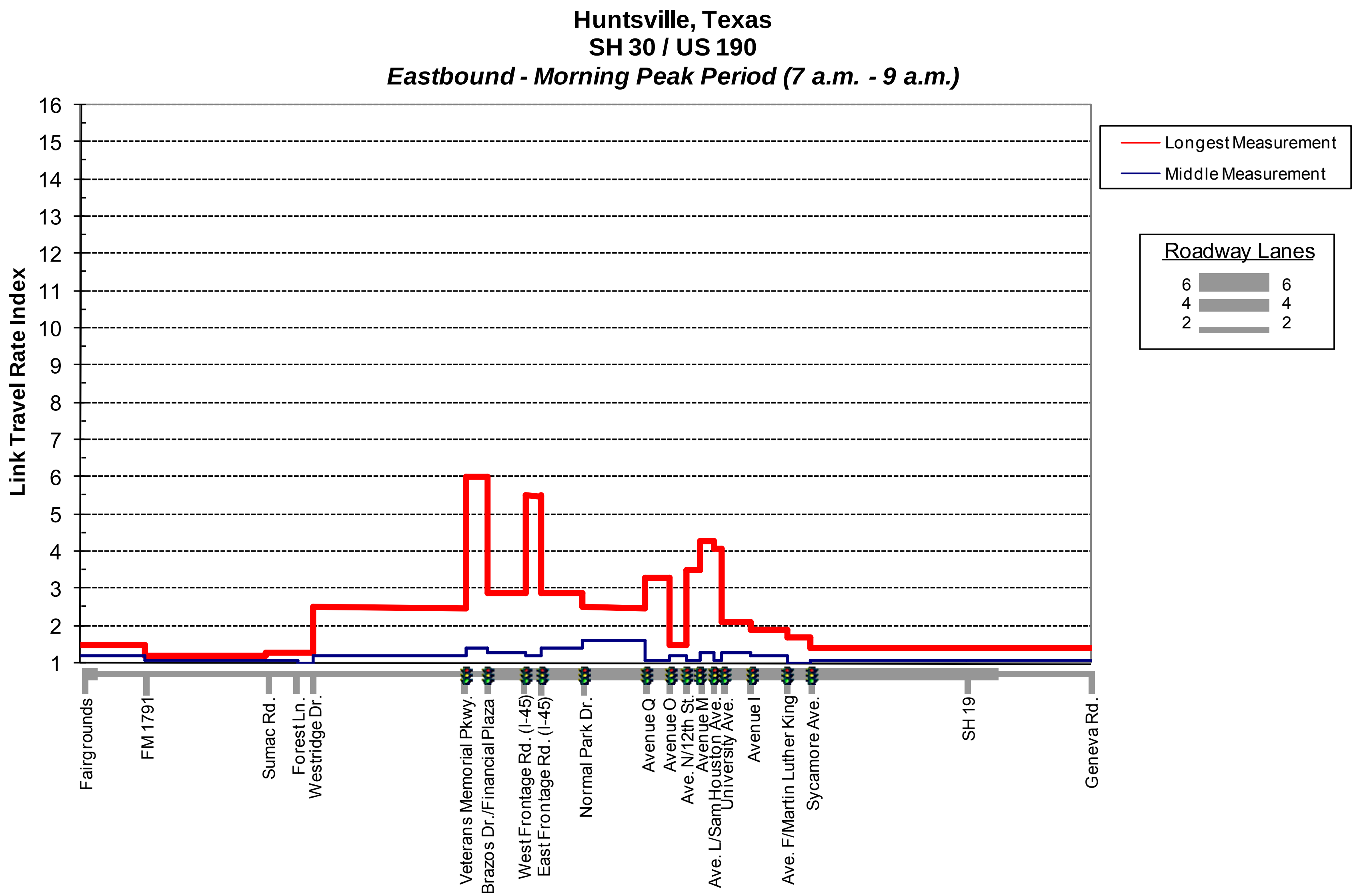


Figure D-49. Link Travel Rate Index for SH 30/190, Eastbound - Morning

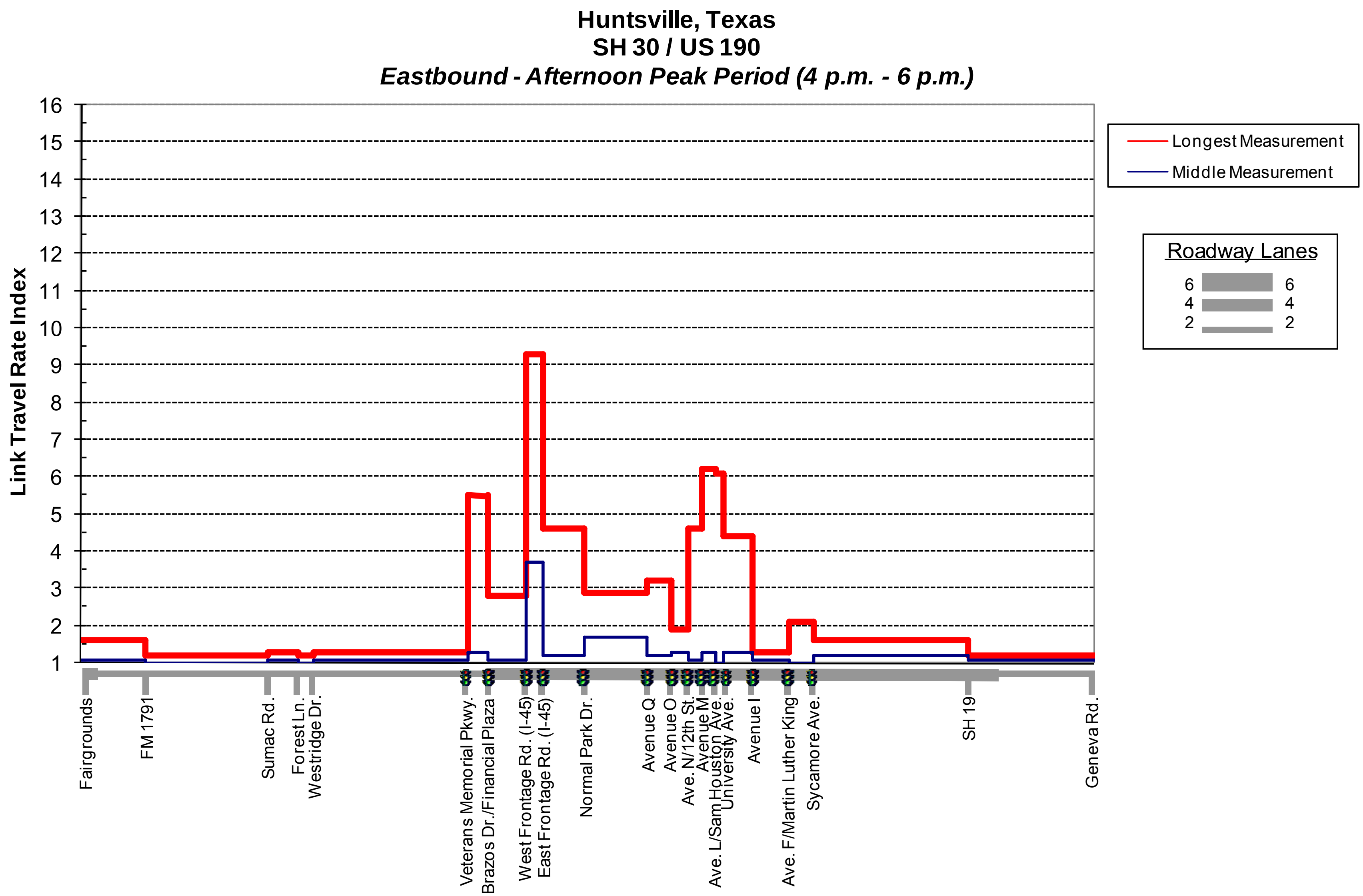


Figure D-50. Link Travel Rate Index for SH 30/190, Eastbound - Afternoon.

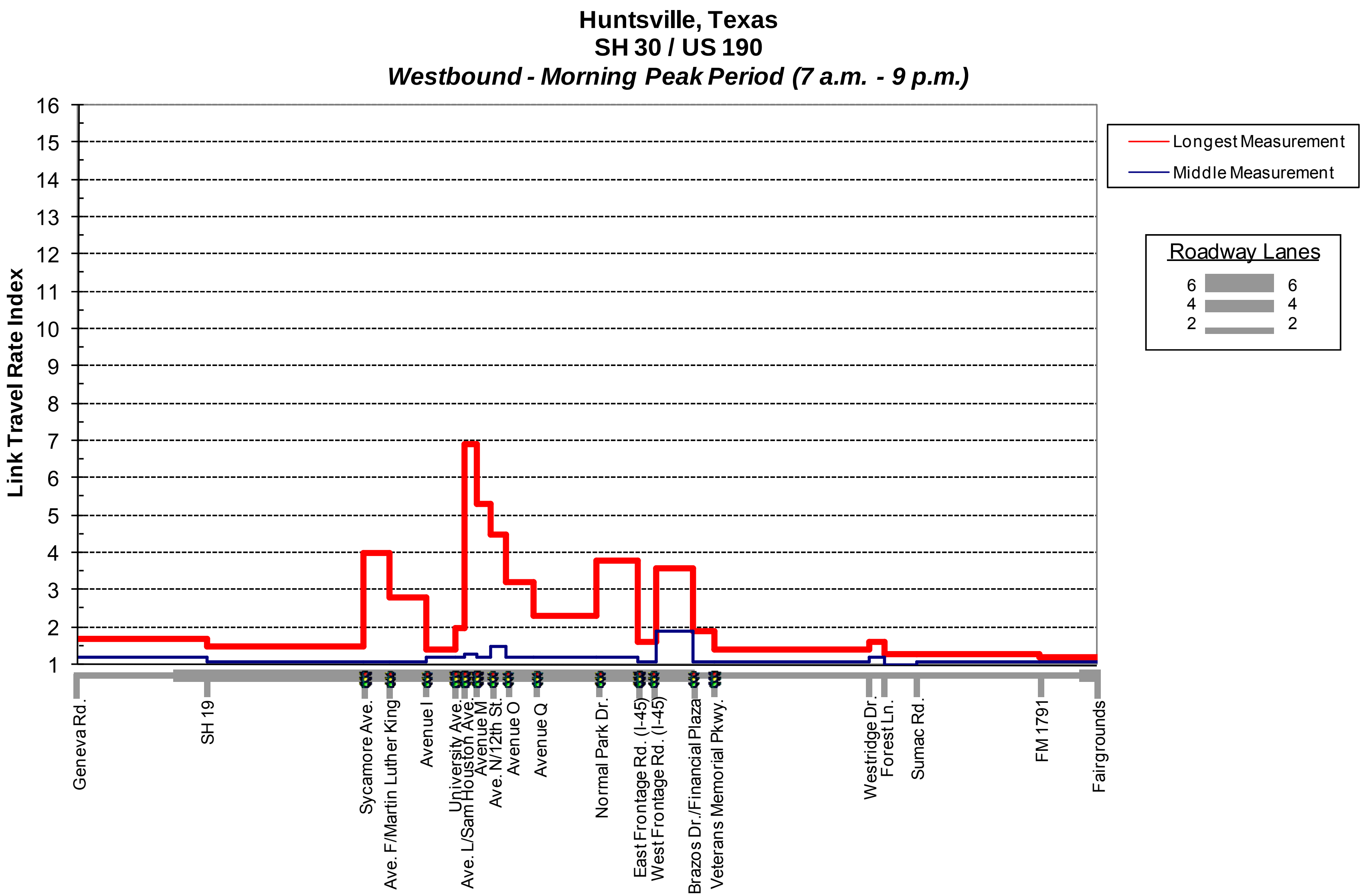


Figure D-51. Link Travel Rate Index for SH 30/190, Westbound - Morning

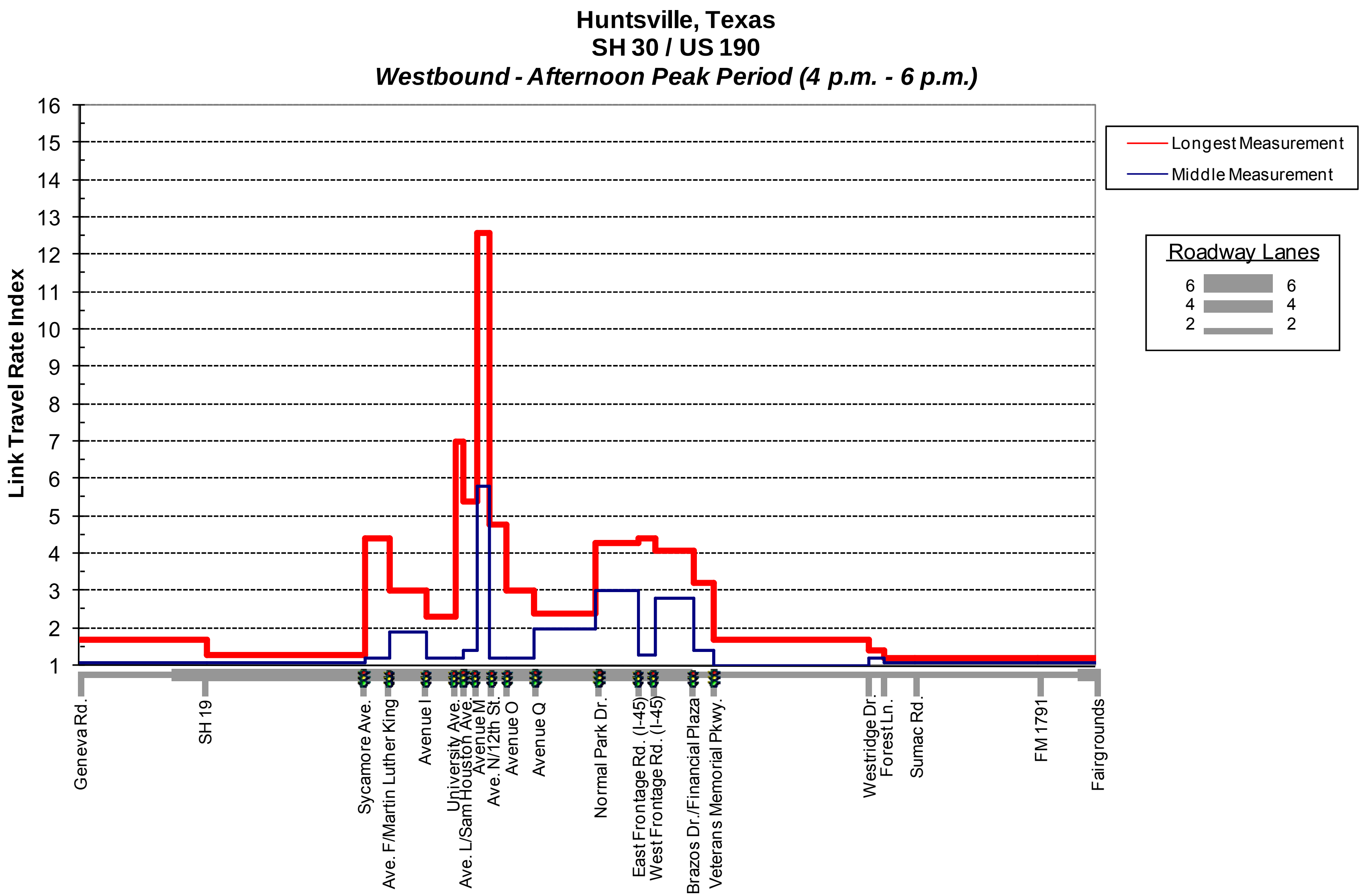


Figure D-52. Link Travel Rate Index for SH 30/190, Westbound - Afternoon.

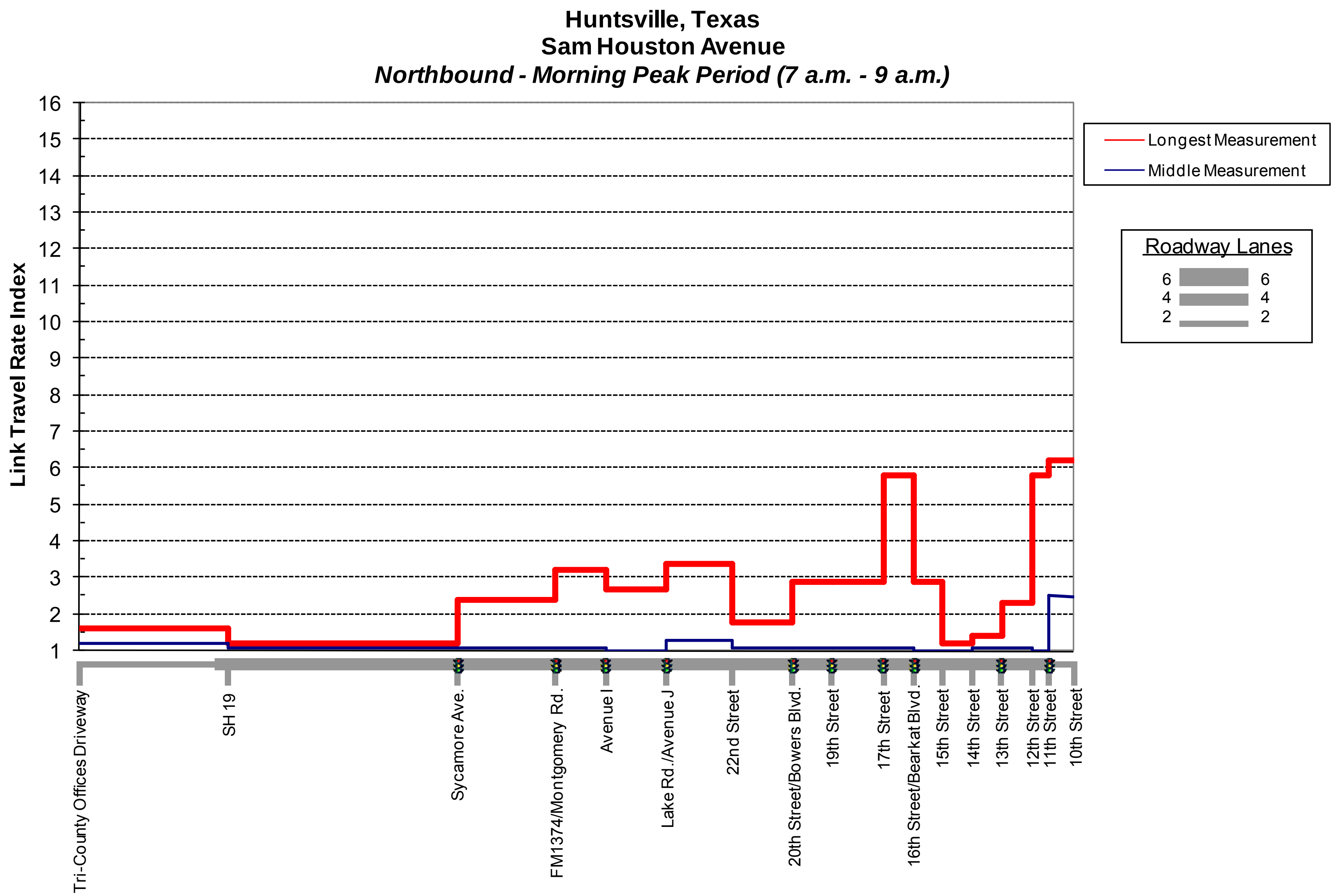


Figure D-53. Link Travel Rate Index for Sam Houston Avenue, Northbound - Morning

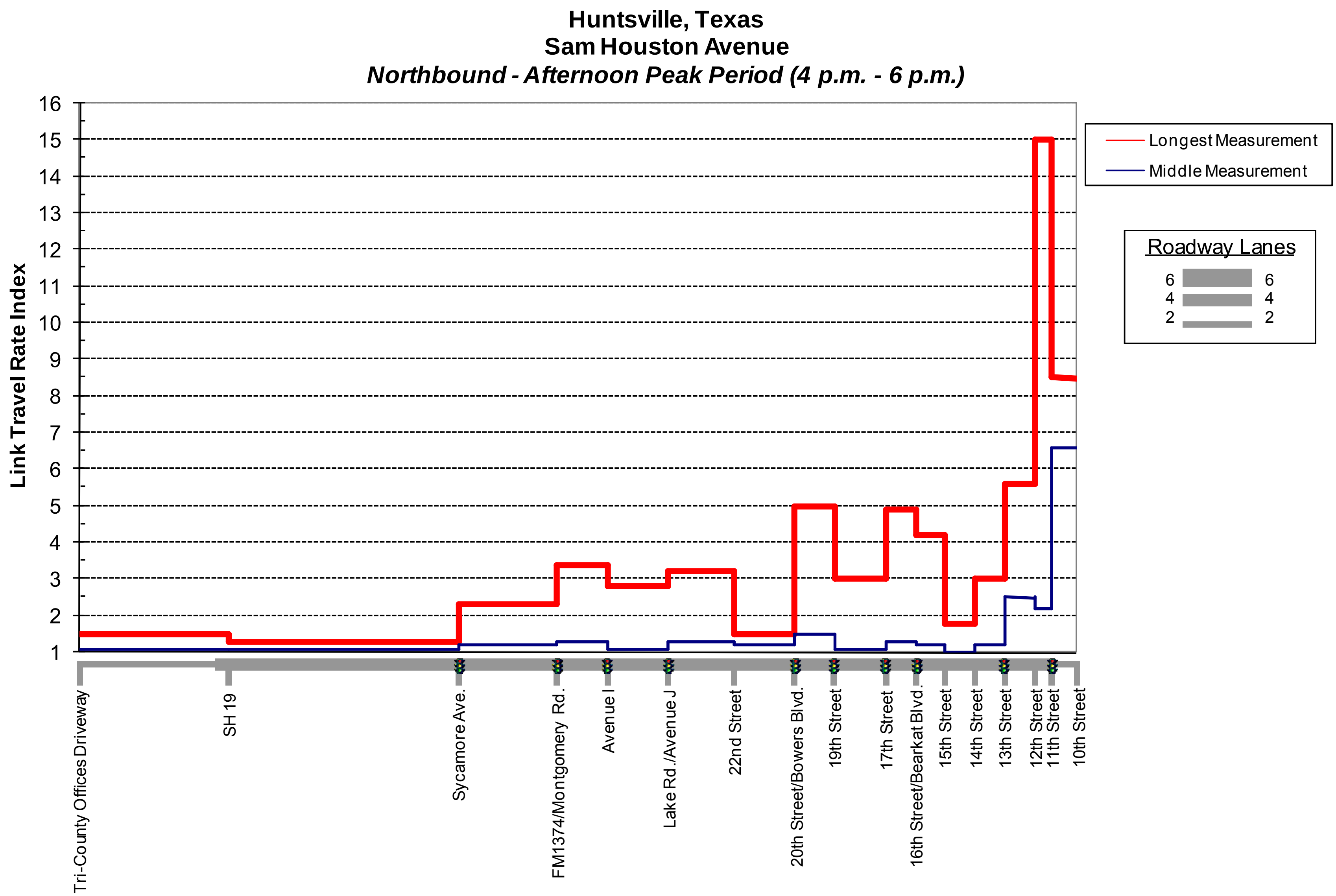


Figure D-54. Link Travel Rate Index for Sam Houston Avenue, Northbound - Afternoon.

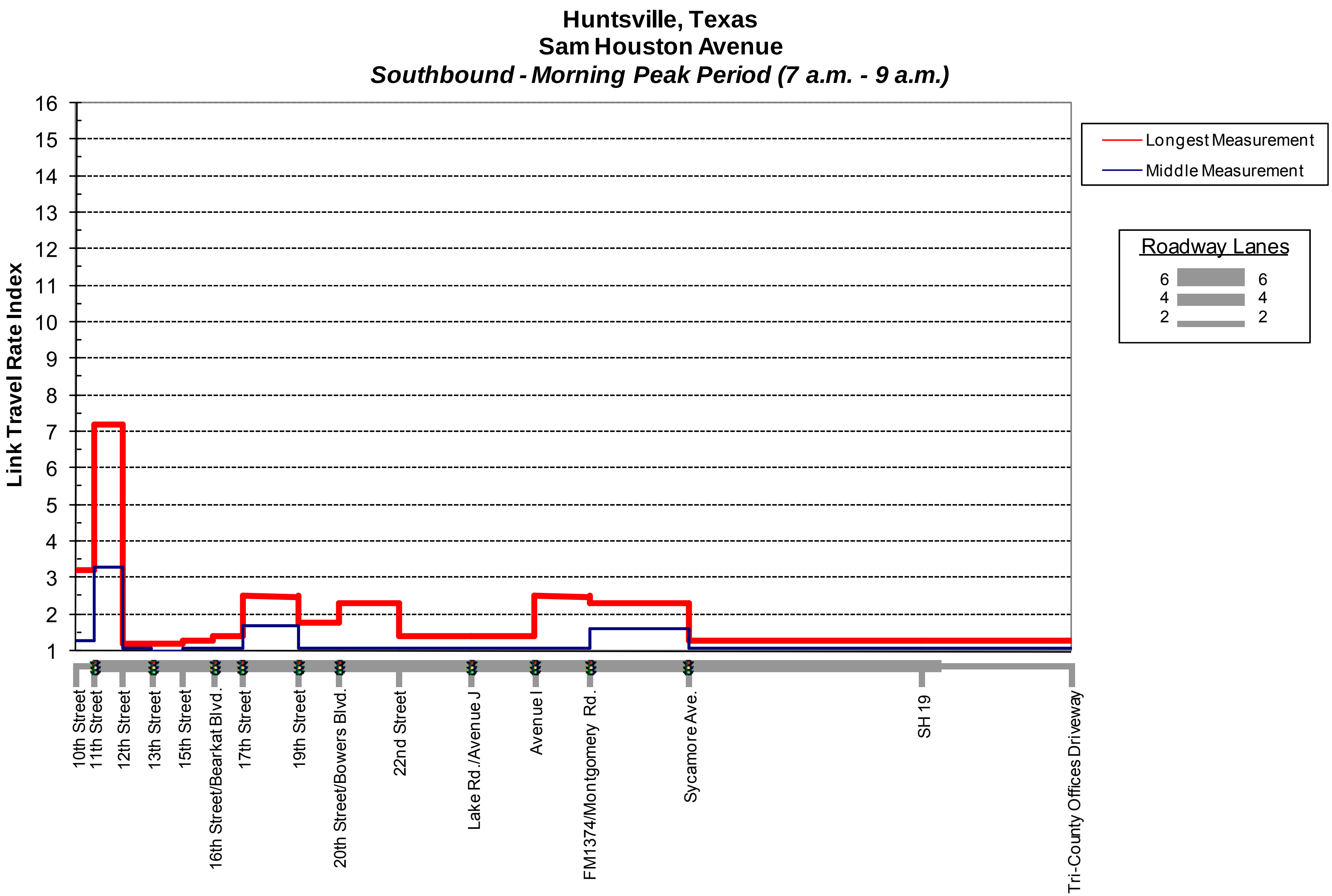


Figure D-55. Link Travel Rate Index for Sam Houston Avenue, Southbound - Morning

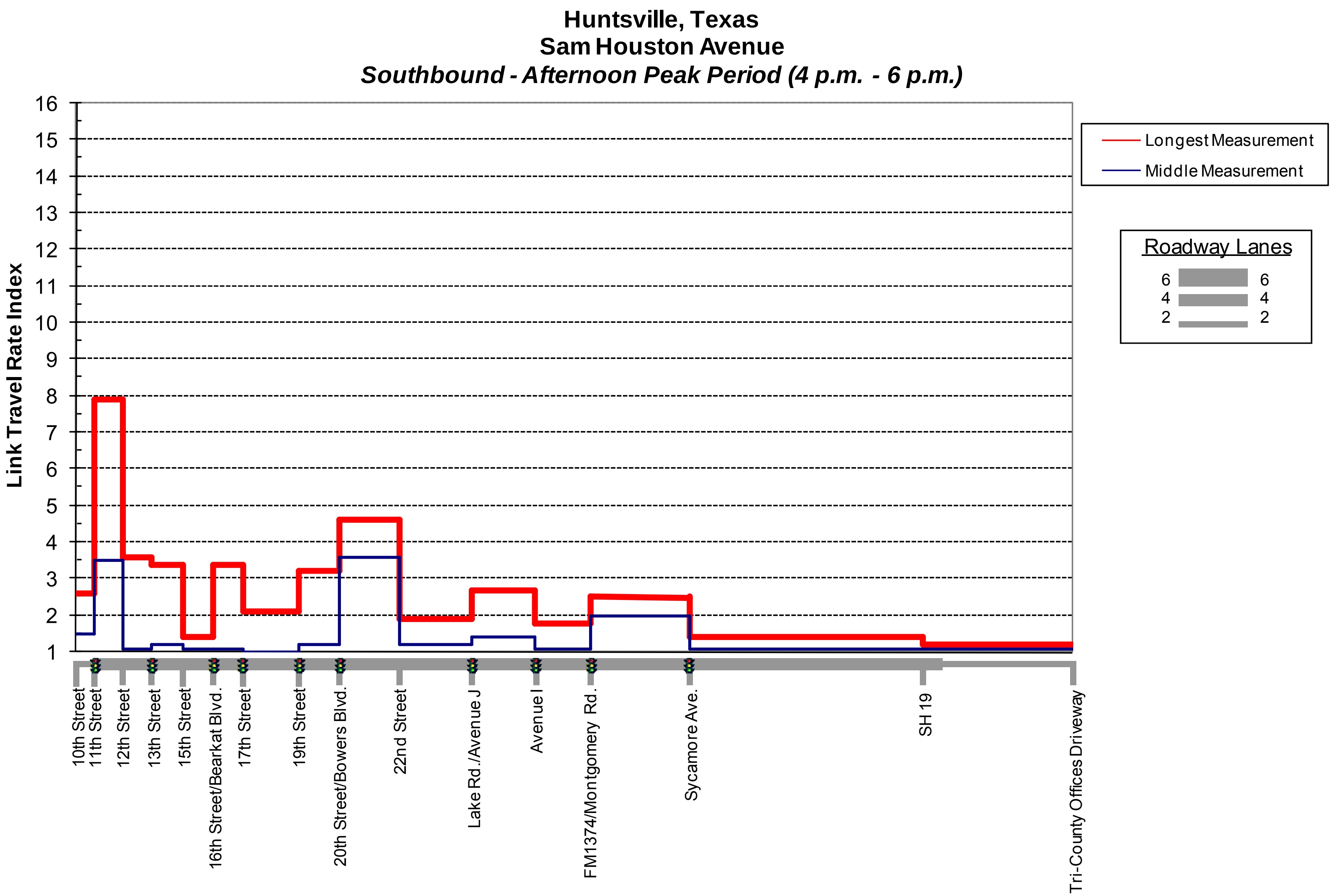


Figure D-56. Link Travel Rate Index for Sam Houston Avenue, Southbound - Afternoon.

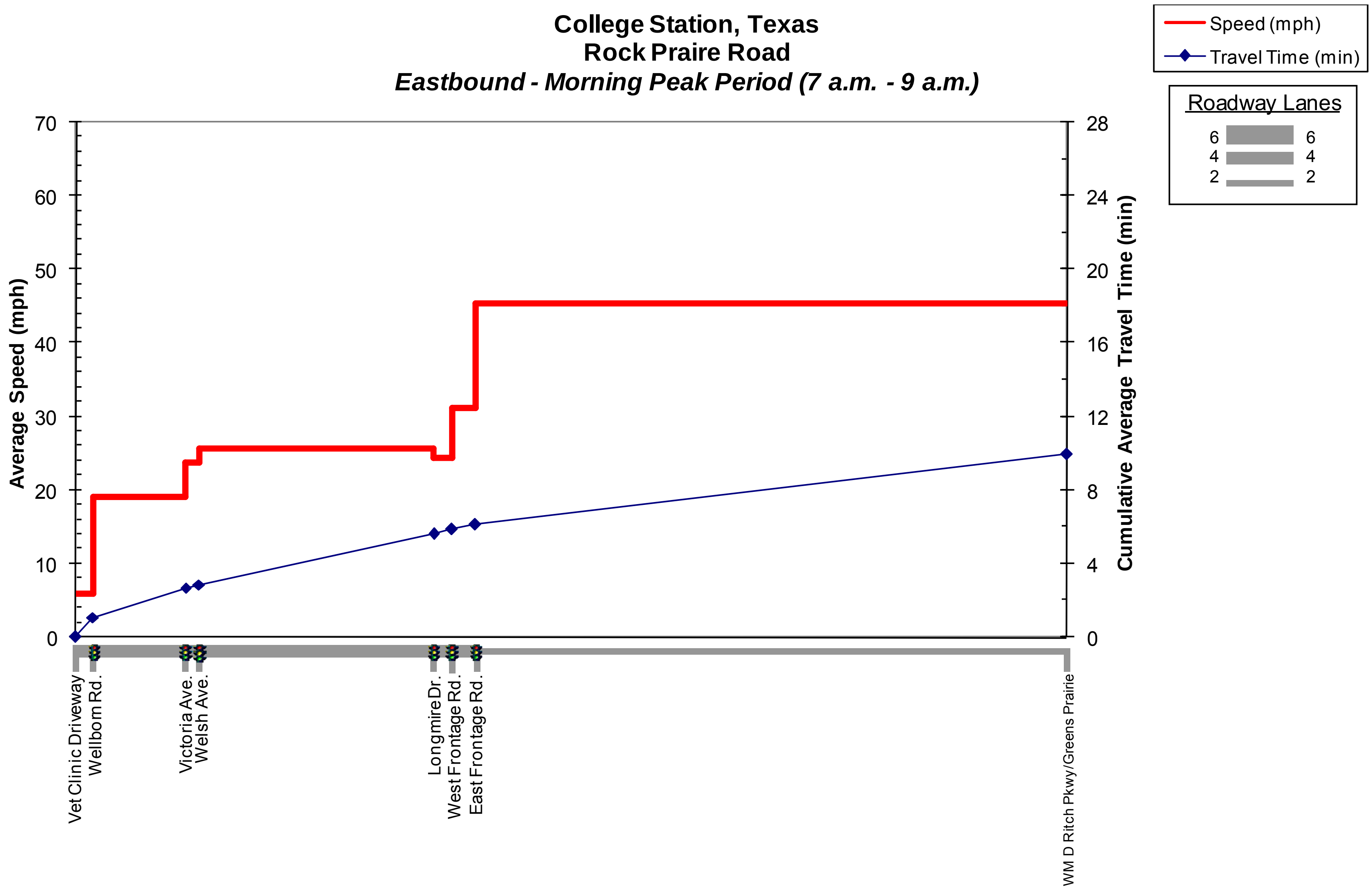


Figure D-57. Average Speed and Cumulative Average Travel Time for Rock Prairie Road, Eastbound - Morning

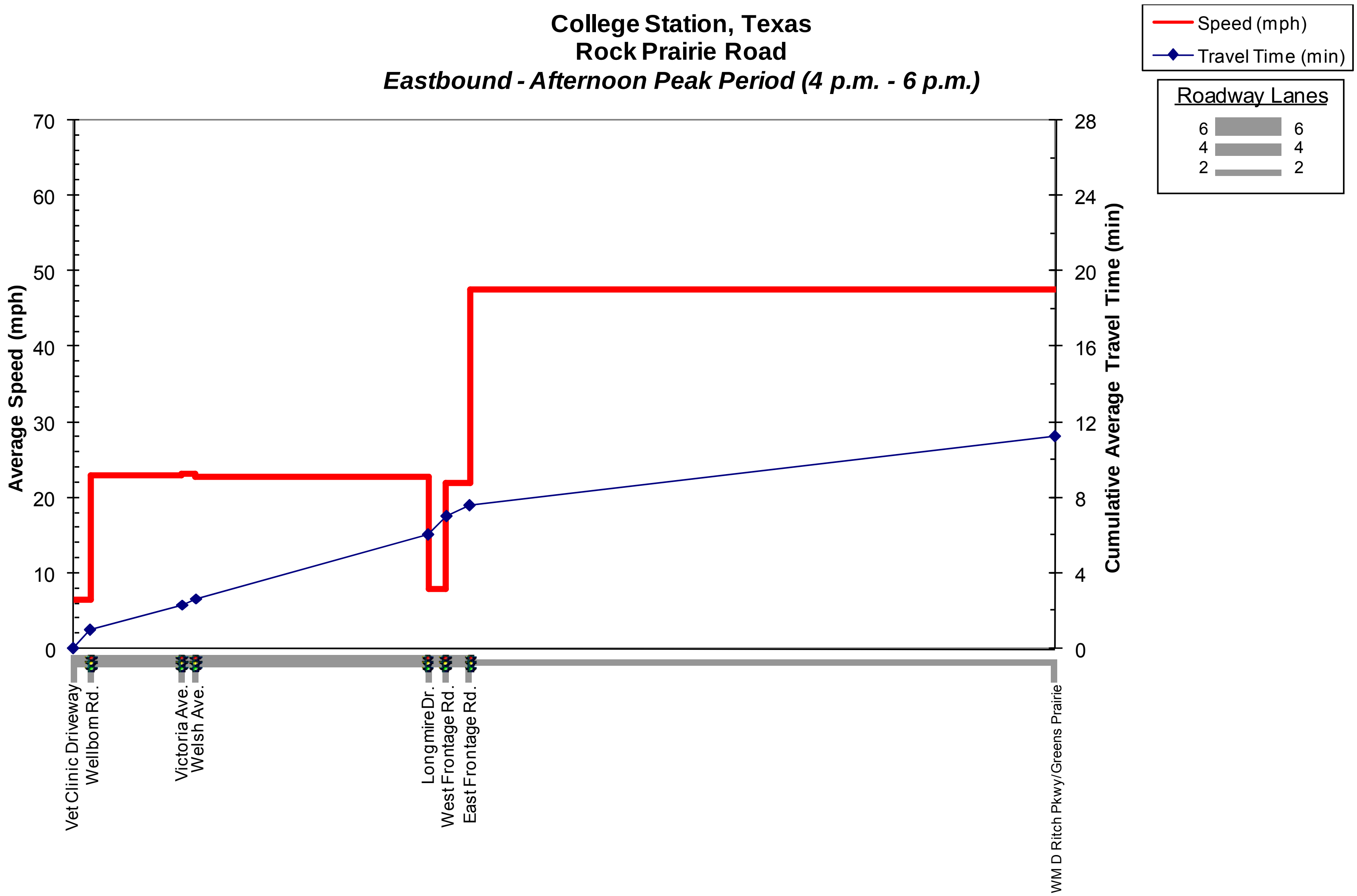


Figure D-58. Average Speed and Cumulative Average Travel Time for Rock Prairie Road, Eastbound - Afternoon.

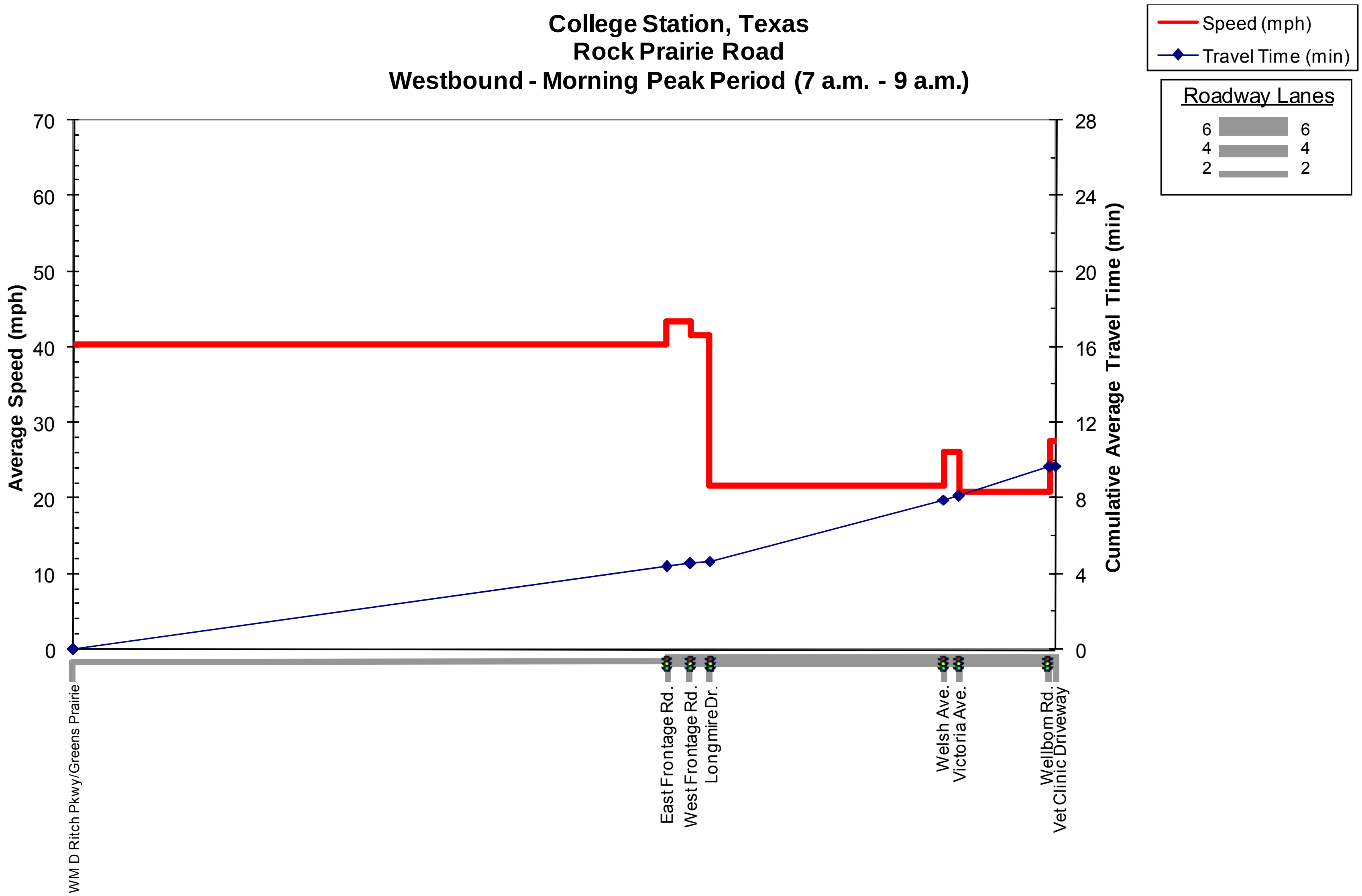


Figure D-59. Average Speed and Cumulative Average Travel Time for Rock Prairie Road, Westbound - Morning

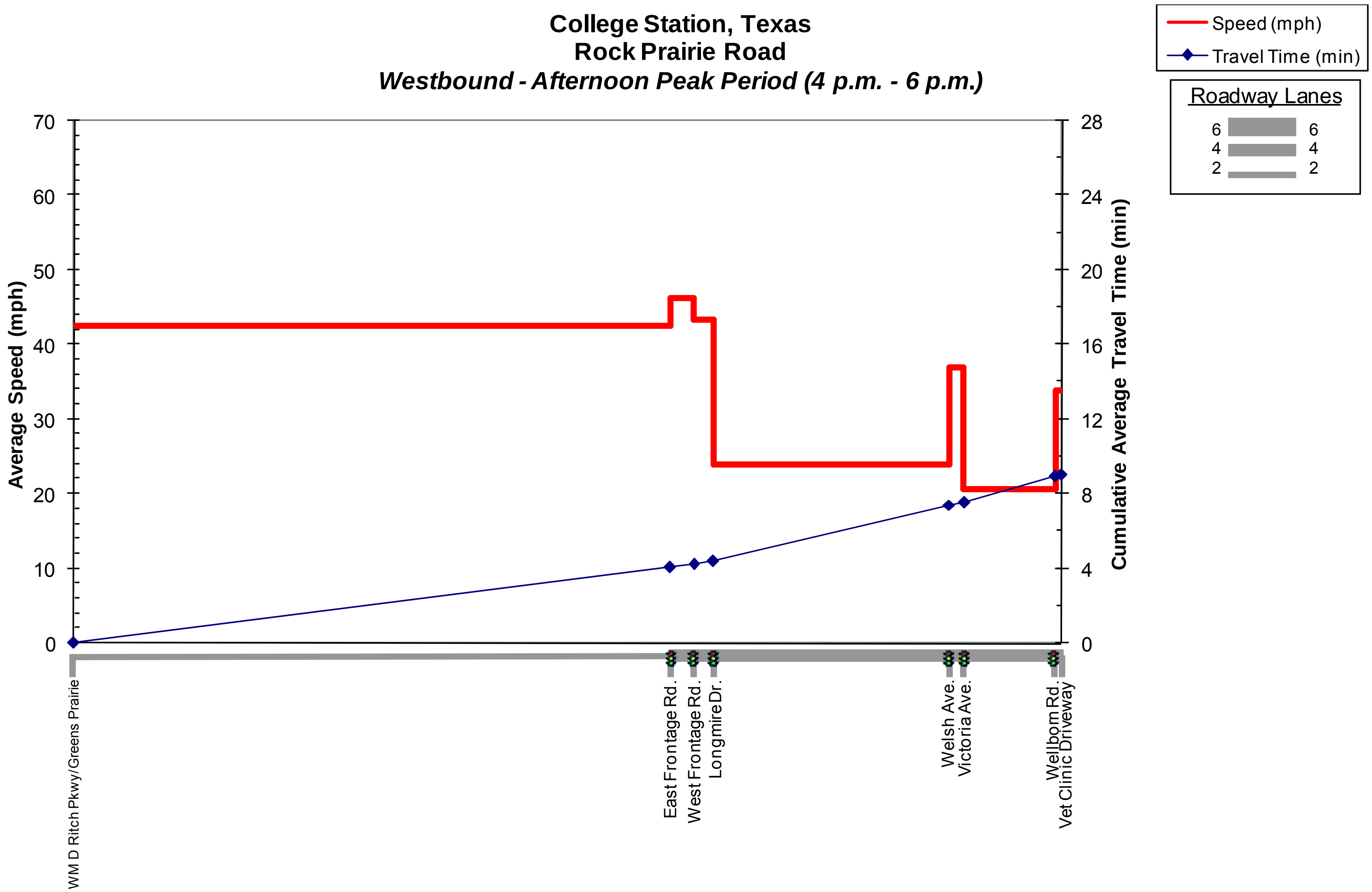


Figure D-60. Average Speed and Cumulative Average Travel Time for Rock Prairie Road, Westbound - Afternoon.

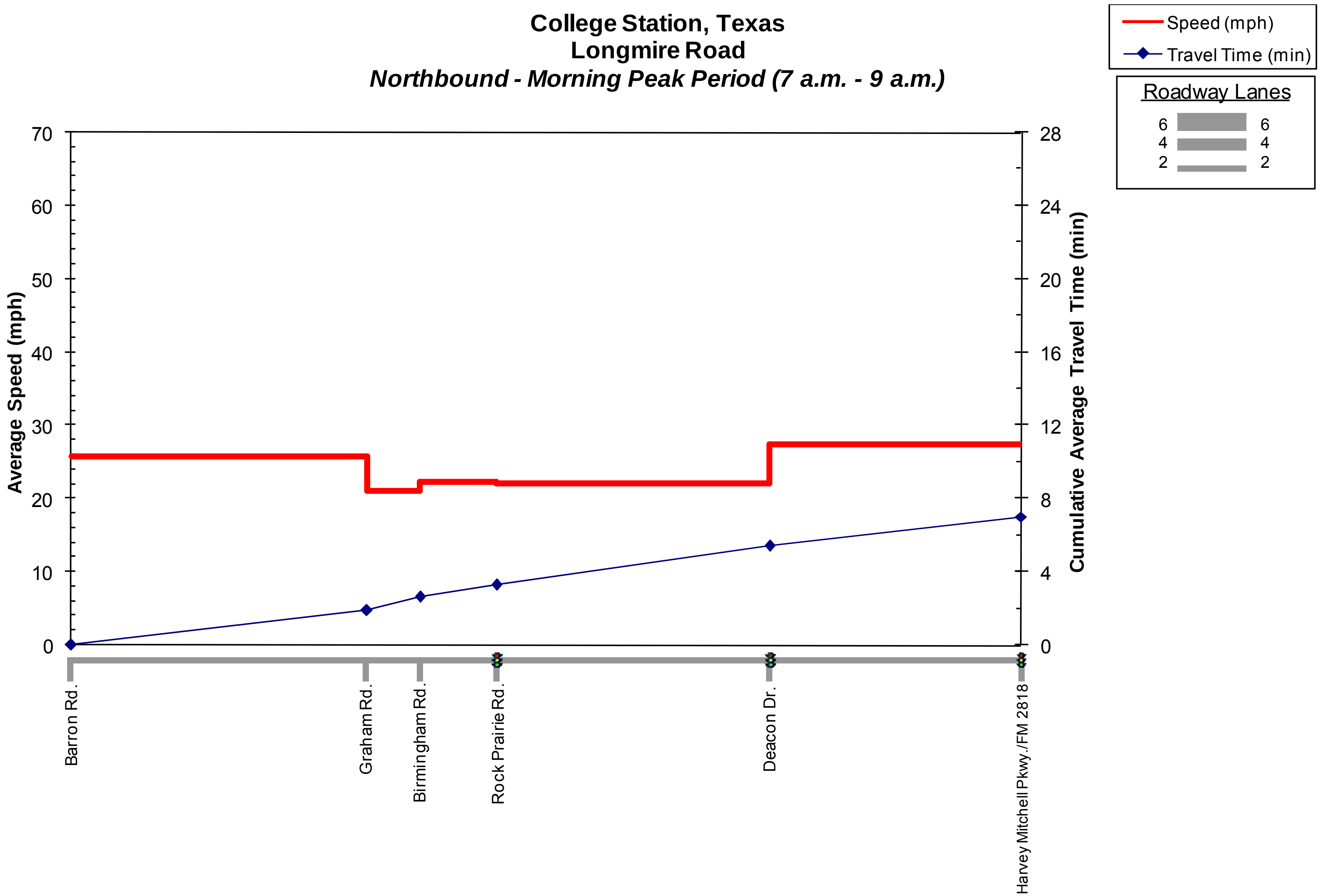


Figure D-61. Average Speed and Cumulative Average Travel Time for Longmire Road, Northbound - Morning

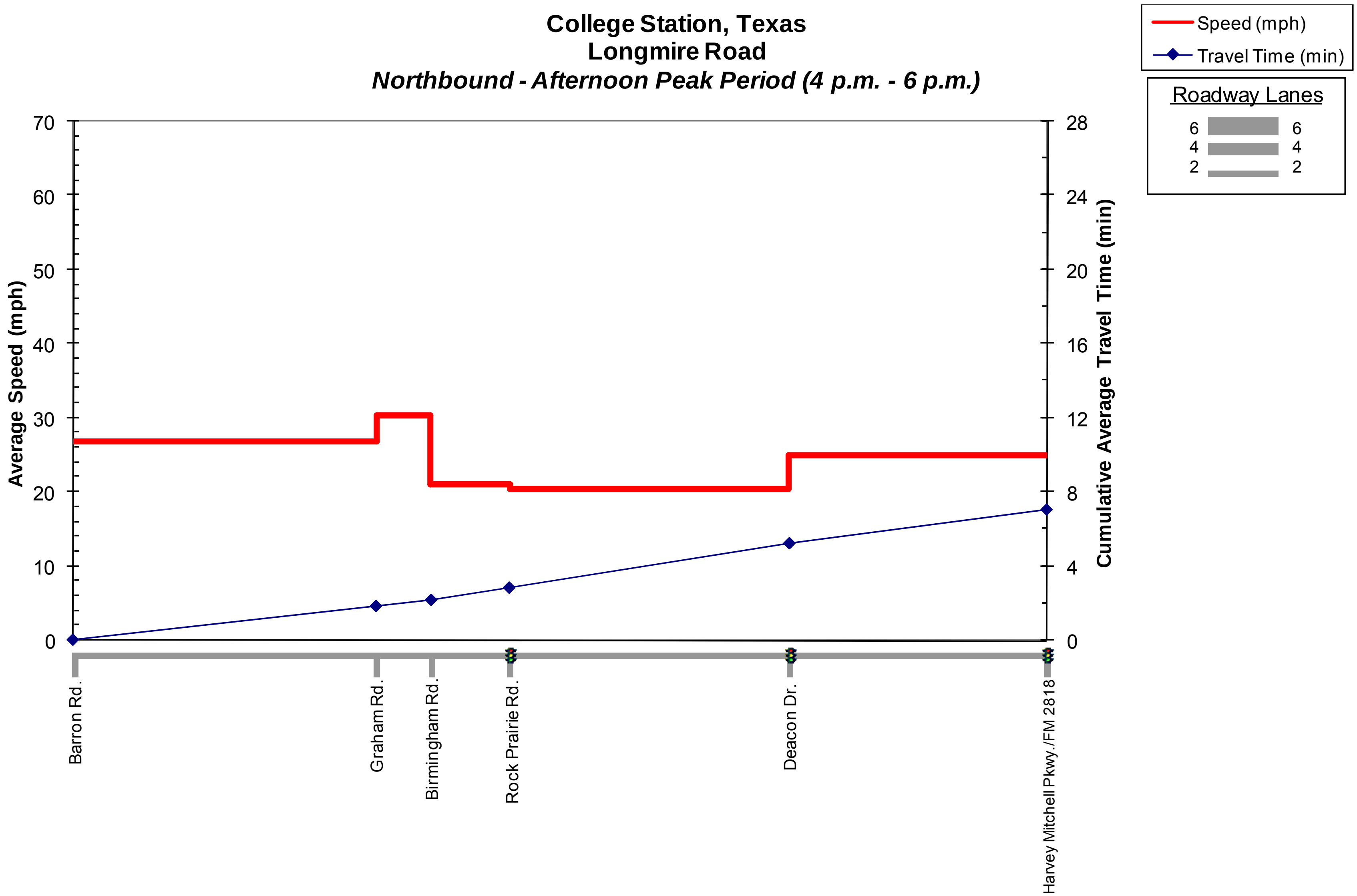


Figure D-62. Average Speed and Cumulative Average Travel Time for Longmire Road, Northbound - Afternoon.

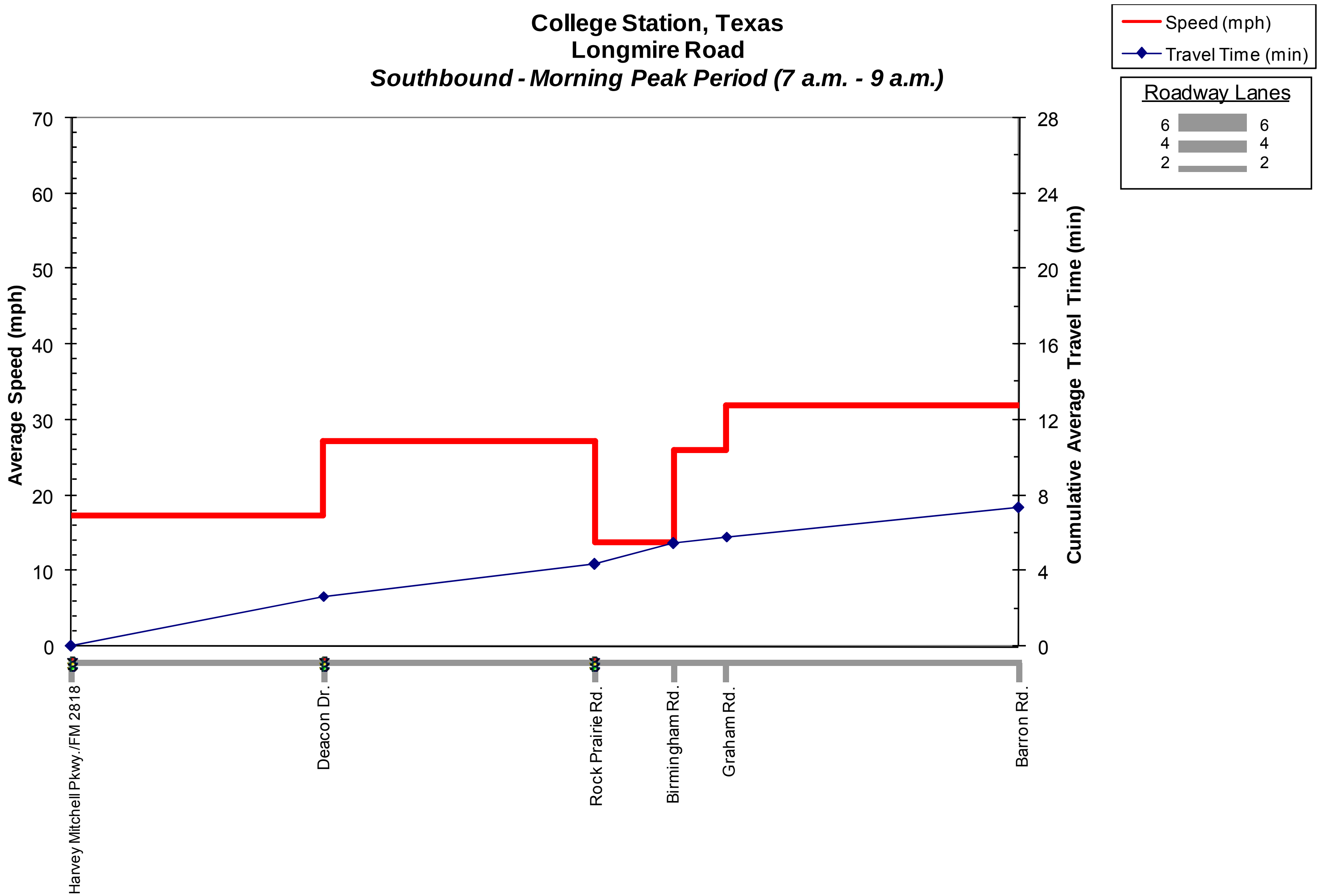


Figure D-63. Average Speed and Cumulative Average Travel Time for Longmire Road, Southbound - Morning

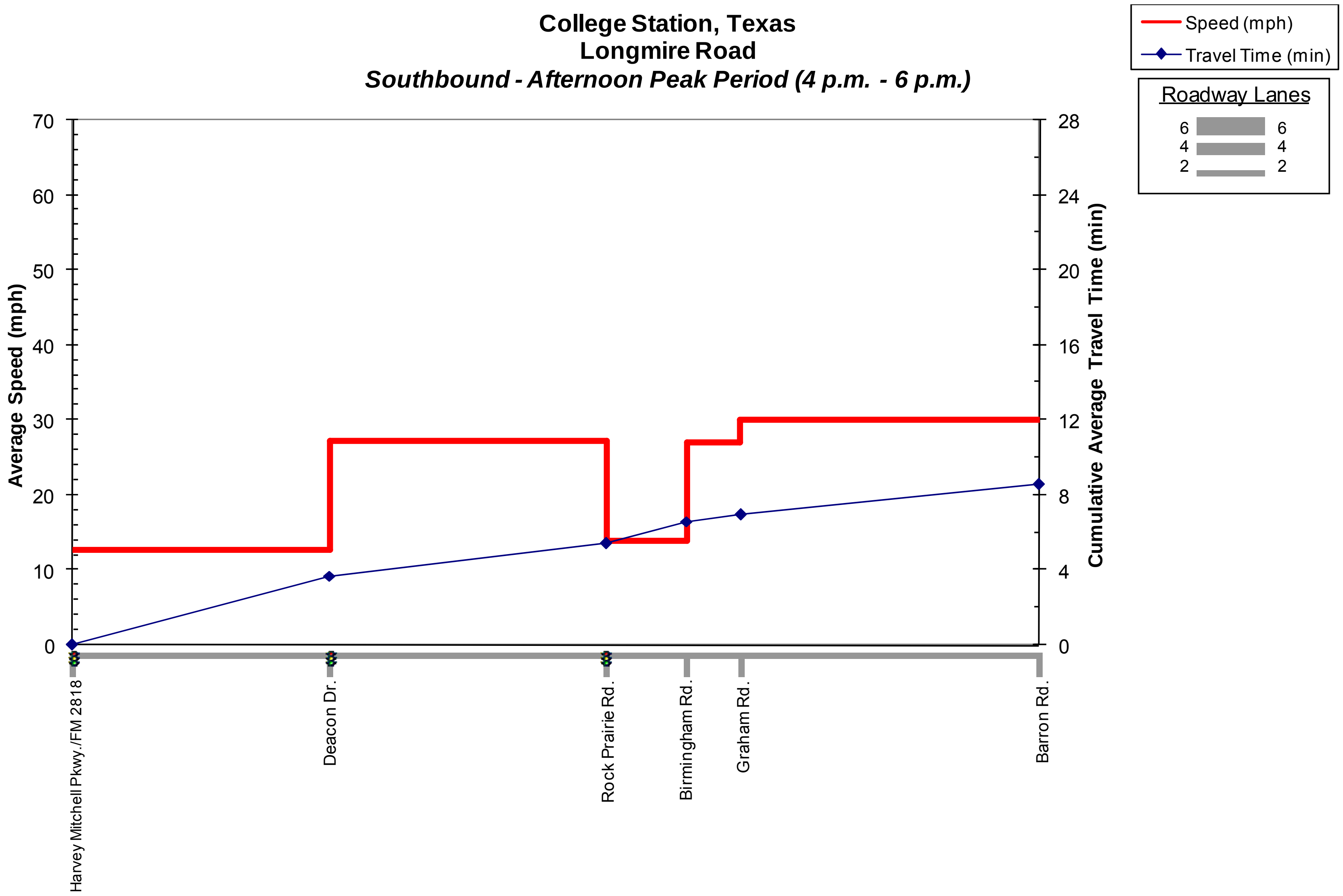


Figure D-64. Average Speed and Cumulative Average Travel Time for Longmire Road, Southbound - Afternoon.

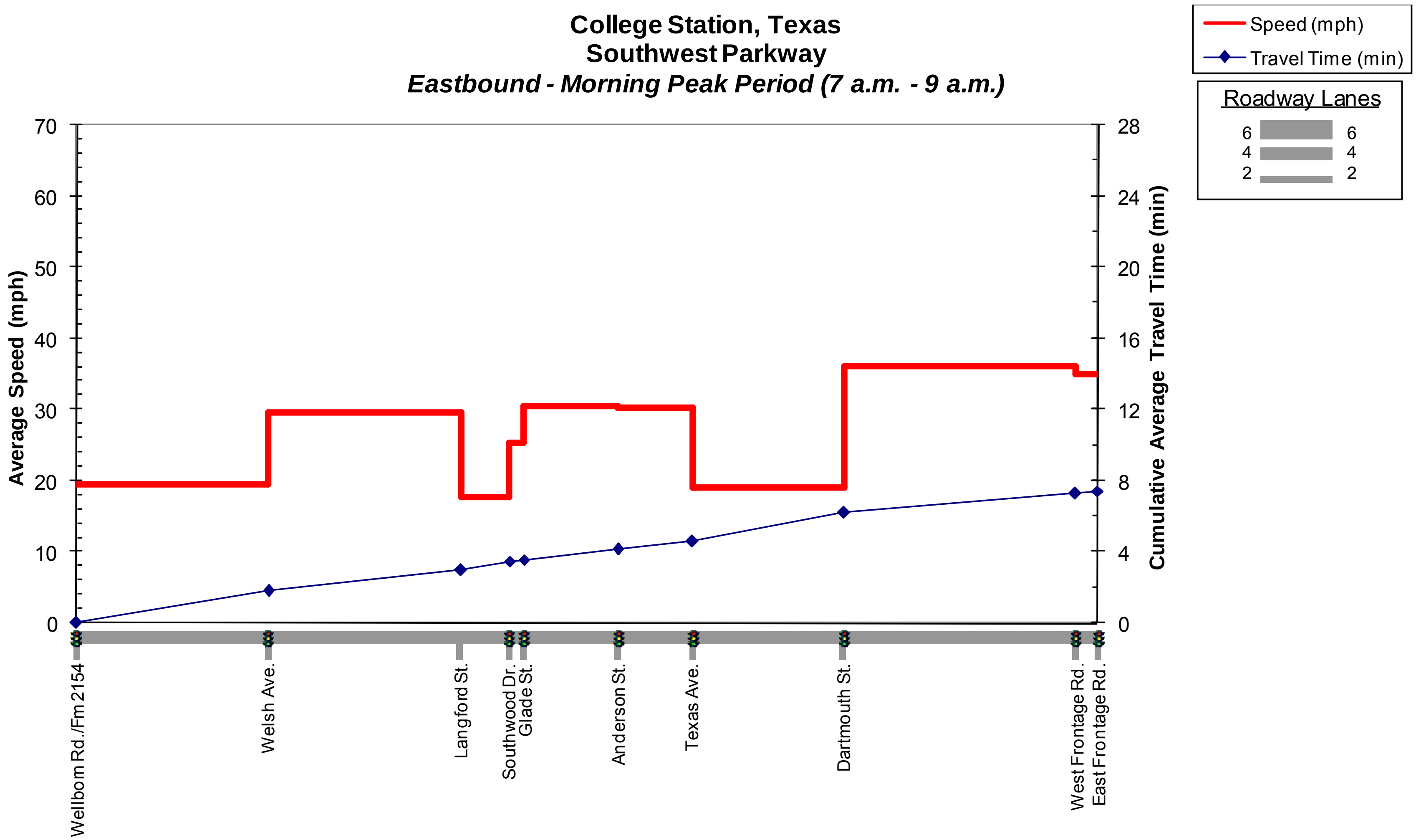


Figure D-65. Average Speed and Cumulative Average Travel Time for Southwest Parkway, Eastbound - Morning

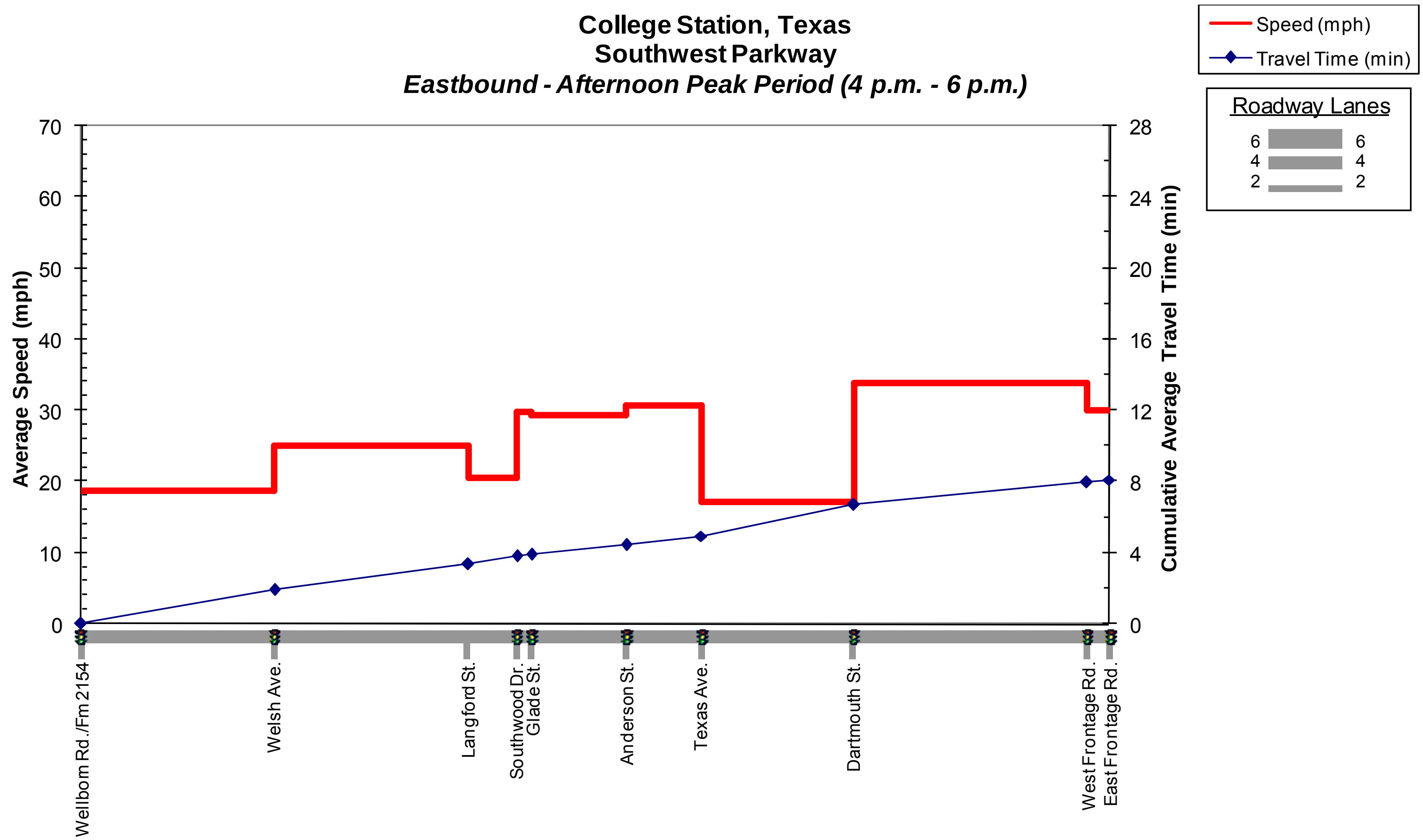


Figure D-66. Average Speed and Cumulative Average Travel Time for Southwest Parkway, Eastbound - Afternoon.

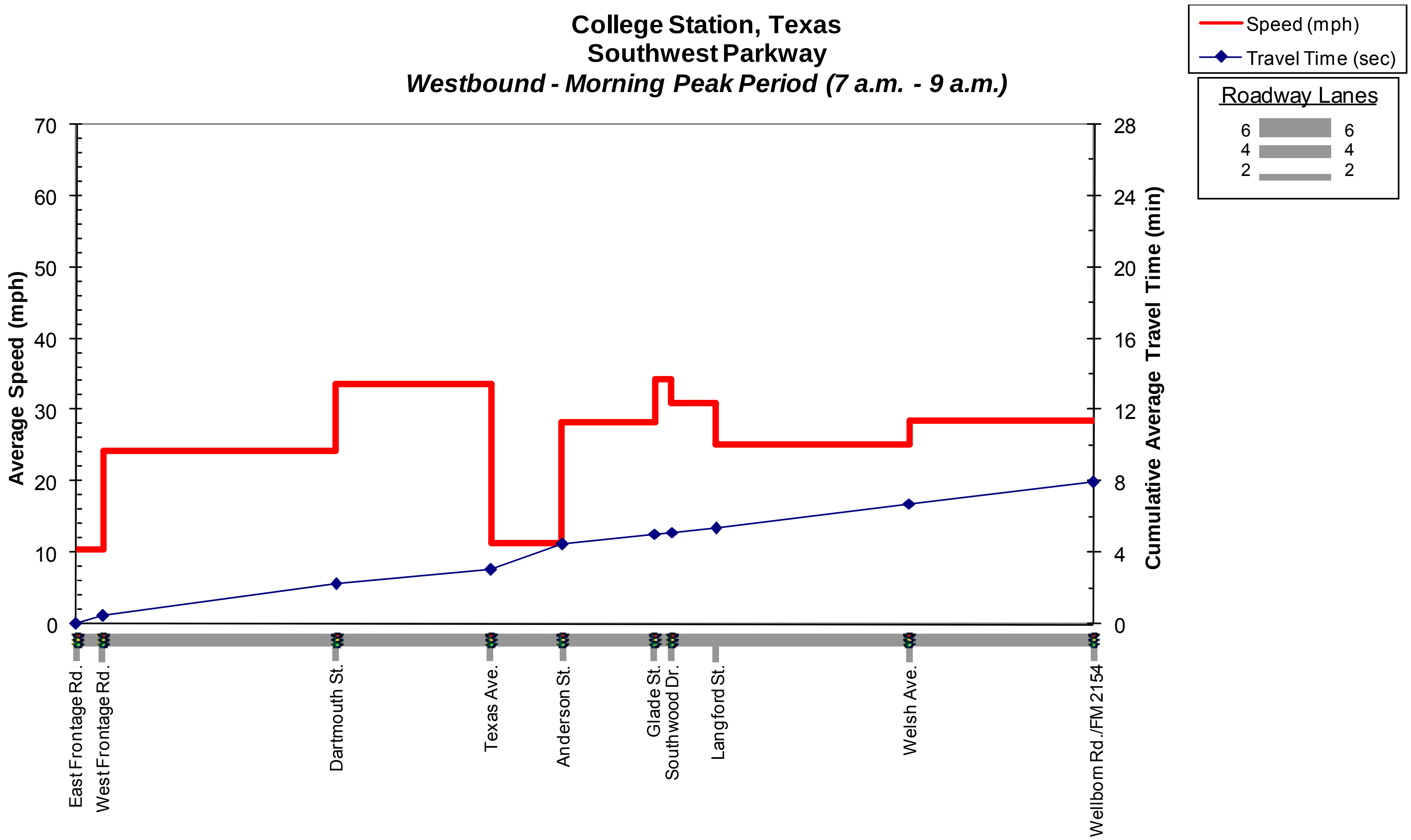


Figure D-67. Average Speed and Cumulative Average Travel Time for Southwest Parkway, Westbound - Morning

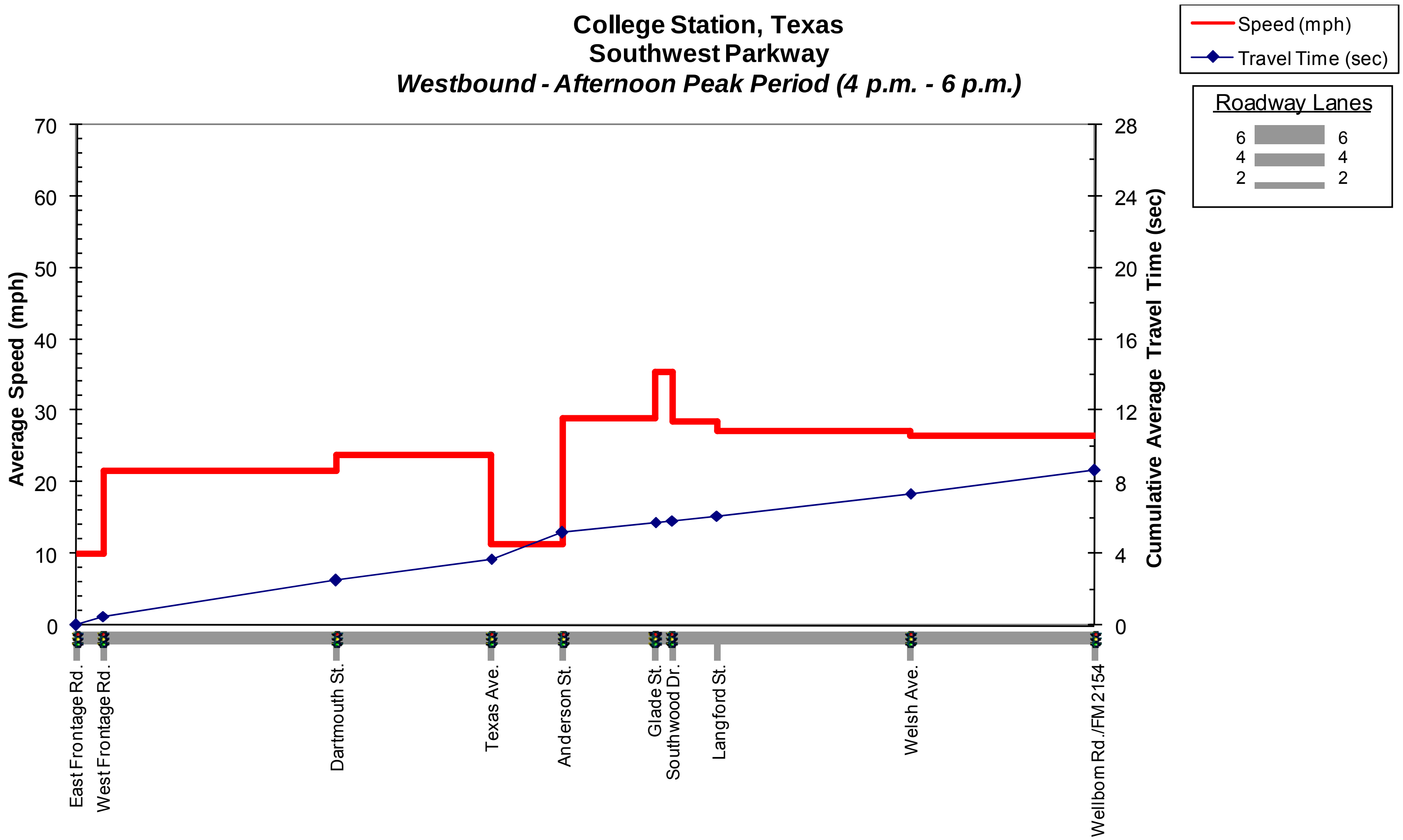


Figure D-68. Average Speed and Cumulative Average Travel Time for Southwest Parkway, Westbound - Afternoon.

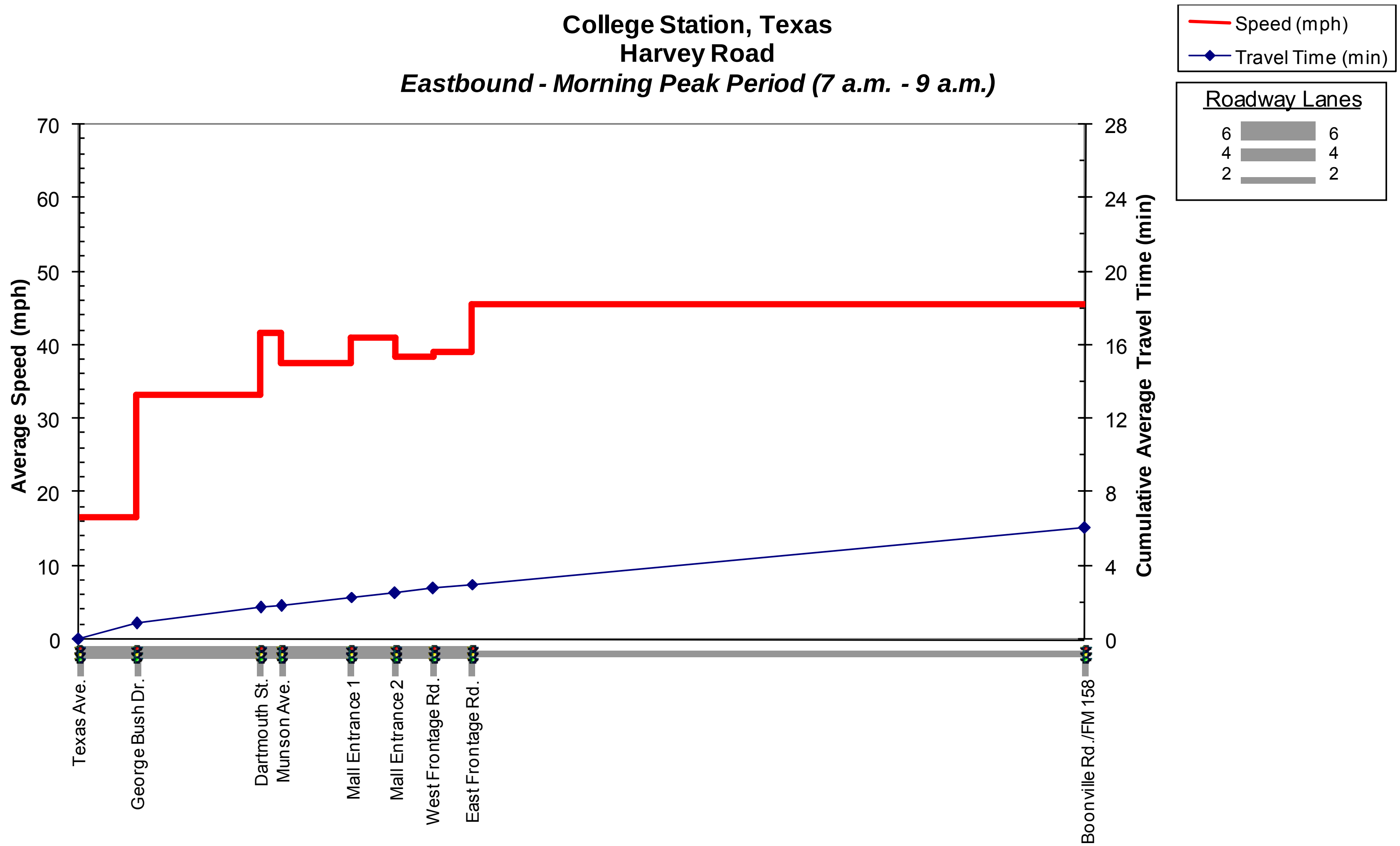


Figure D-69. Average Speed and Cumulative Average Travel Time for Harvey Road, Eastbound - Morning

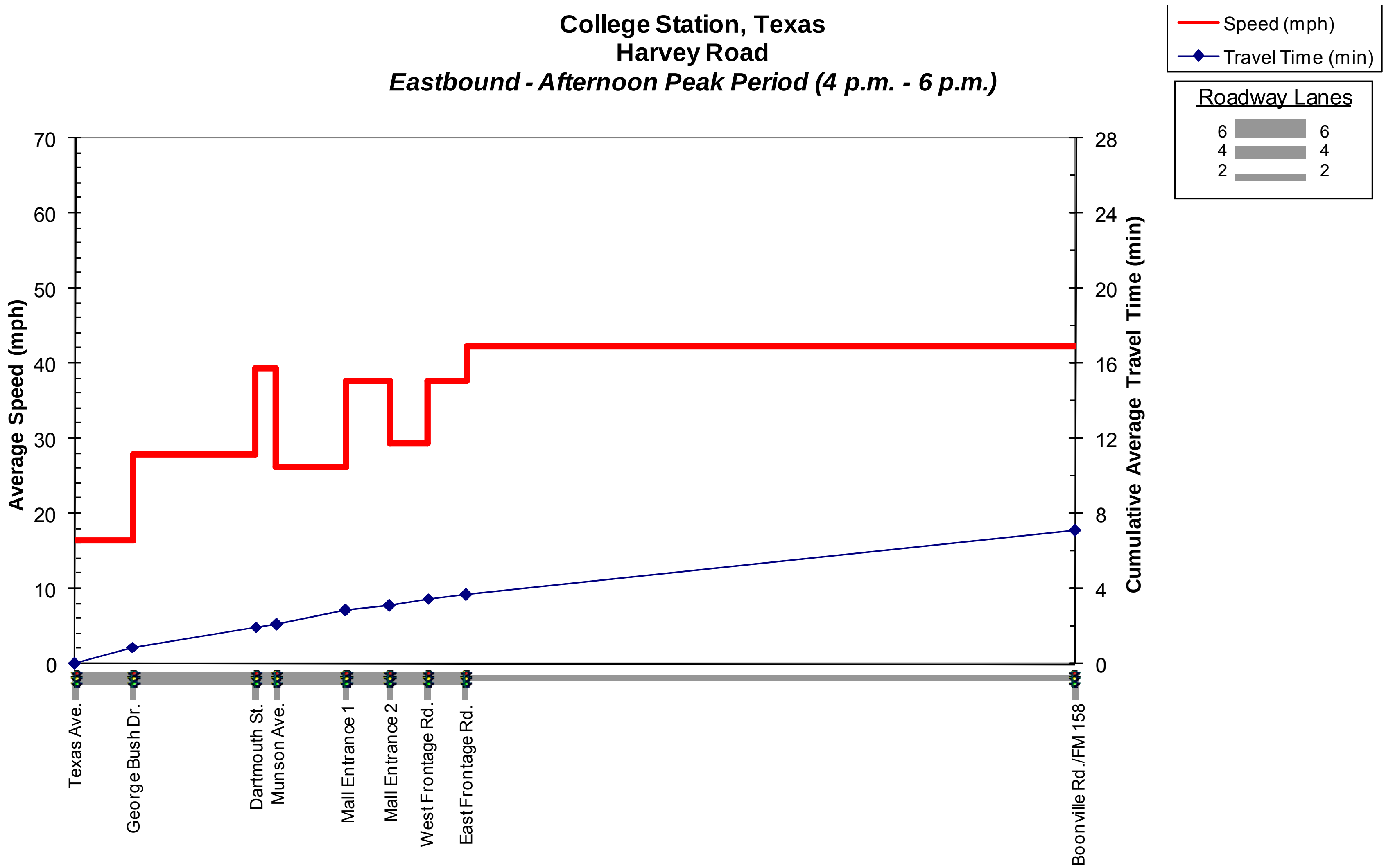


Figure D-70. Average Speed and Cumulative Average Travel Time for Harvey Road, Eastbound - Afternoon.

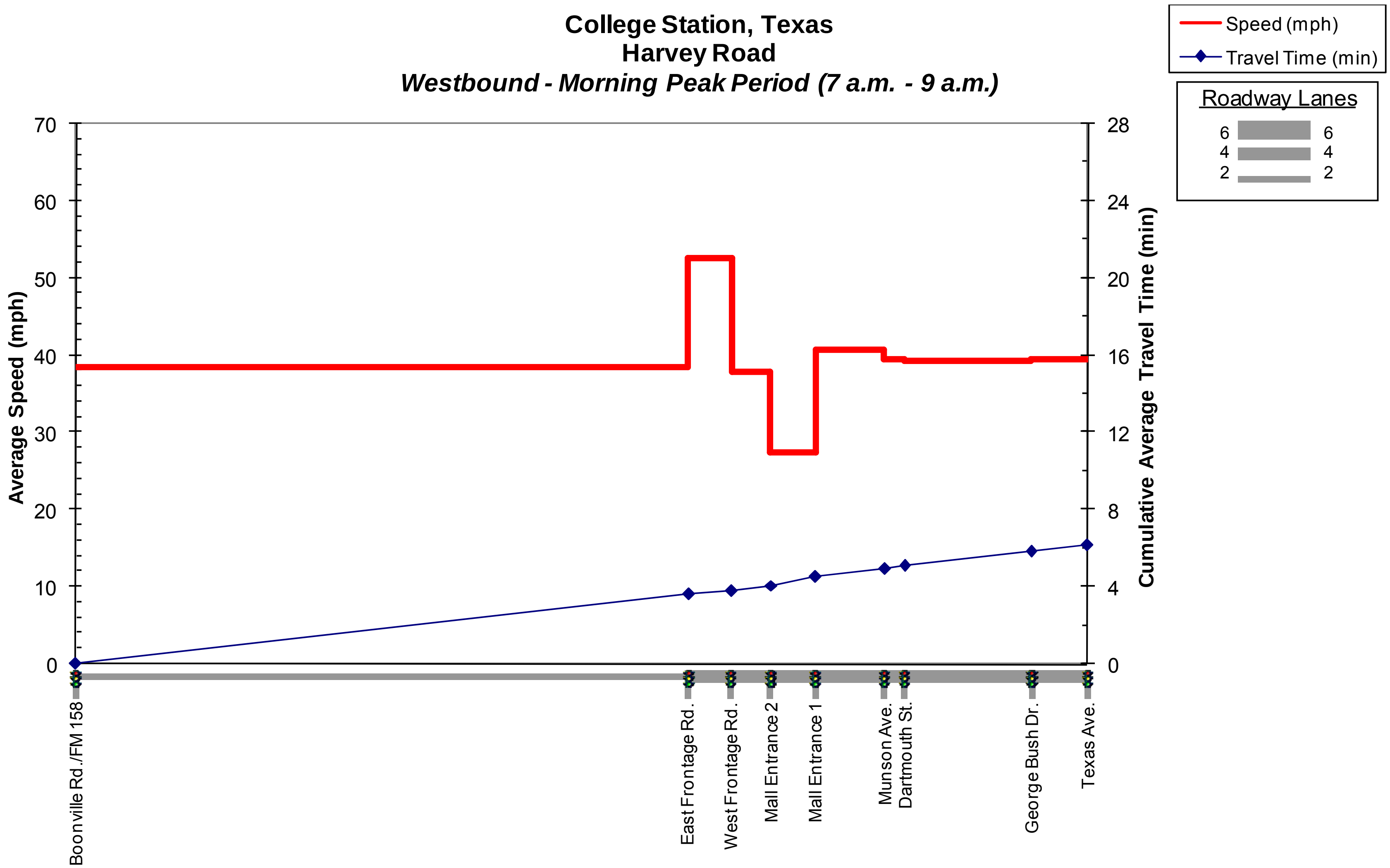


Figure D-71. Average Speed and Cumulative Average Travel Time for Harvey Road, Westbound - Morning

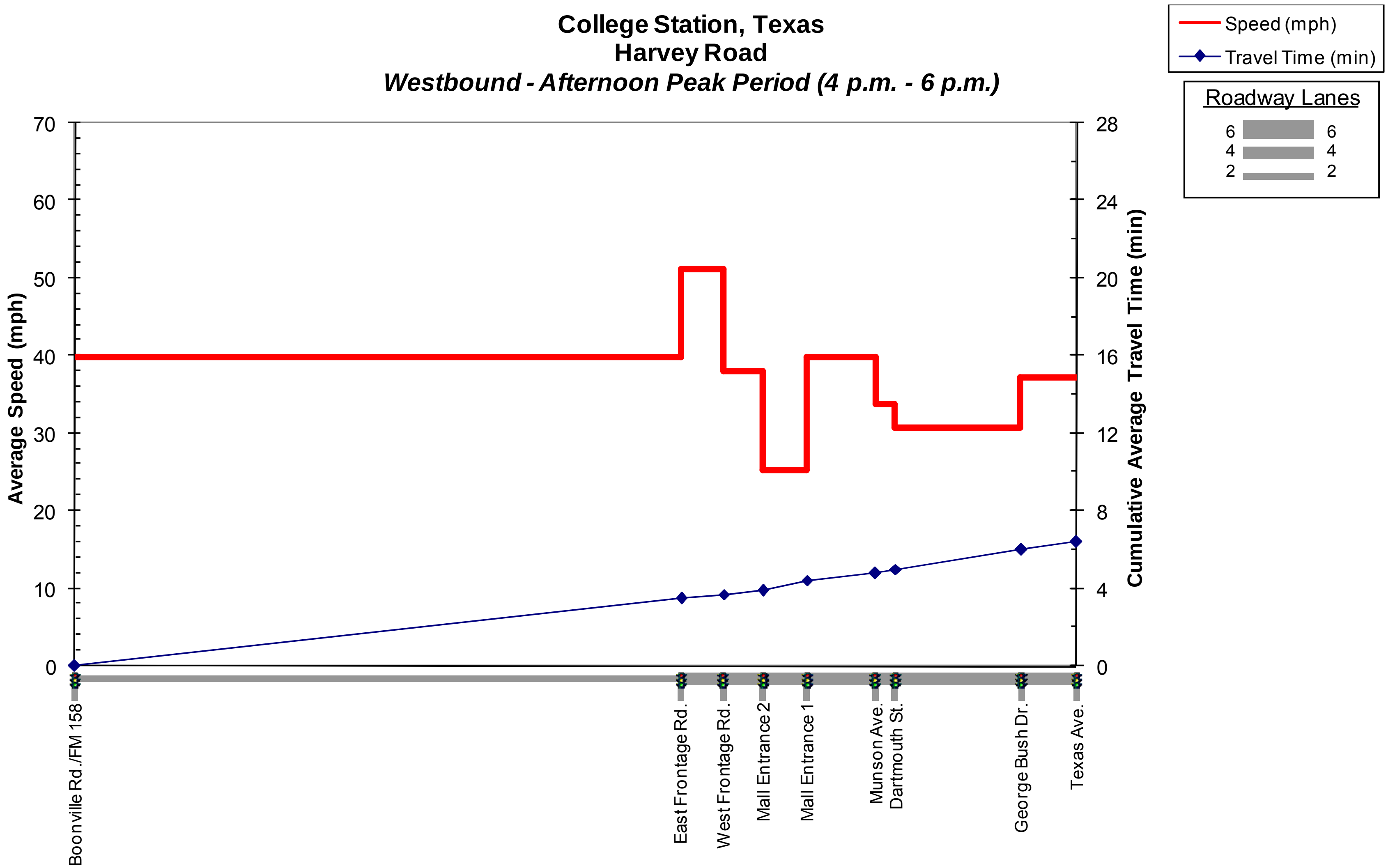


Figure D-72. Average Speed and Cumulative Average Travel Time for Harvey Road, Westbound - Afternoon.

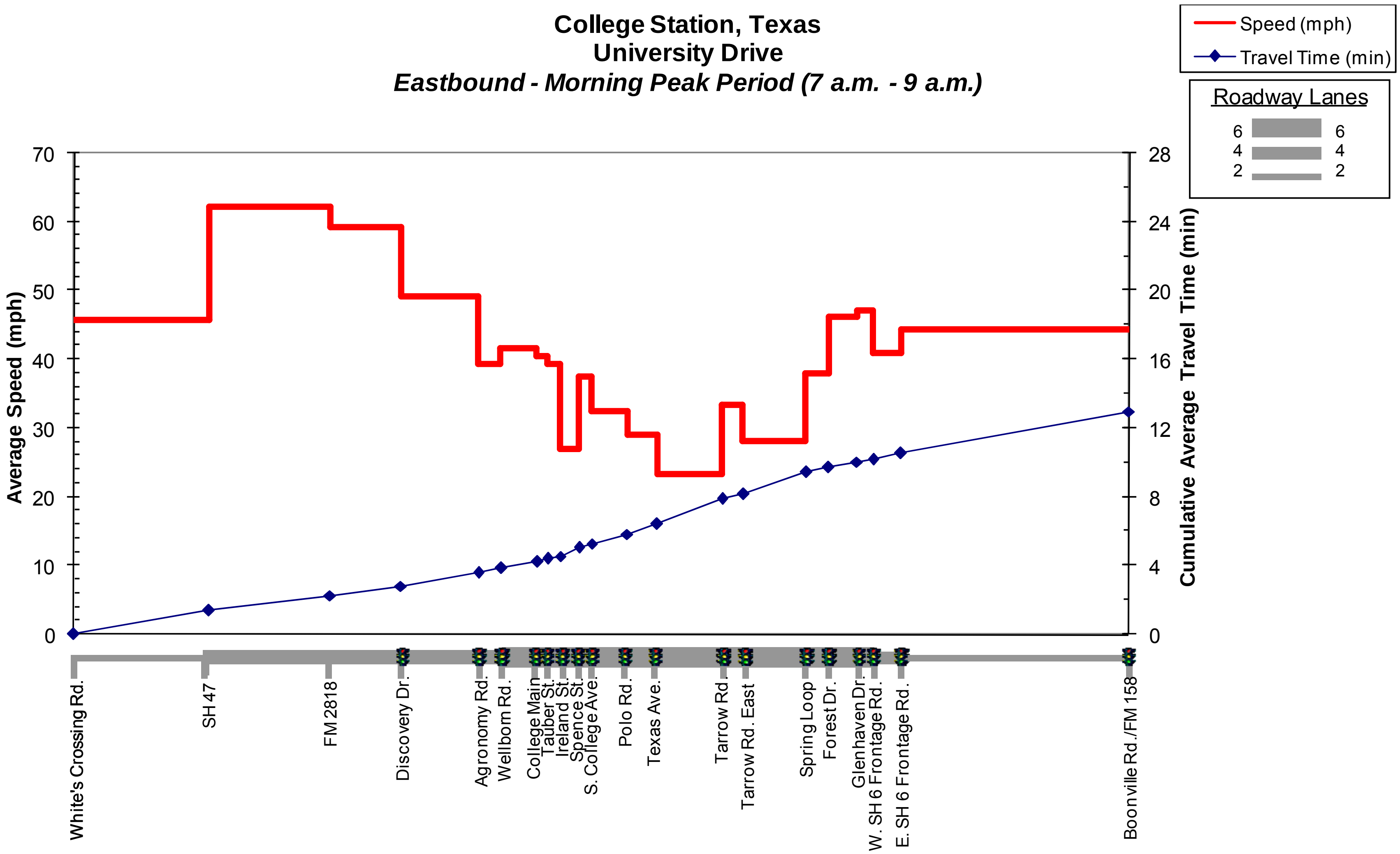


Figure D-73. Average Speed and Cumulative Average Travel Time for University Drive, Eastbound - Morning

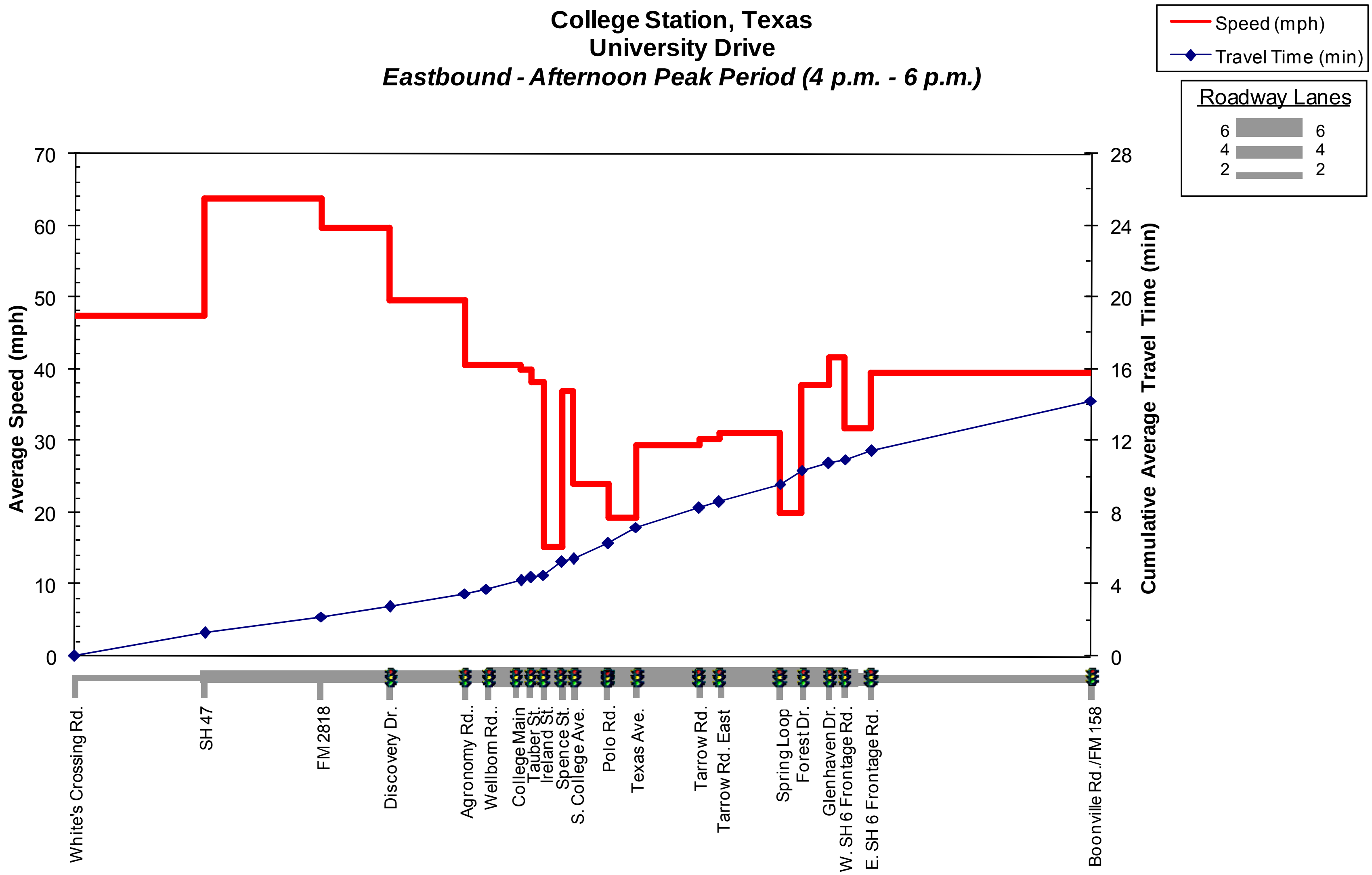


Figure D-74. Average Speed and Cumulative Average Travel Time for University Drive, Eastbound - Afternoon.

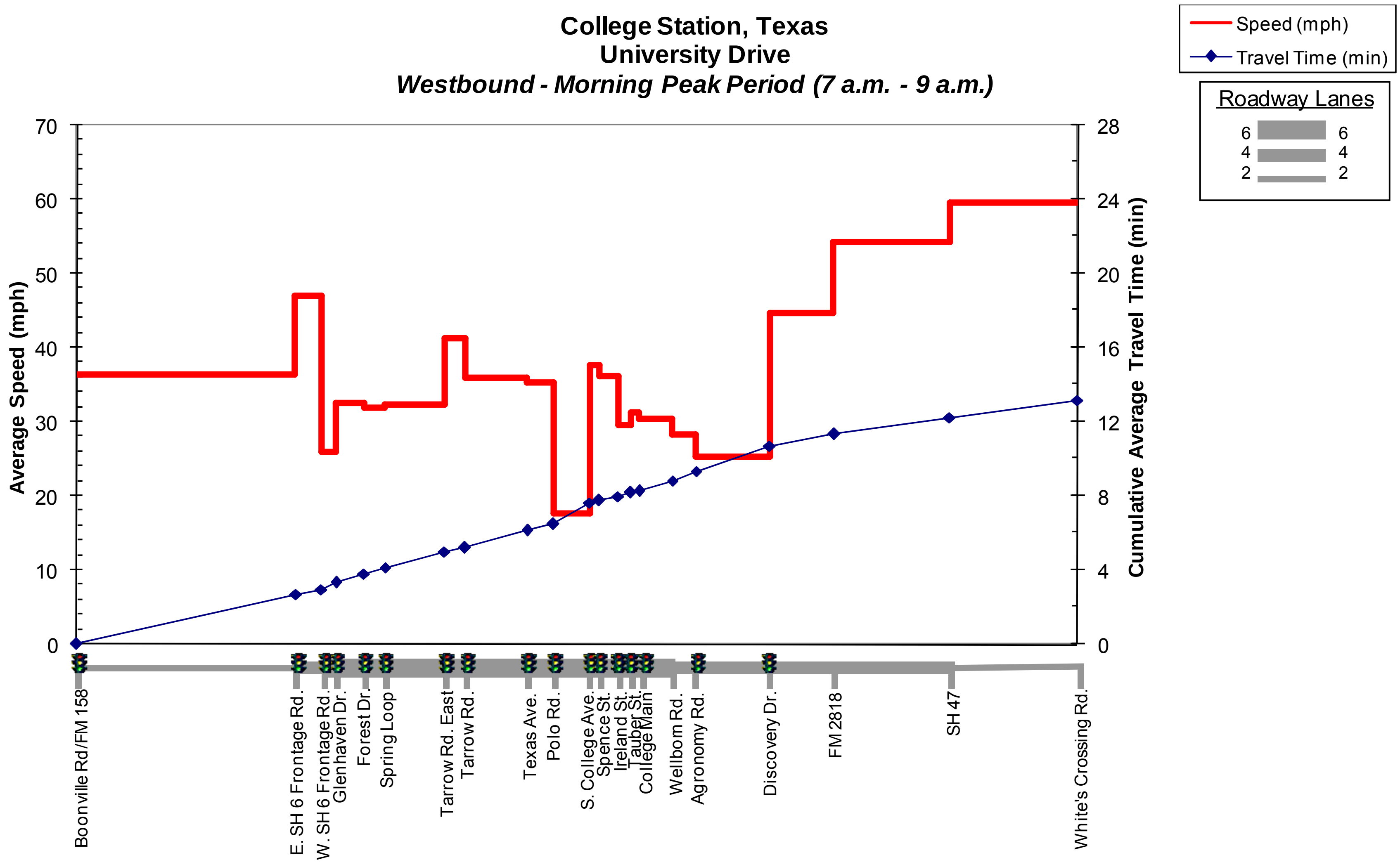


Figure D-75. Average Speed and Cumulative Average Travel Time for University Drive, Westbound - Morning

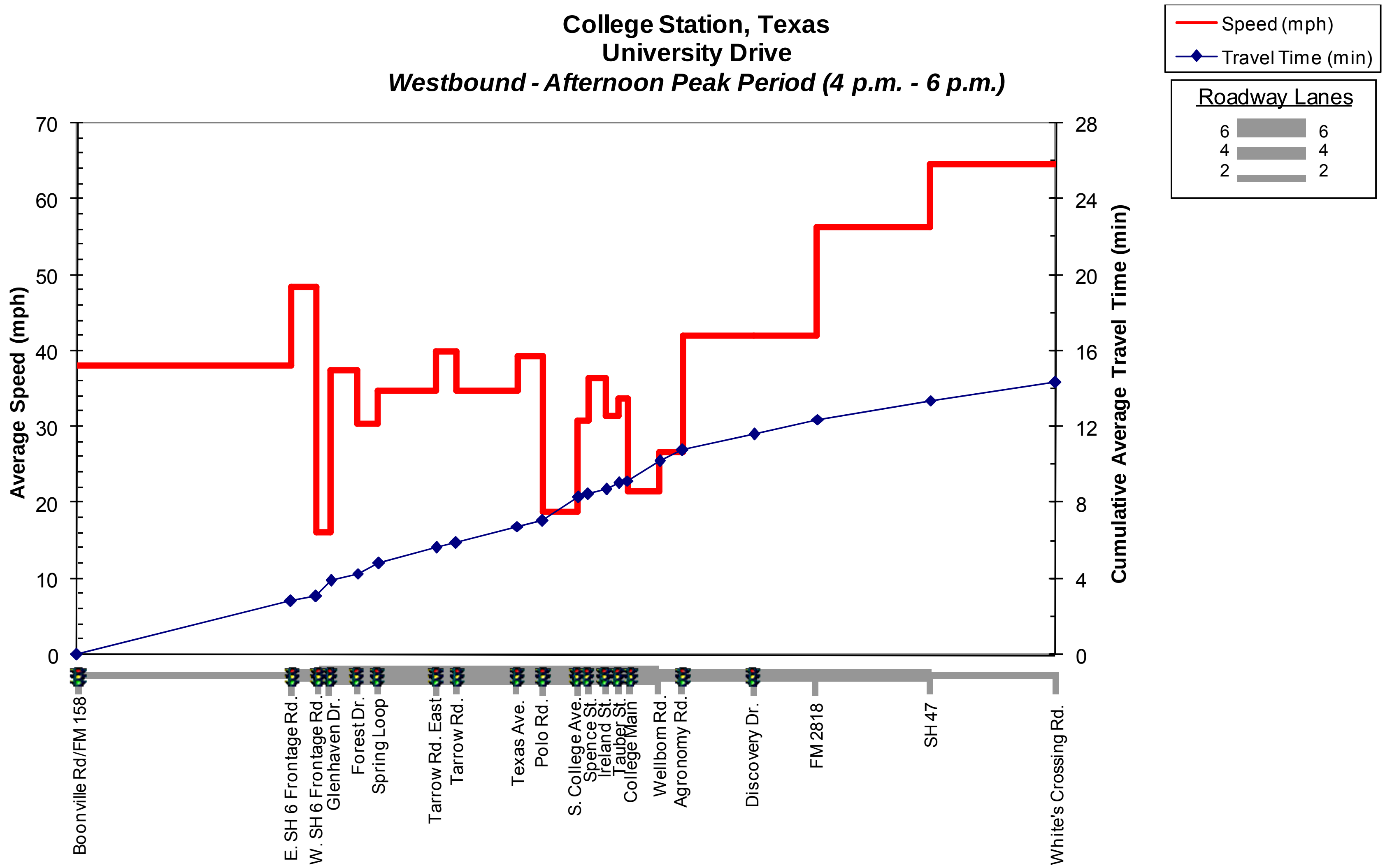


Figure D-76. Average Speed and Cumulative Average Travel Time for University Drive, Westbound - Afternoon.

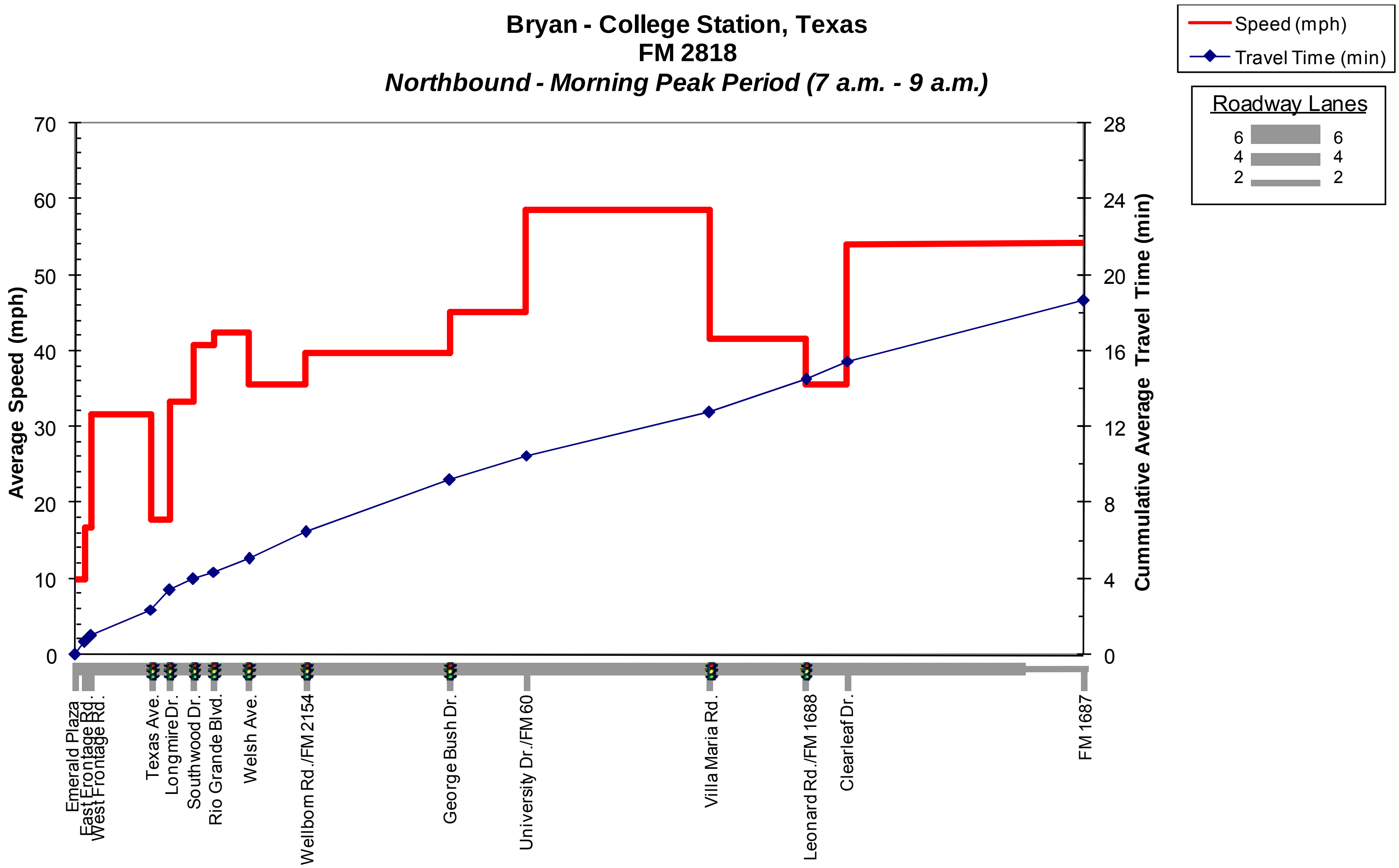


Figure D-77. Average Speed and Cumulative Average Travel Time for FM 2818, Northbound - Morning

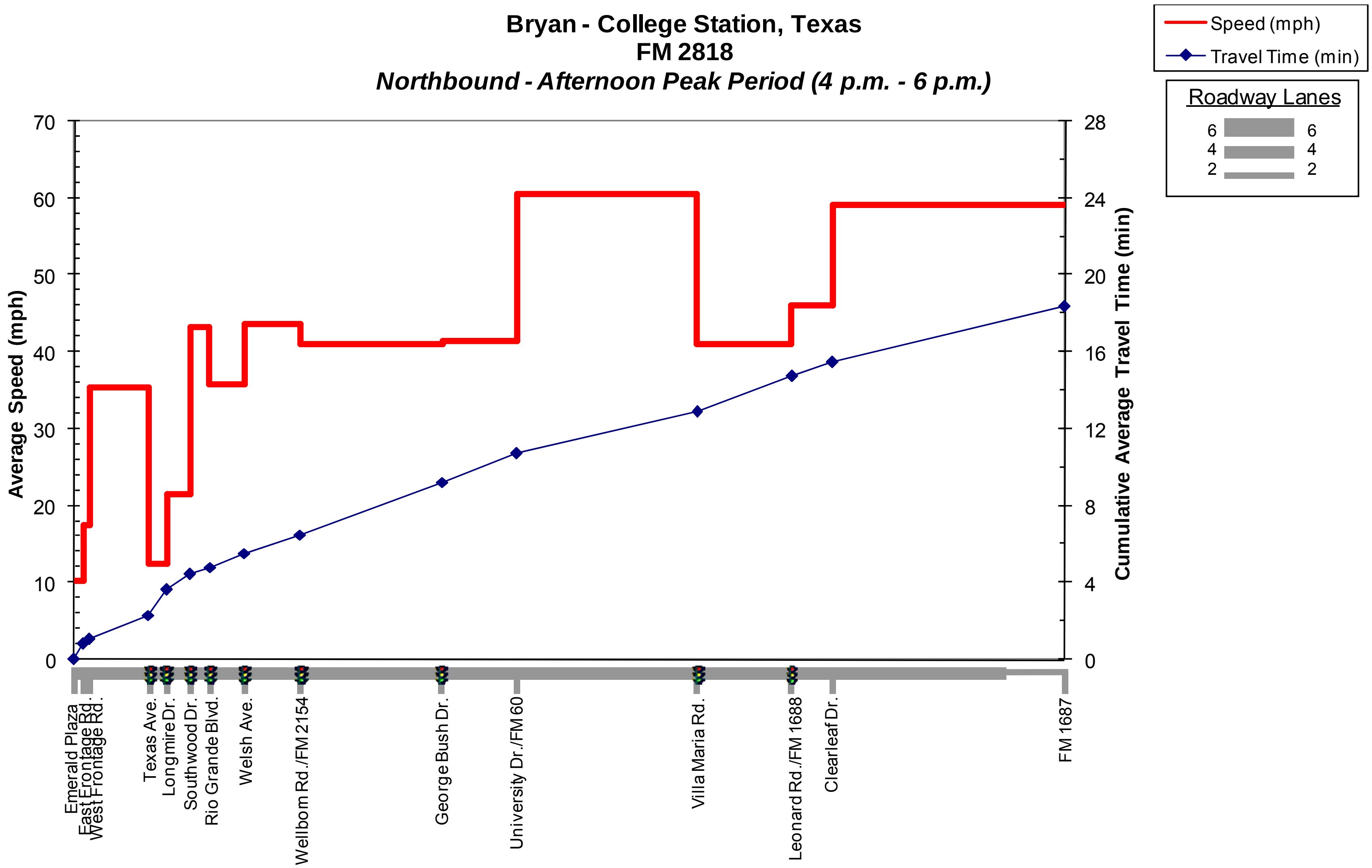


Figure D-78. Average Speed and Cumulative Average Travel Time for FM 2818, Northbound - Afternoon.

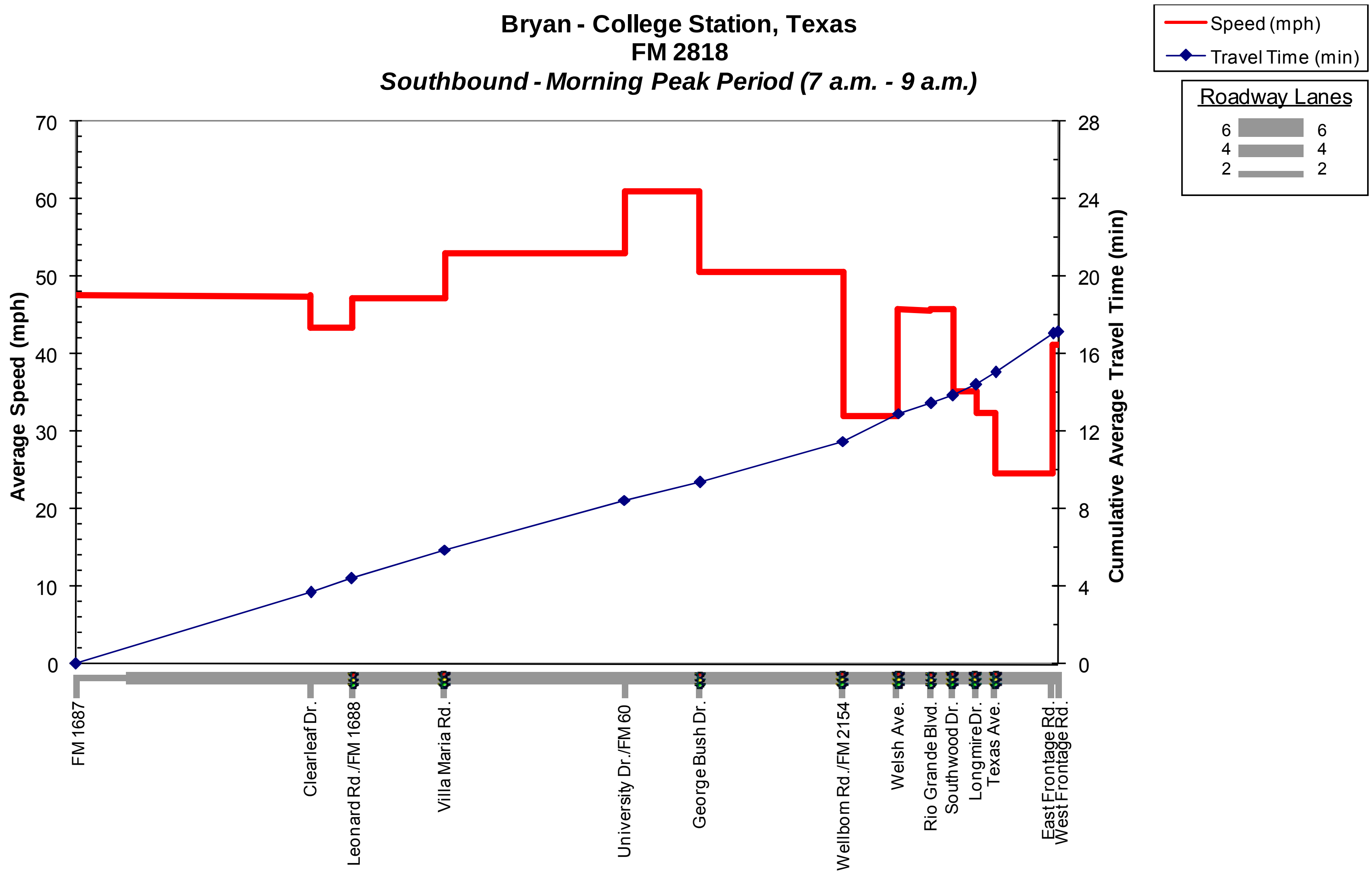


Figure D-79. Average Speed and Cumulative Average Travel Time for FM 2818, Southbound - Morning

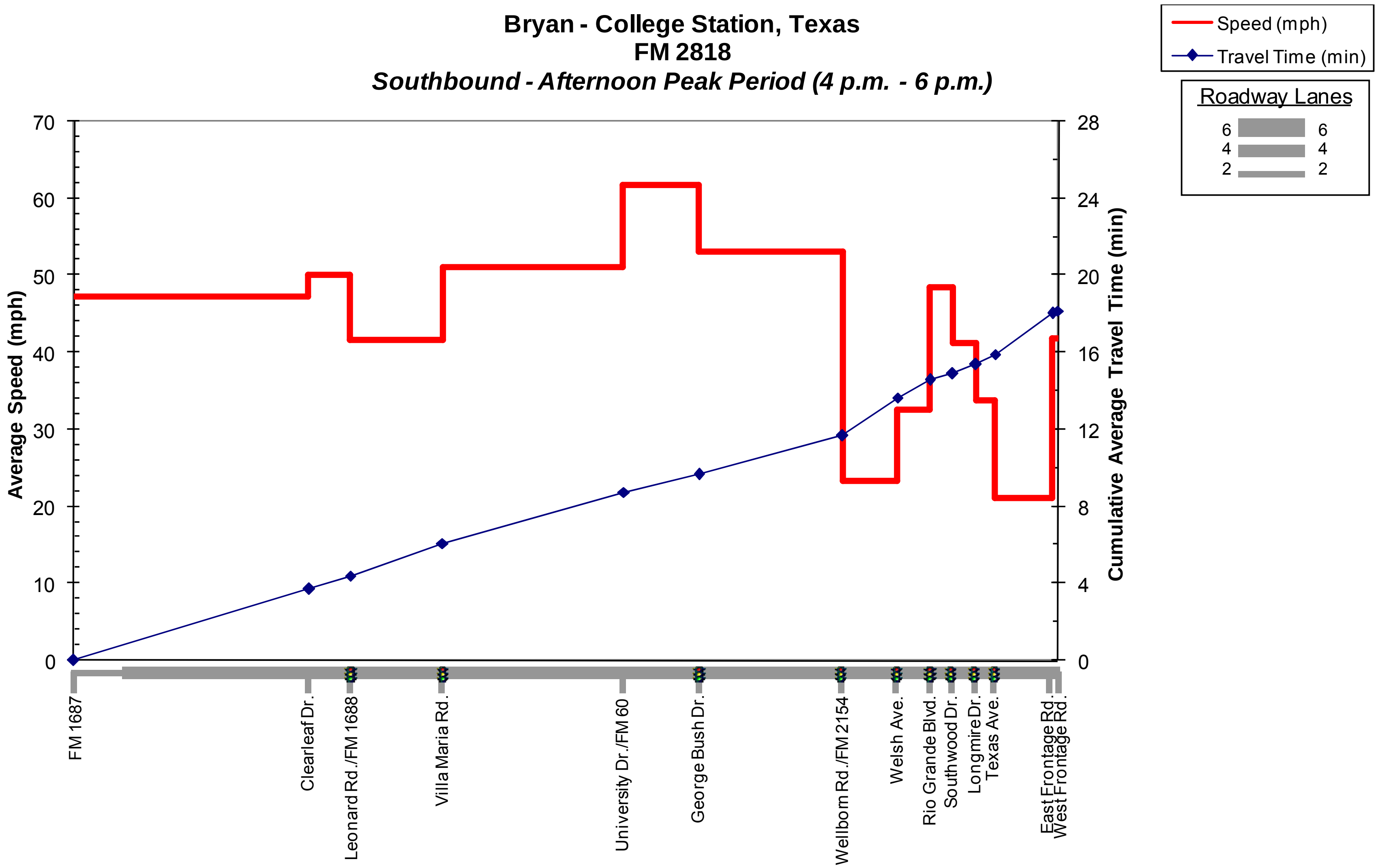


Figure D-80. Average Speed and Cumulative Average Travel Time for FM 2818, Southbound - Afternoon.

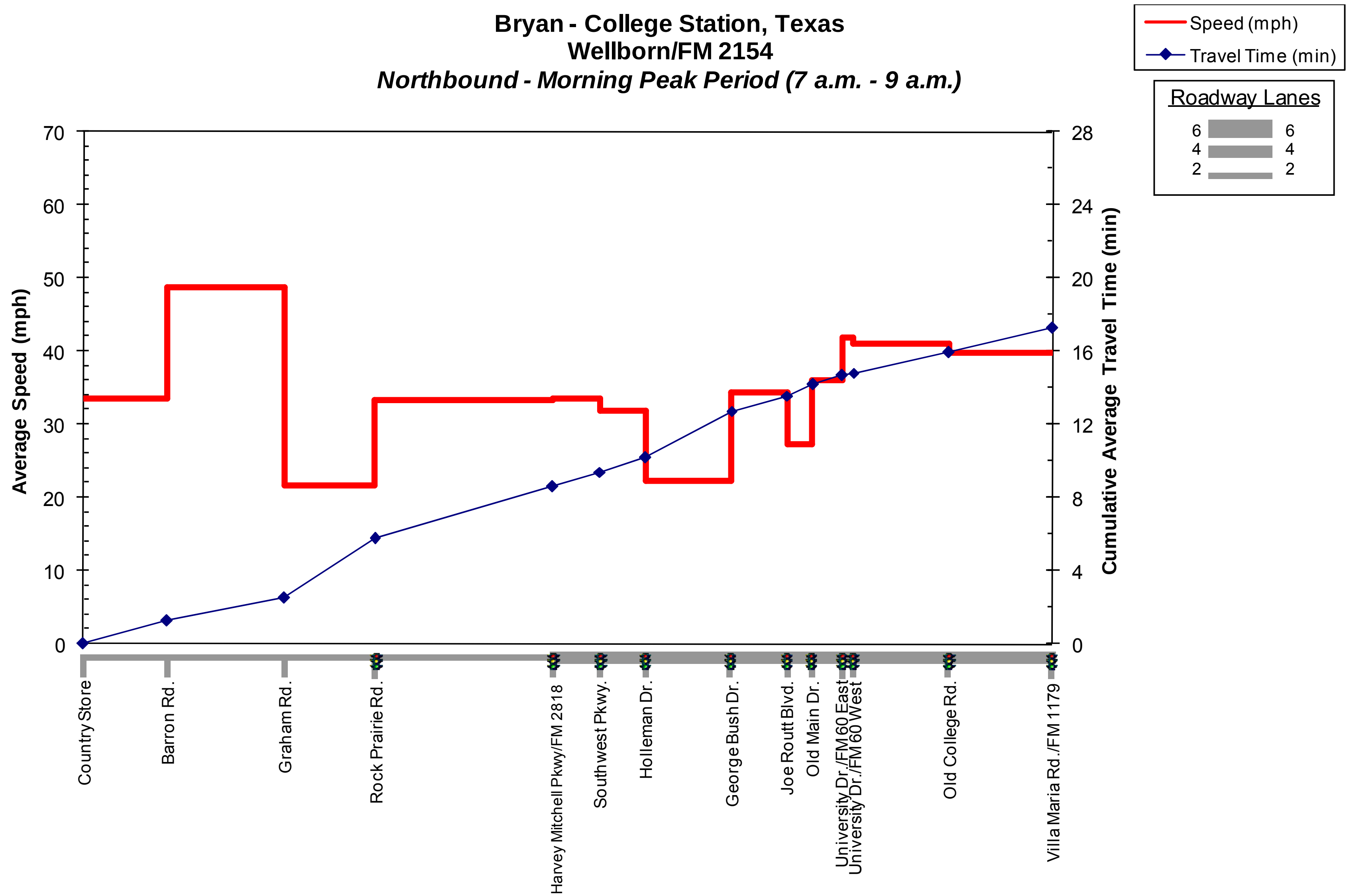


Figure D-81. Average Speed and Cumulative Average Travel Time for Wellborn/FM 2154, Northbound - Morning

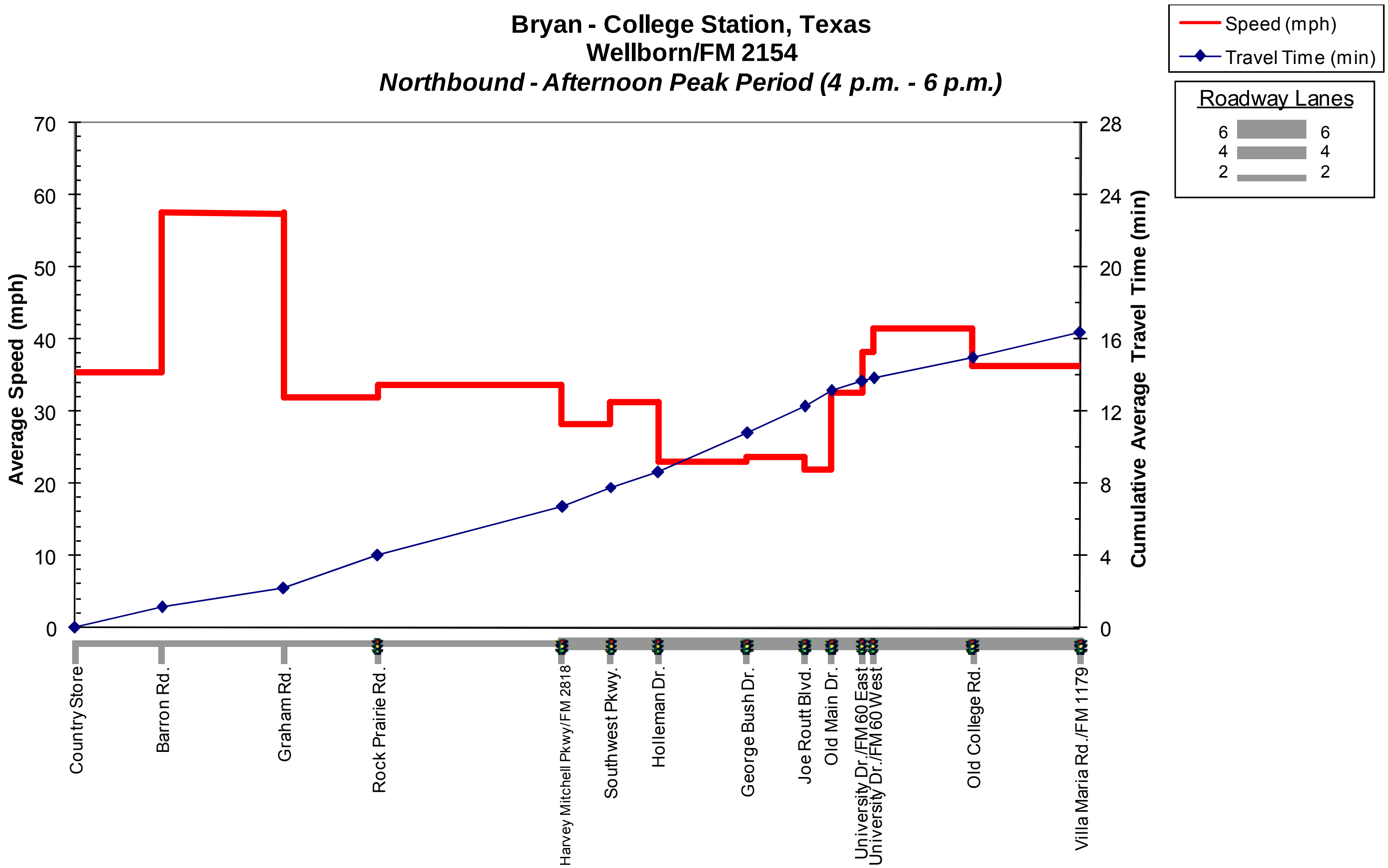


Figure D-82. Average Speed and Cumulative Average Travel Time for Wellborn/FM 2154, Northbound - Afternoon.

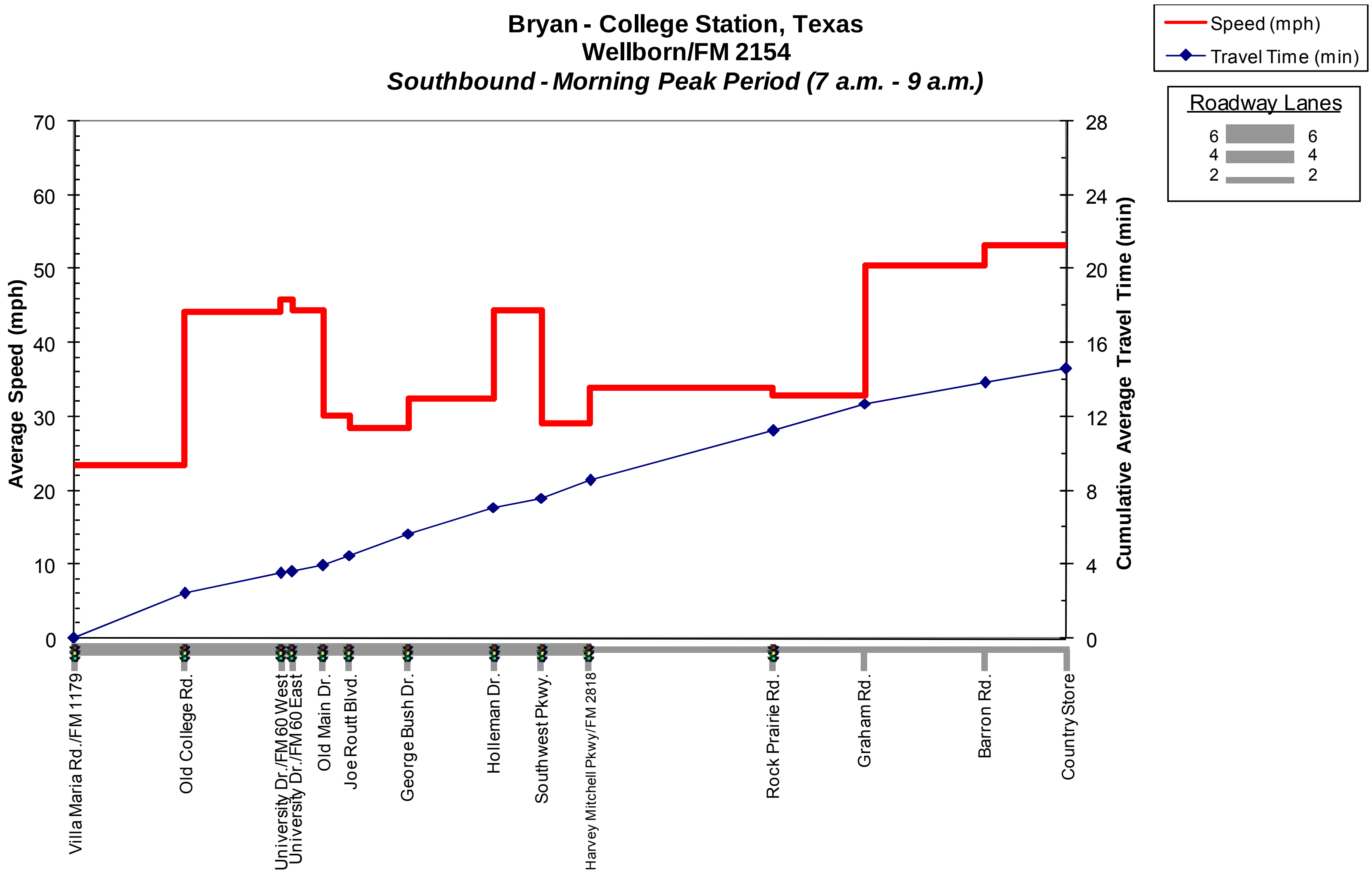


Figure D-83. Average Speed and Cumulative Average Travel Time for Wellborn/FM 2154, Southbound - Morning

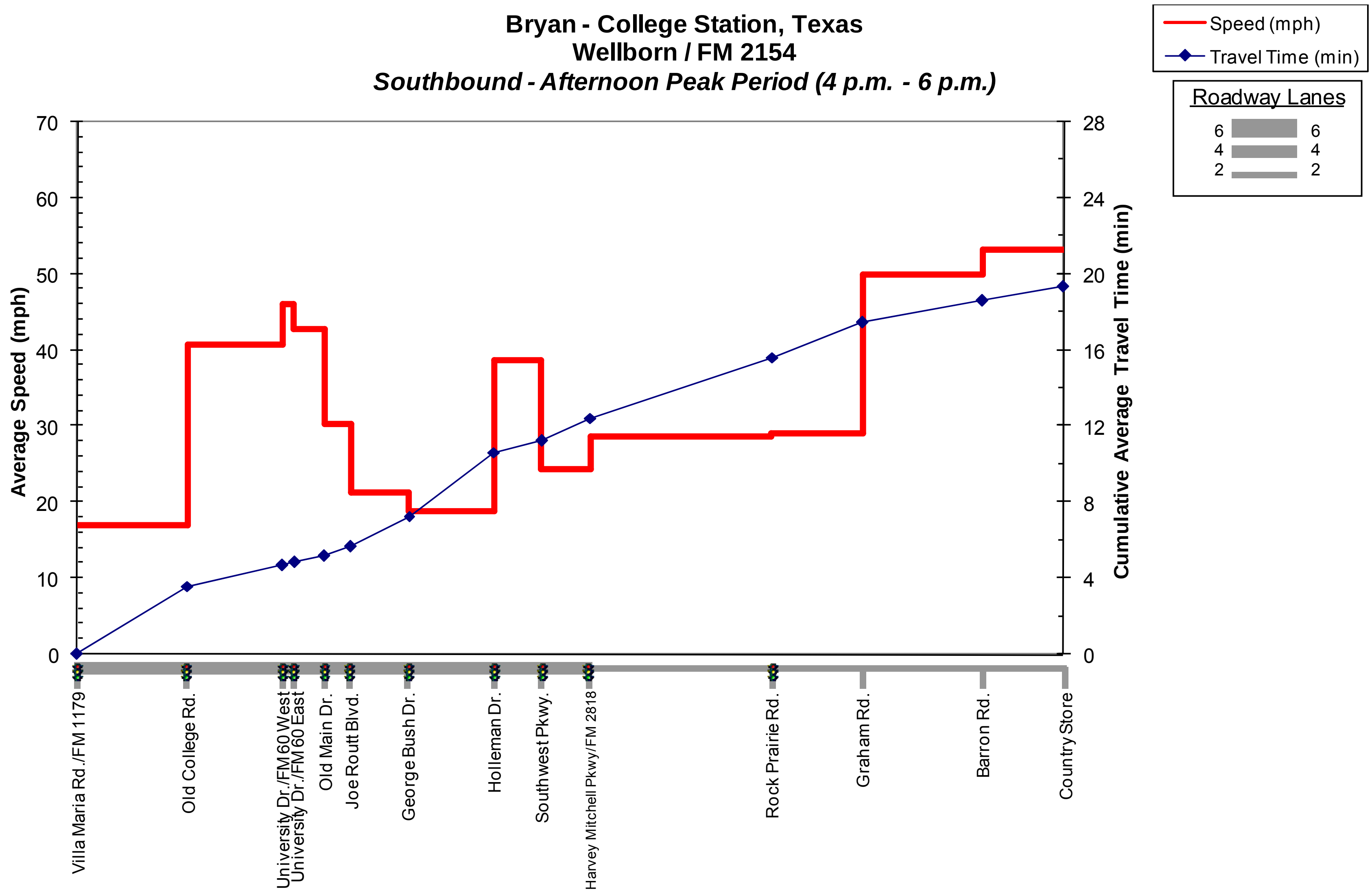


Figure D-84. Average Speed and Cumulative Average Travel Time for Wellborn/FM 2154, Southbound - Afternoon.

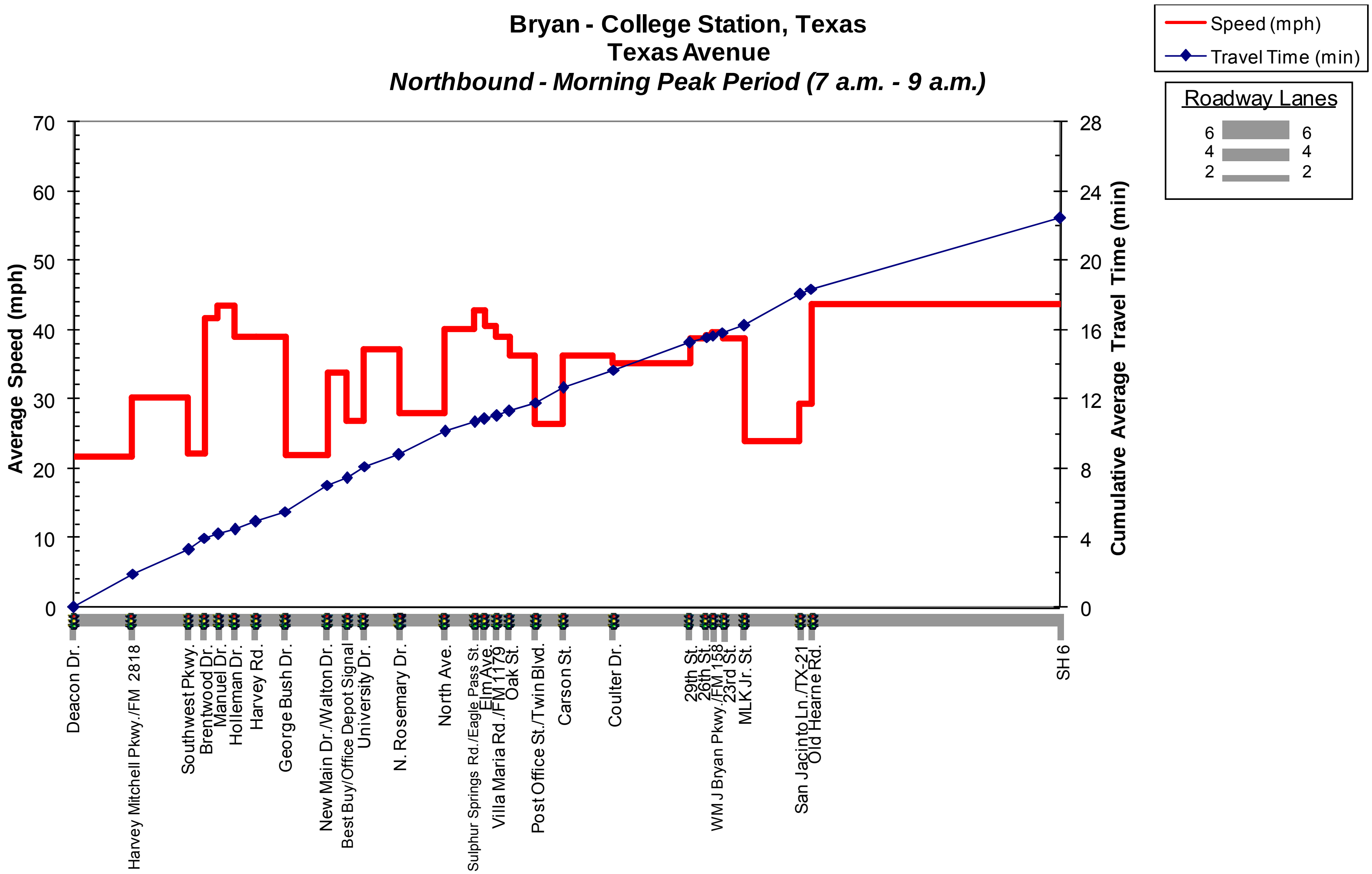


Figure D-85. Average Speed and Cumulative Average Travel Time for Texas Avenue, Northbound - Morning

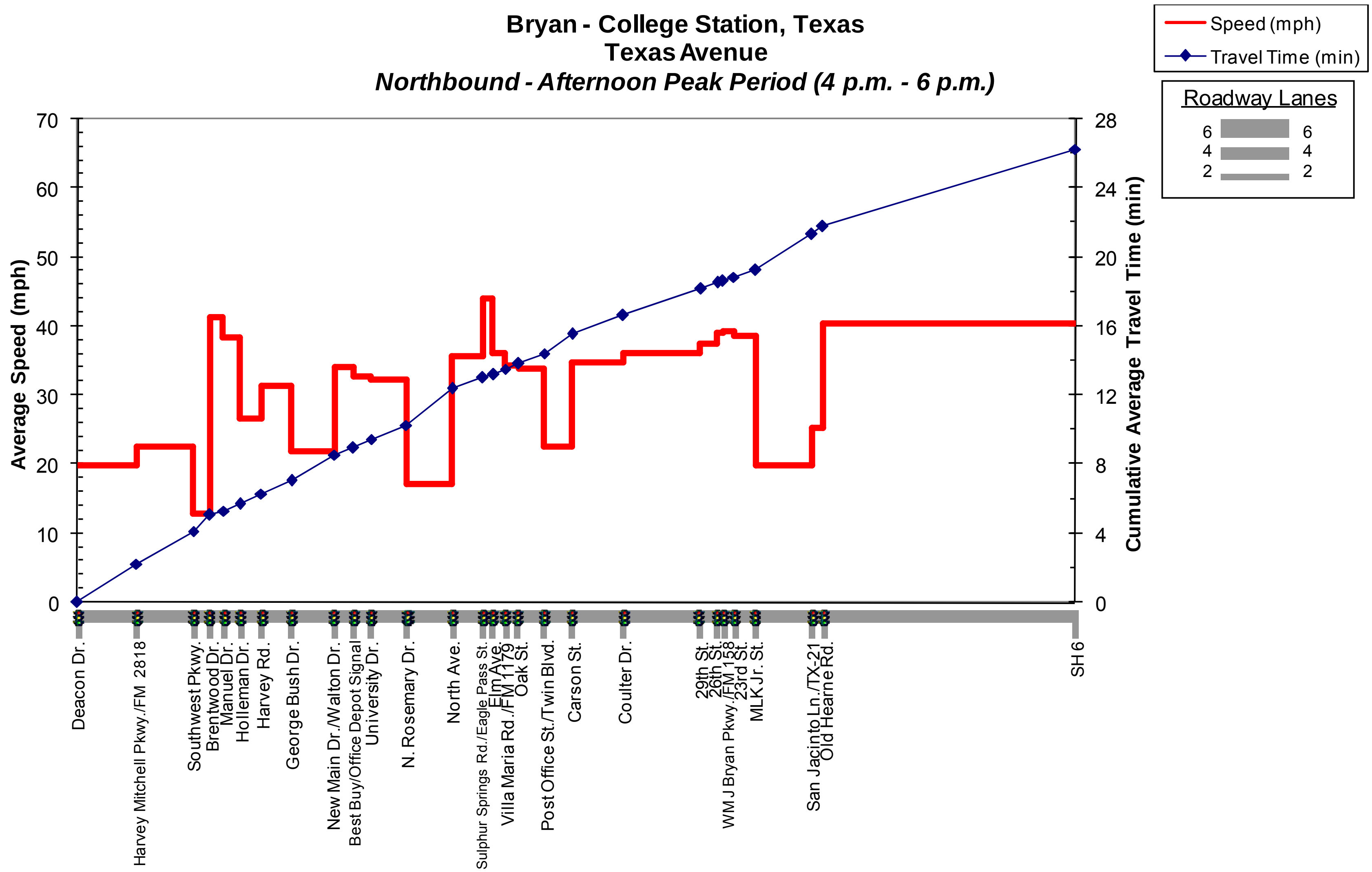


Figure D-86. Average Speed and Cumulative Average Travel Time for Texas Avenue, Northbound - Afternoon.

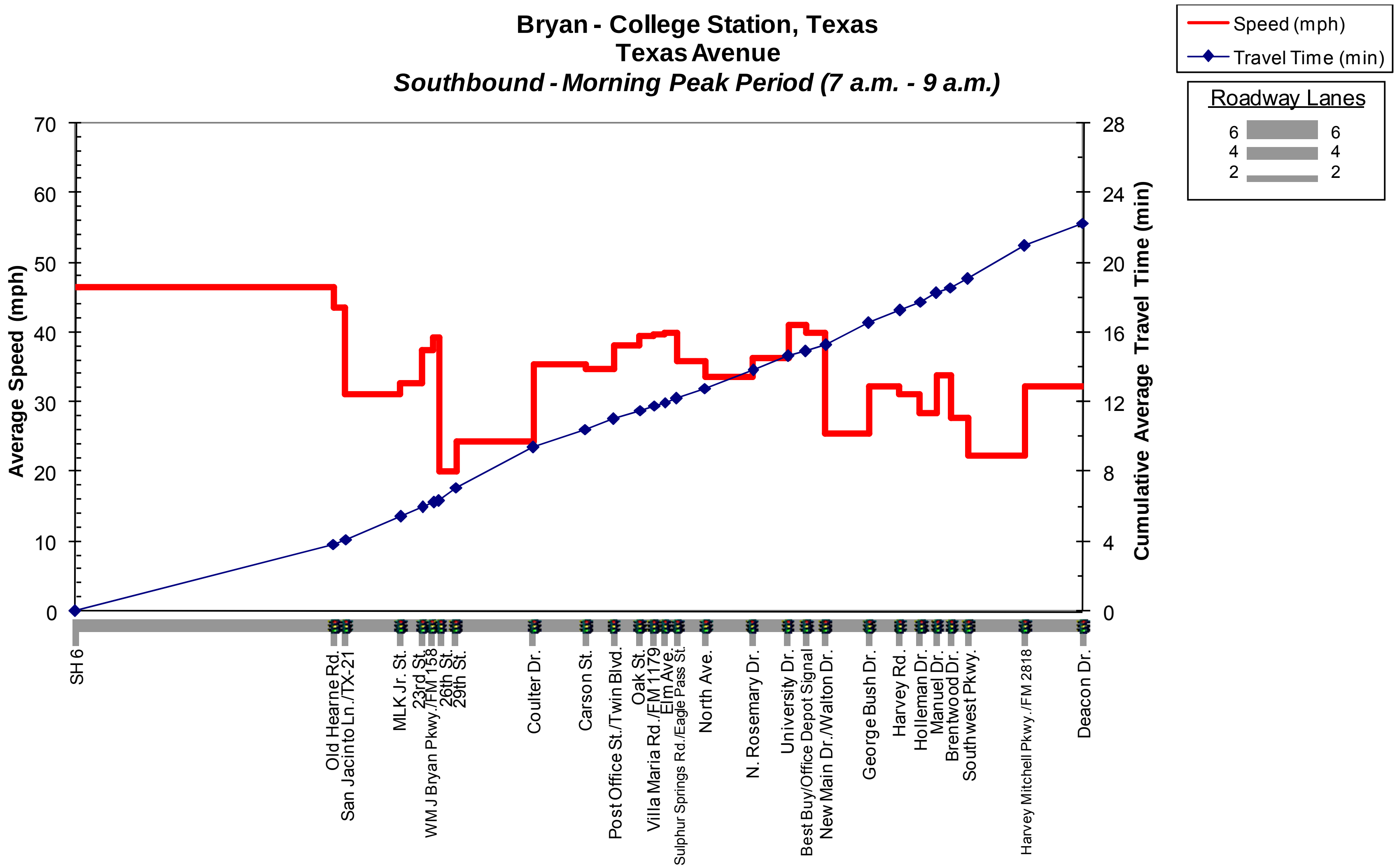


Figure D-87. Average Speed and Cumulative Average Travel Time for Texas Avenue, Southbound - Morning

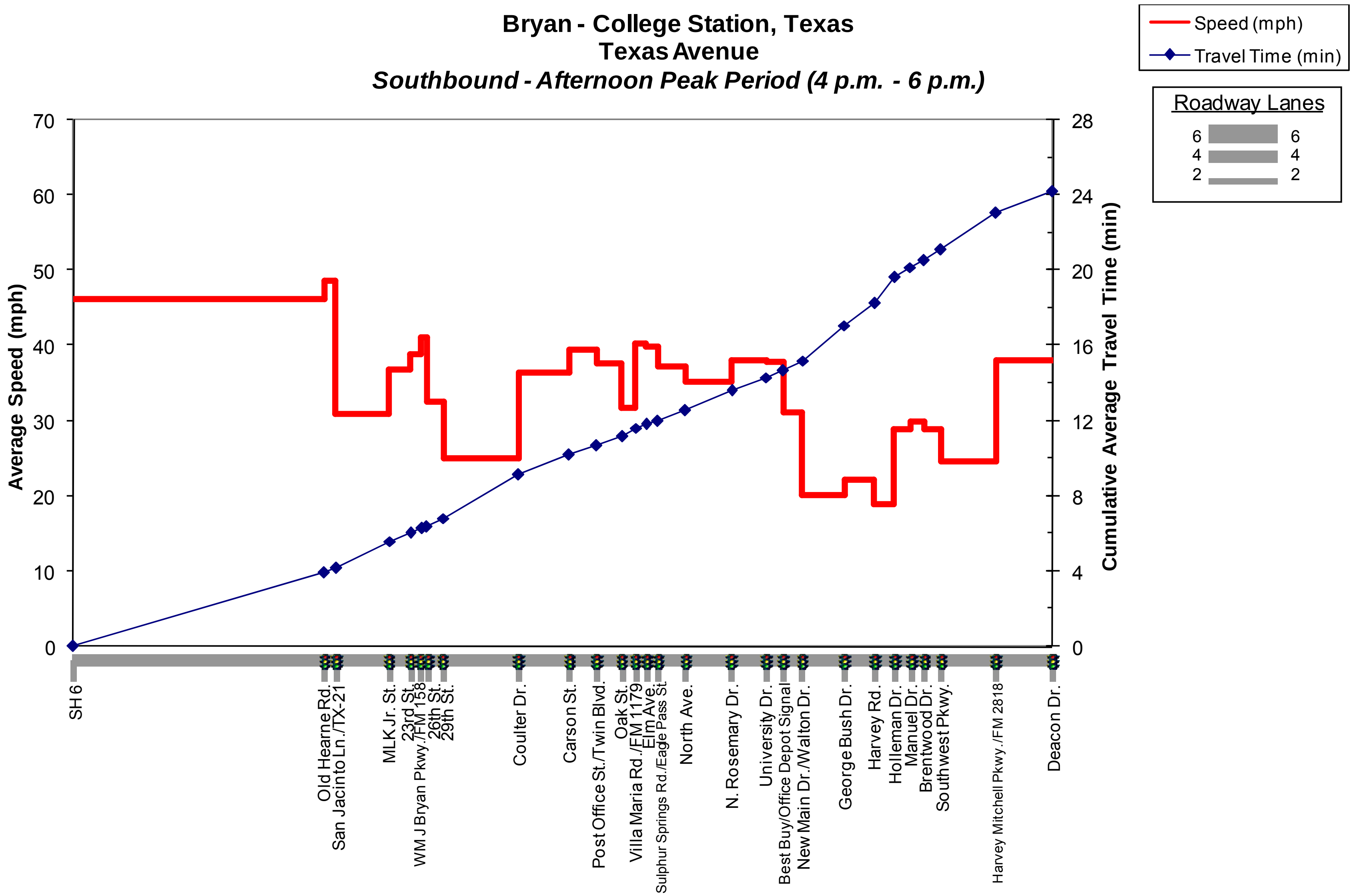


Figure D-88. Average Speed and Cumulative Average Travel Time for Texas Avenue, Southbound - Afternoon.

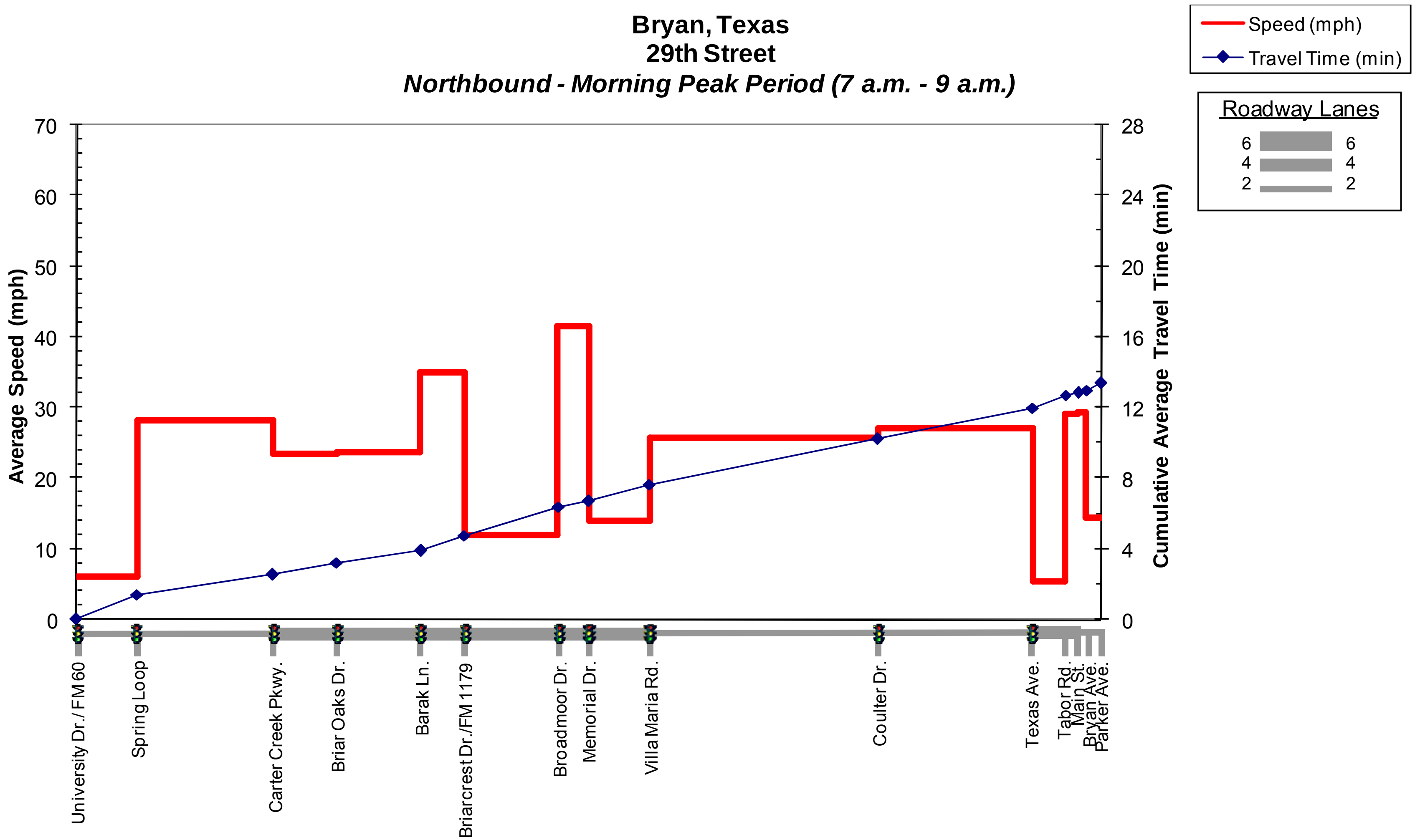


Figure D-89. Average Speed and Cumulative Average Travel Time for 29th Street, Northbound - Morning

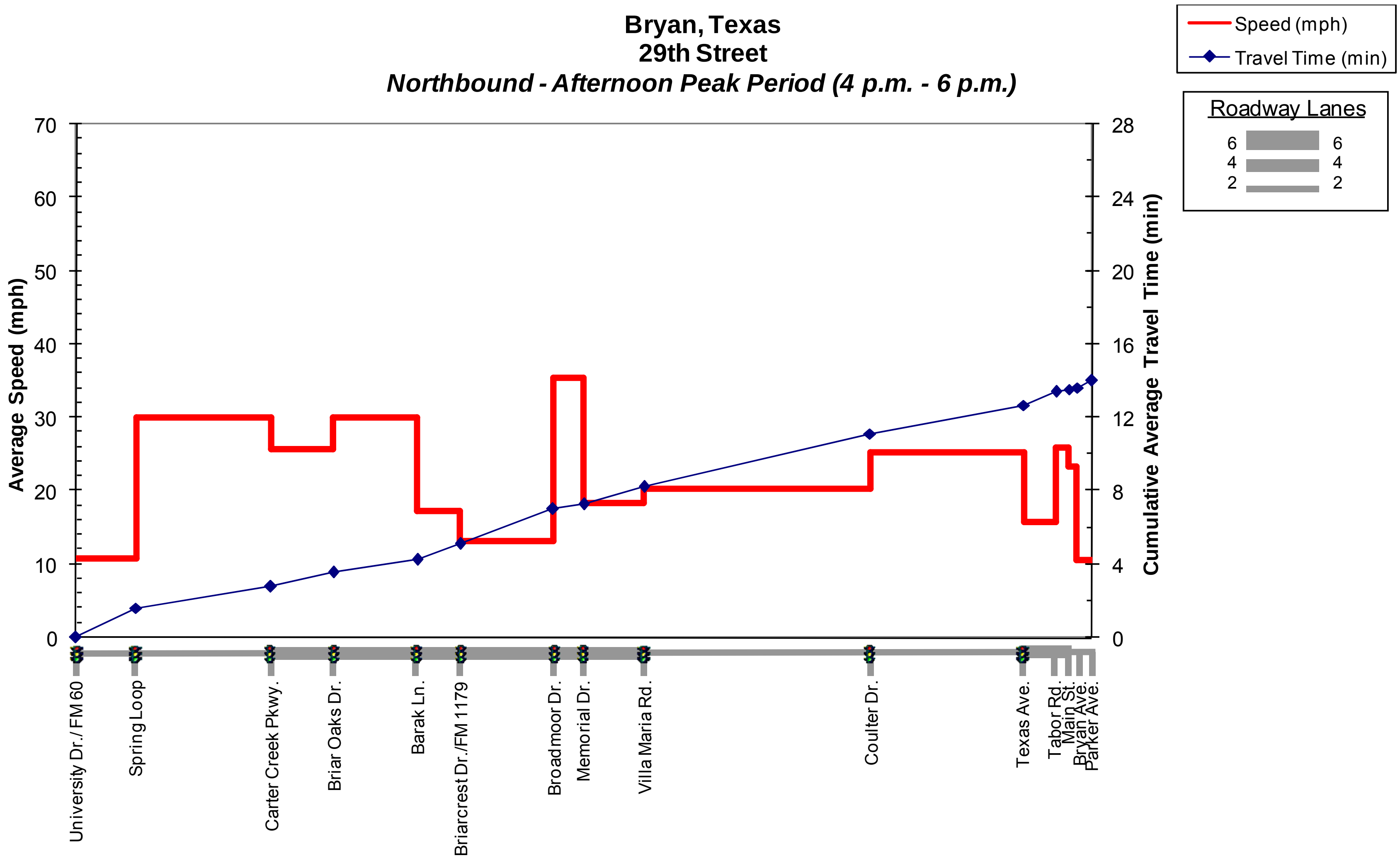


Figure D-90. Average Speed and Cumulative Average Travel Time for 29th Street, Northbound - Afternoon.

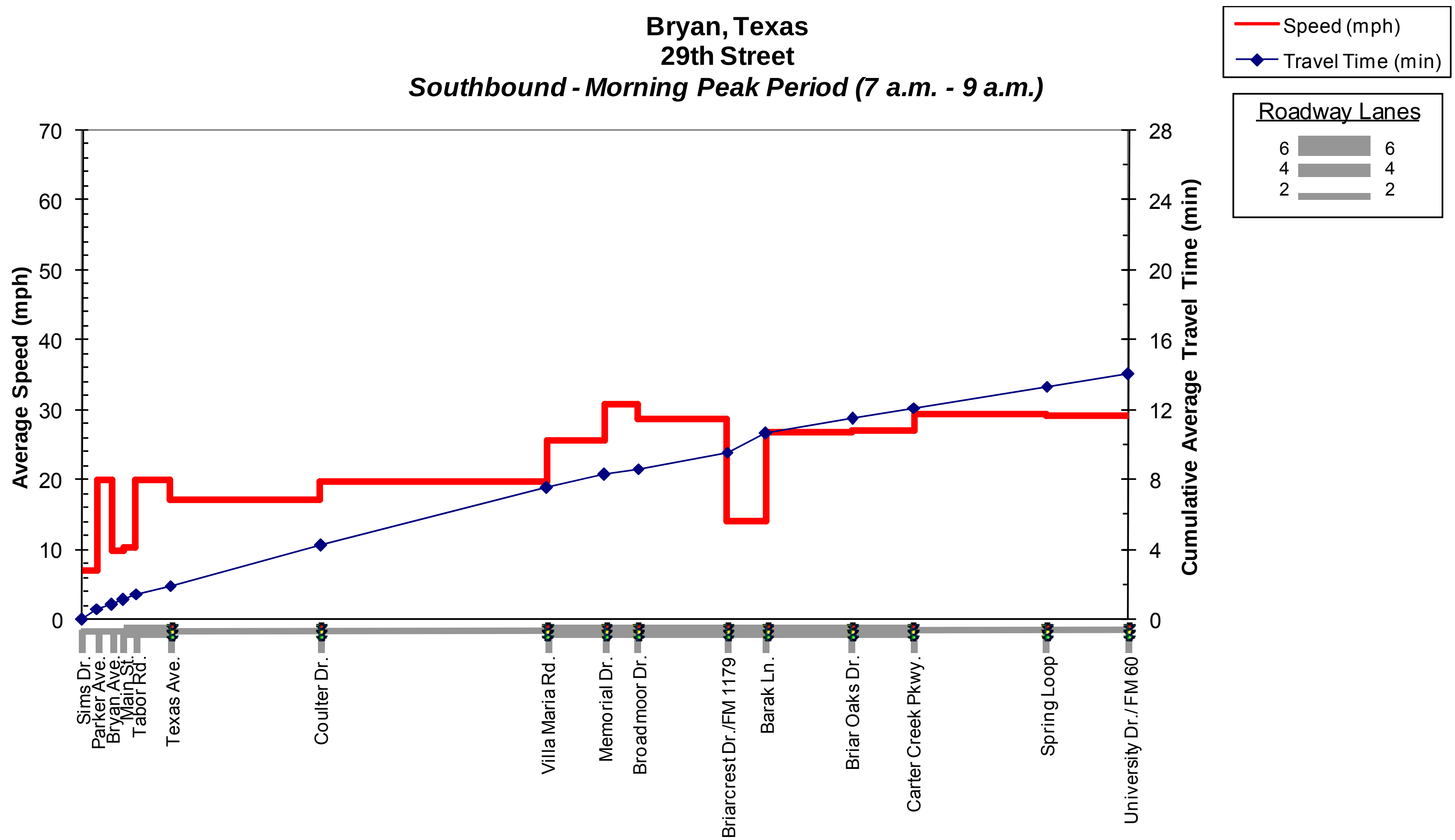


Figure D-91. Average Speed and Cumulative Average Travel Time for 29th Street, Southbound - Morning

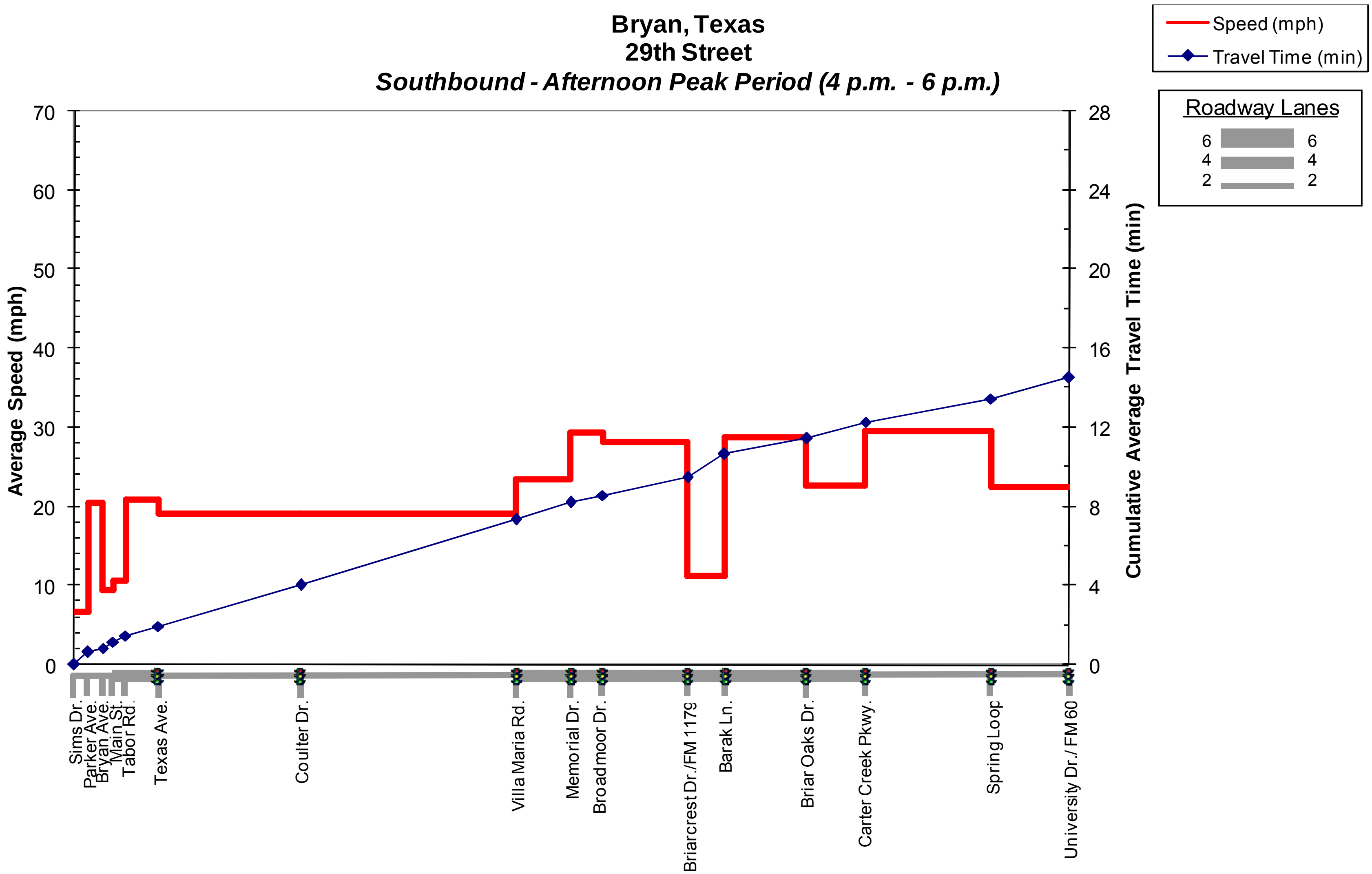


Figure D-92. Average Speed and Cumulative Average Travel Time for 29th Street, Southbound - Afternoon.

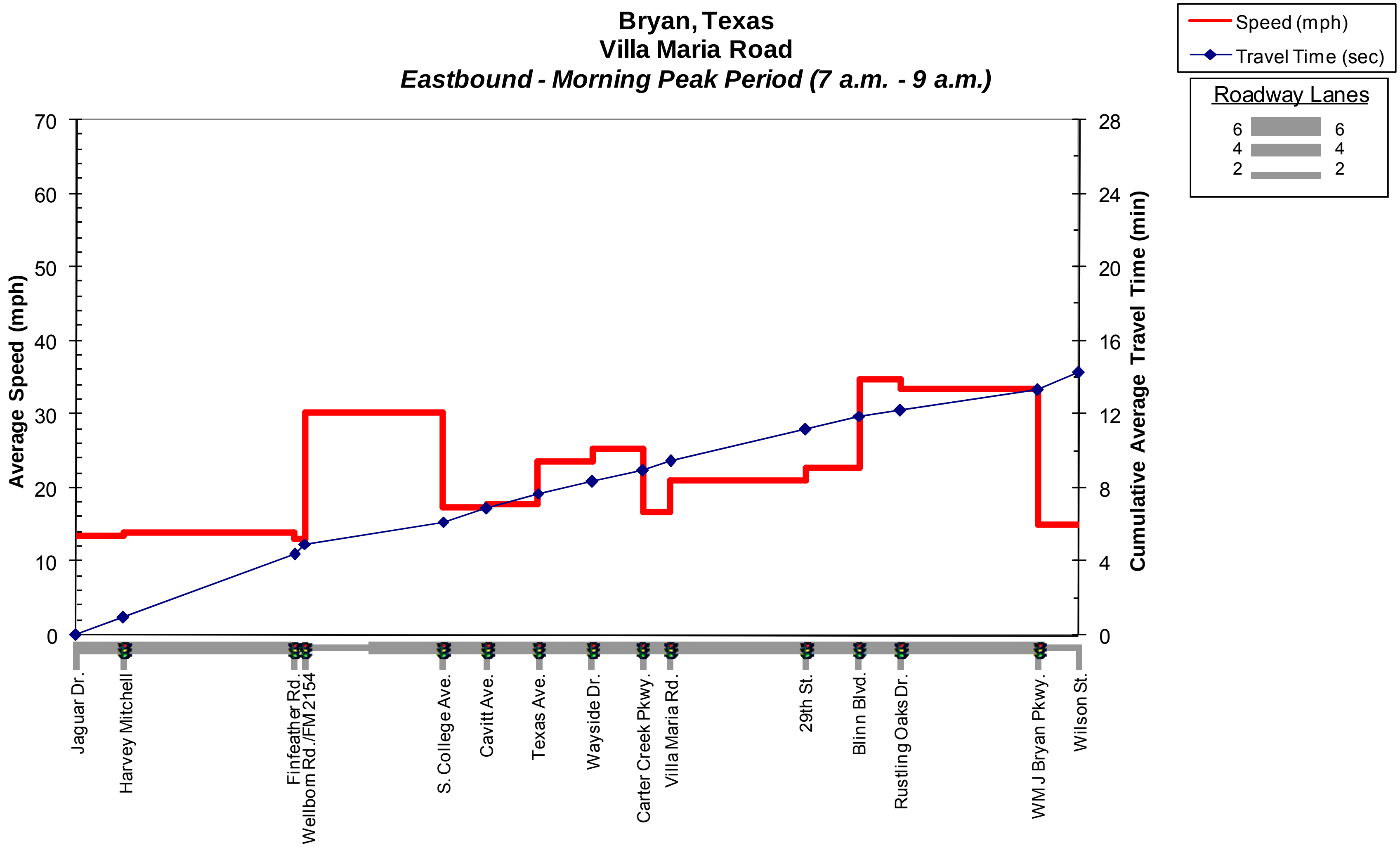


Figure D-93. Average Speed and Cumulative Average Travel Time for Villa Maria Road, Eastbound - Morning

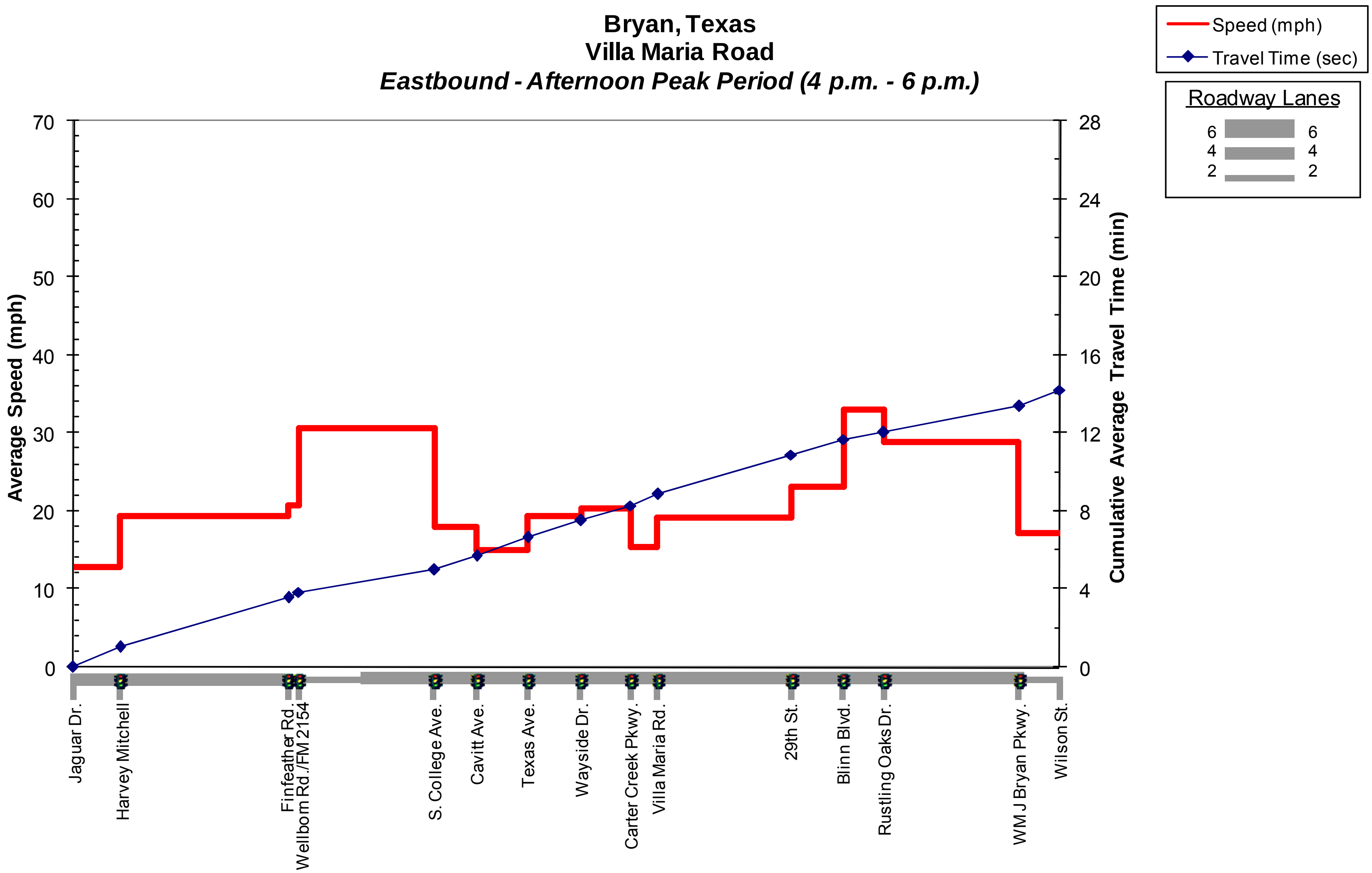


Figure D-94. Average Speed and Cumulative Average Travel Time for Villa Maria Road, Eastbound - Afternoon.

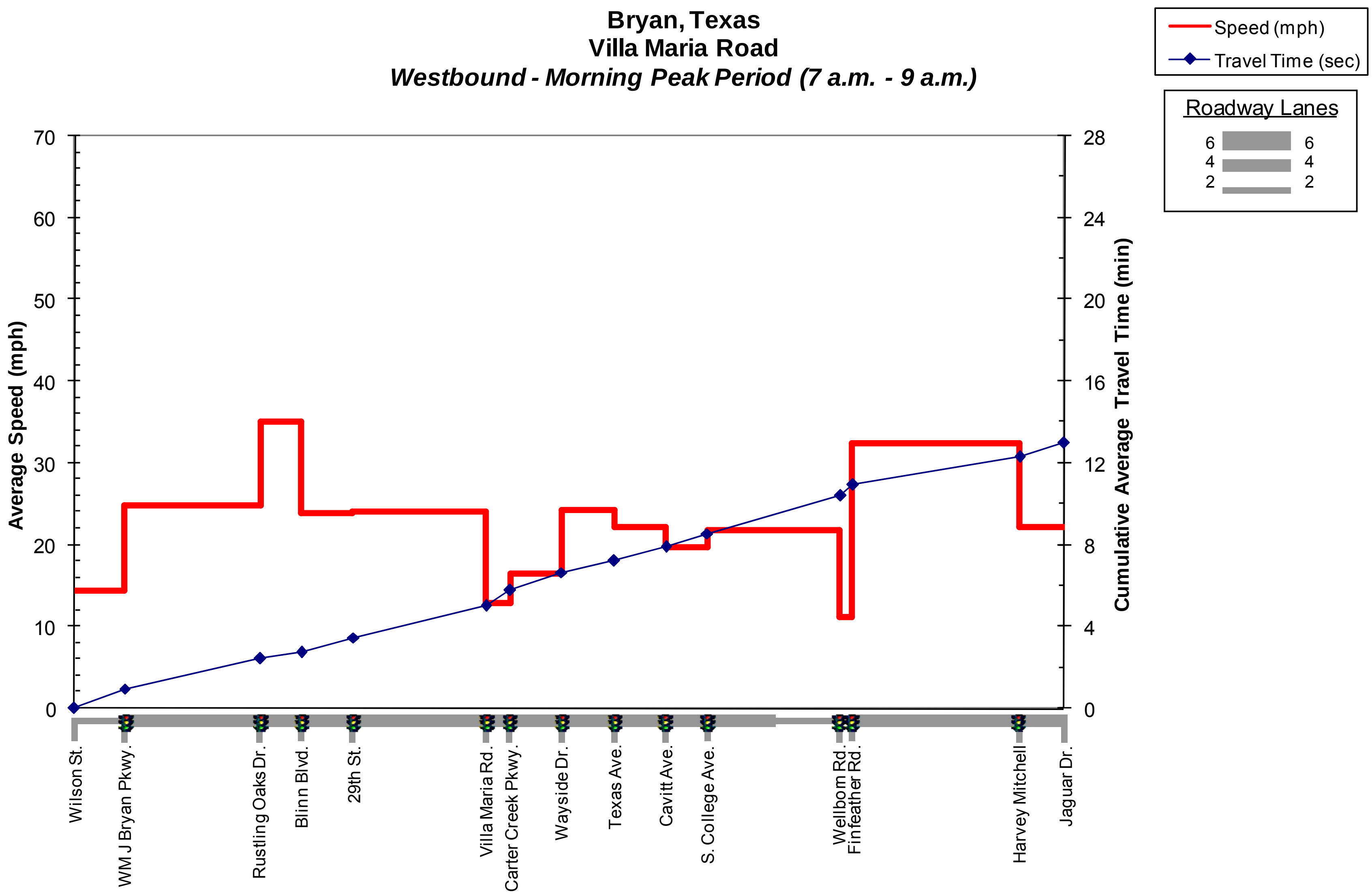


Figure D-95. Average Speed and Cumulative Average Travel Time for Villa Maria Road, Westbound - Morning

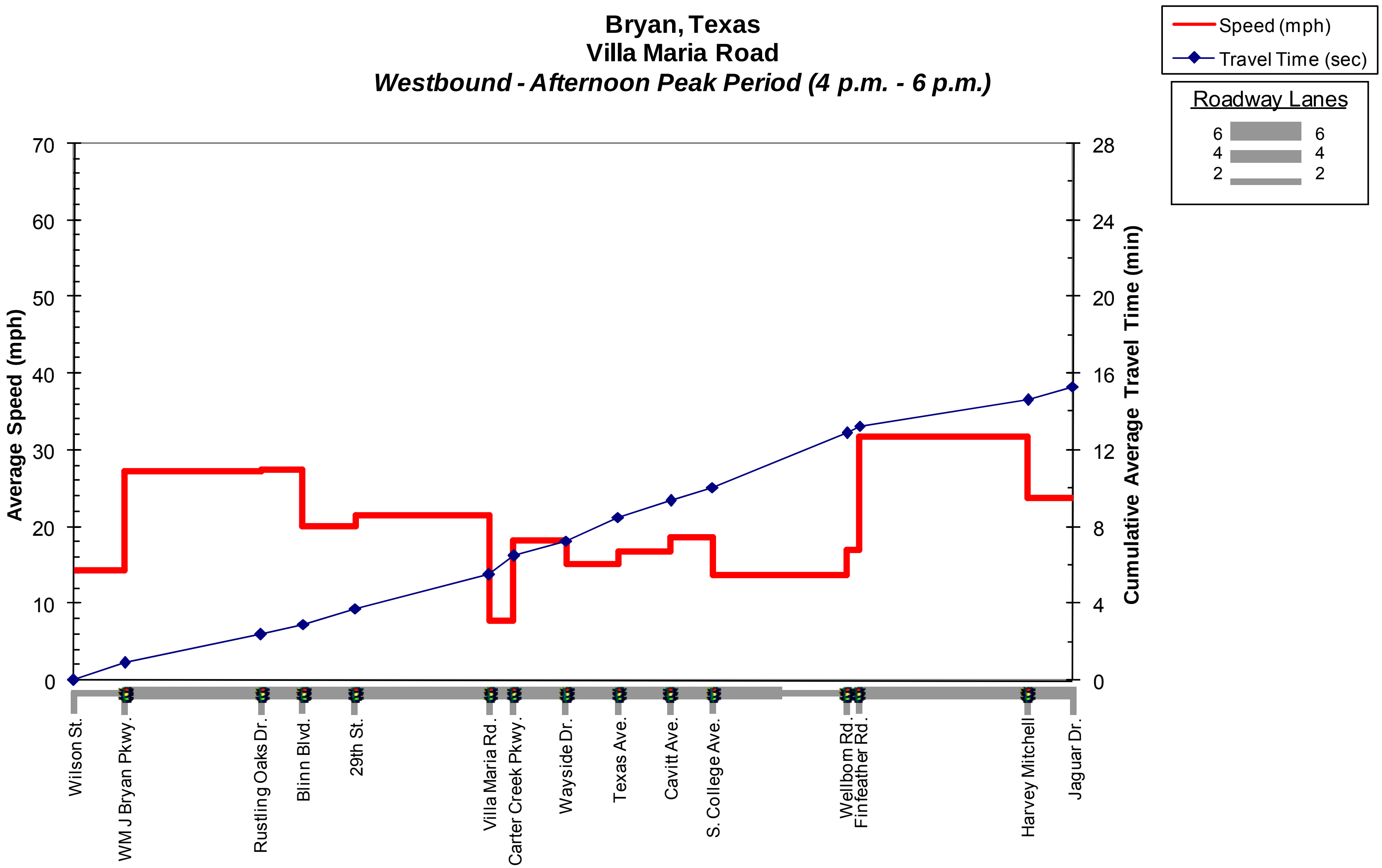


Figure D-96. Average Speed and Cumulative Average Travel Time for Villa Maria Road, Westbound - Afternoon.

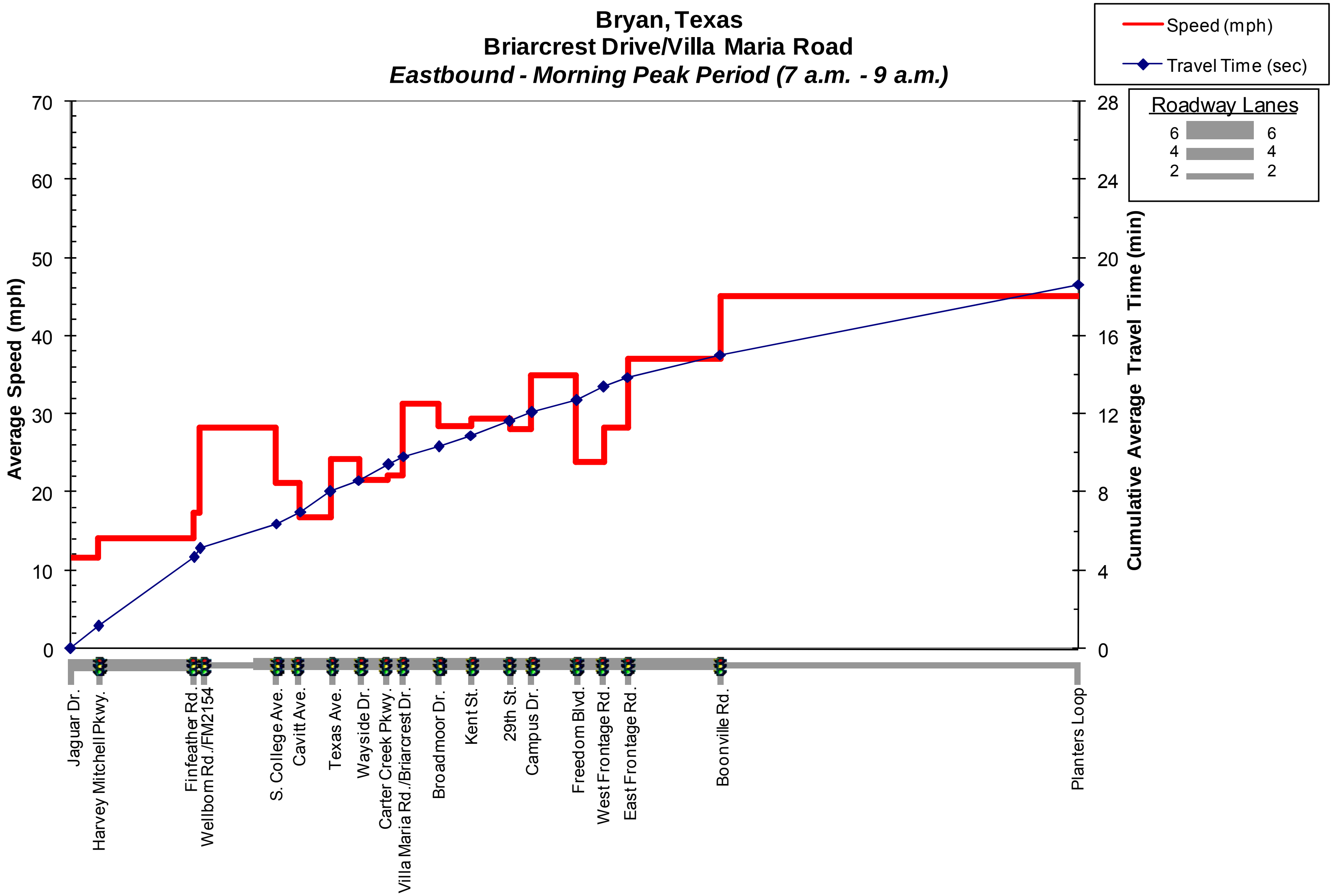


Figure D-97. Average Speed and Cumulative Average Travel Time for Briarcrest Drive/Villa Maria Road, Eastbound - Morning

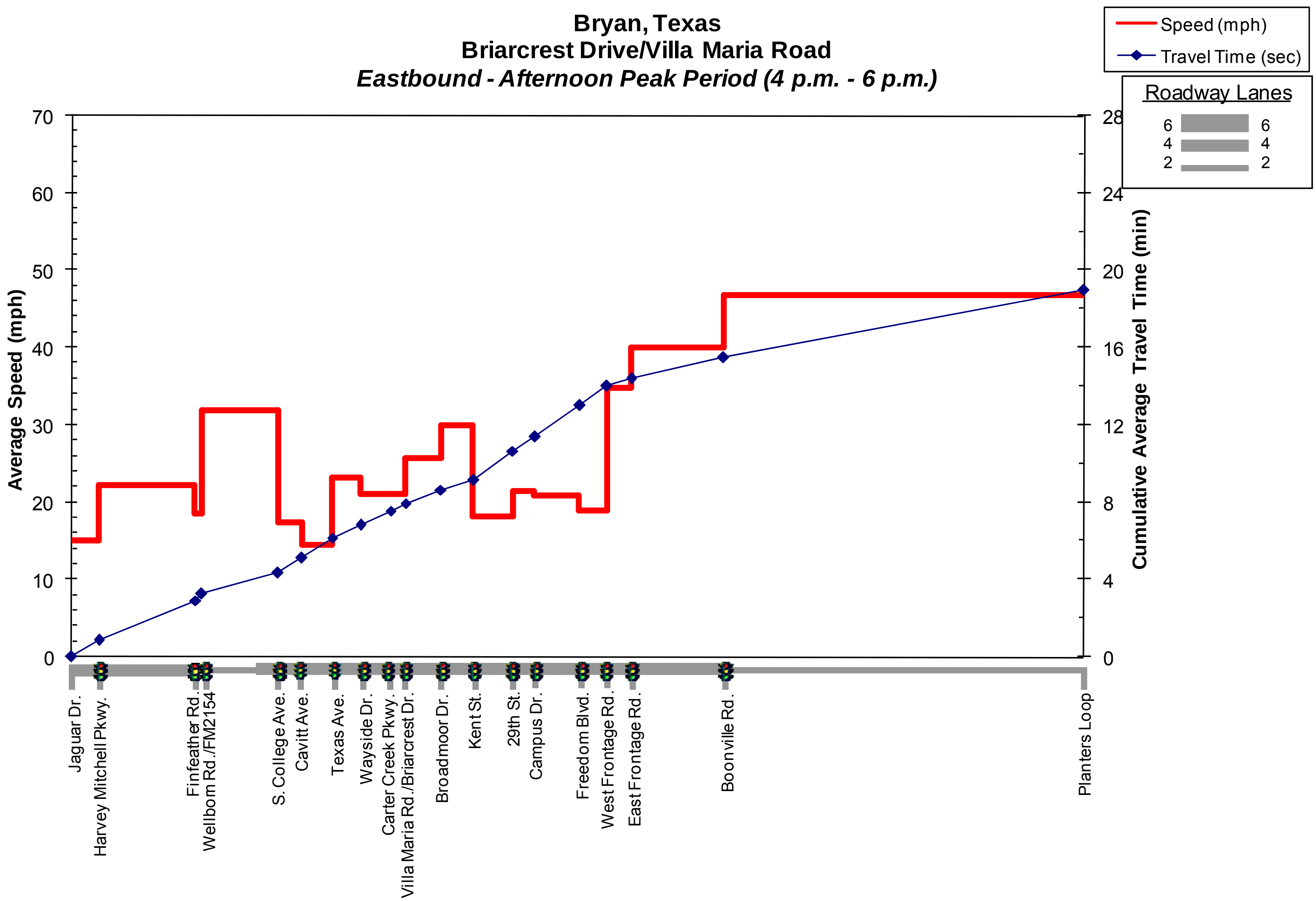


Figure D-98. Average Speed and Cumulative Average Travel Time for Briarcrest Drive/Villa Maria Road, Eastbound - Afternoon.

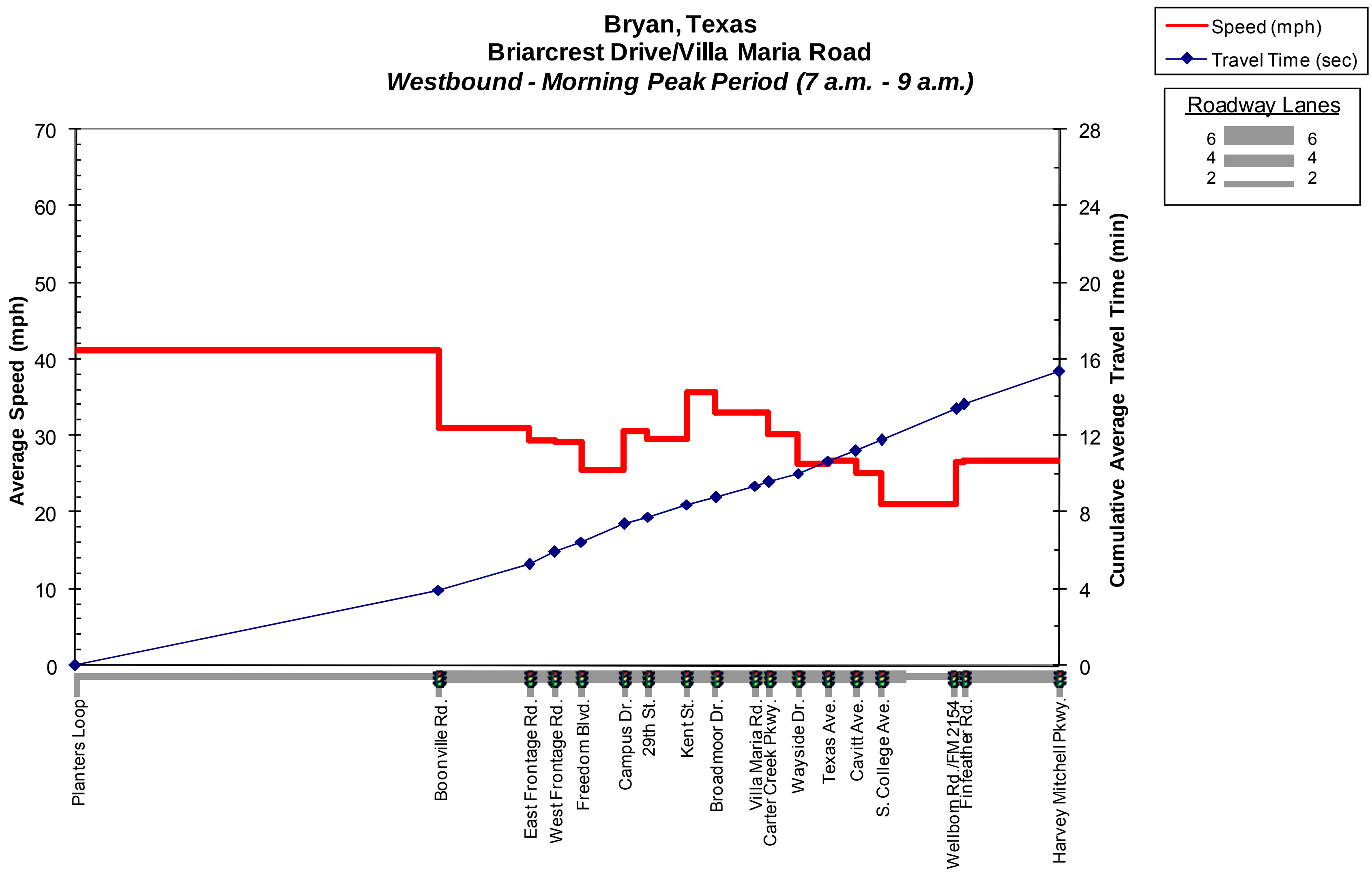


Figure D-99. Average Speed and Cumulative Average Travel Time for Briarcrest Drive/Villa Maria Road, Westbound - Morning

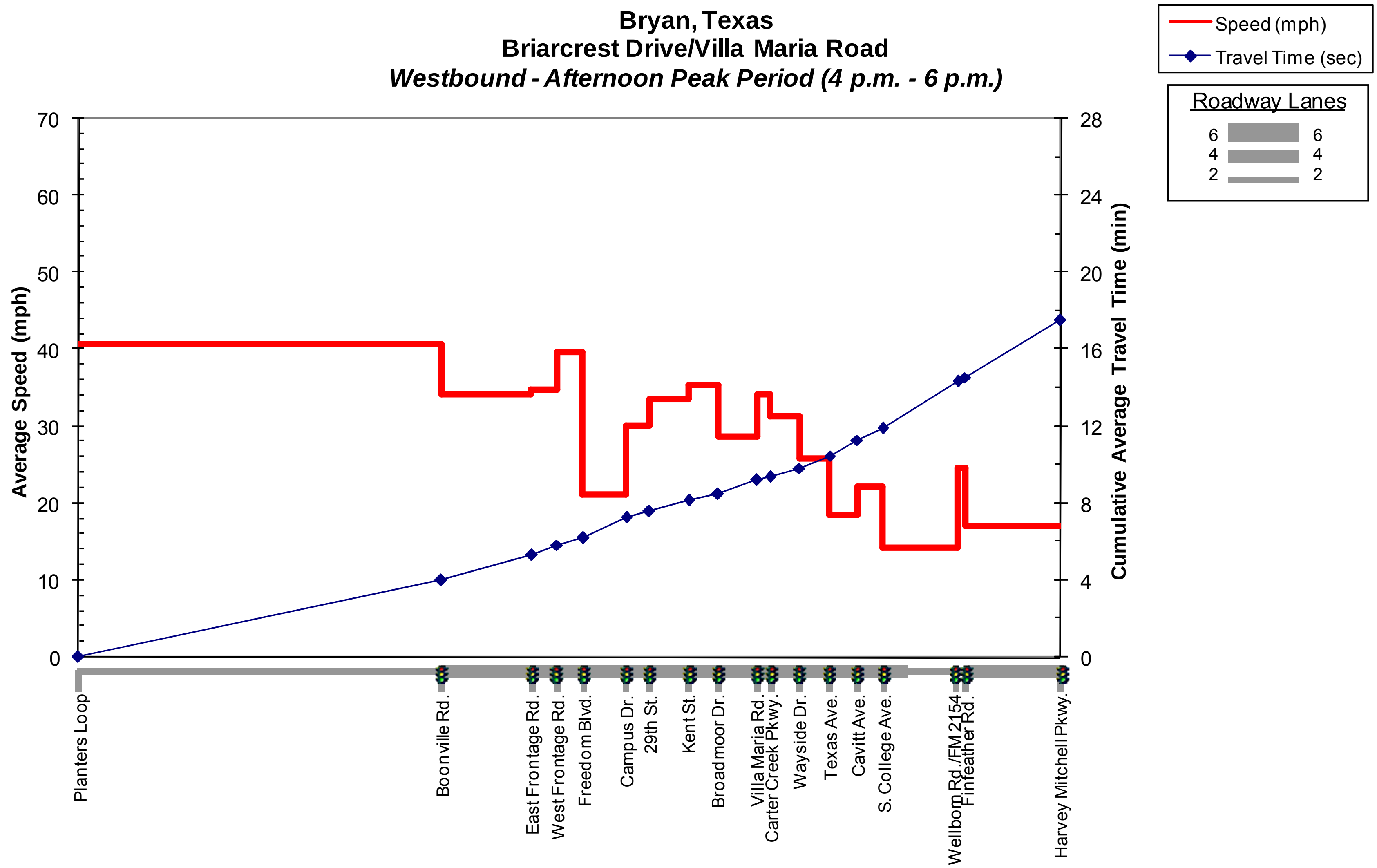


Figure D-100. Average Speed and Cumulative Average Travel Time for Briarcrest Drive/Villa Maria Road, Westbound - Afternoon.

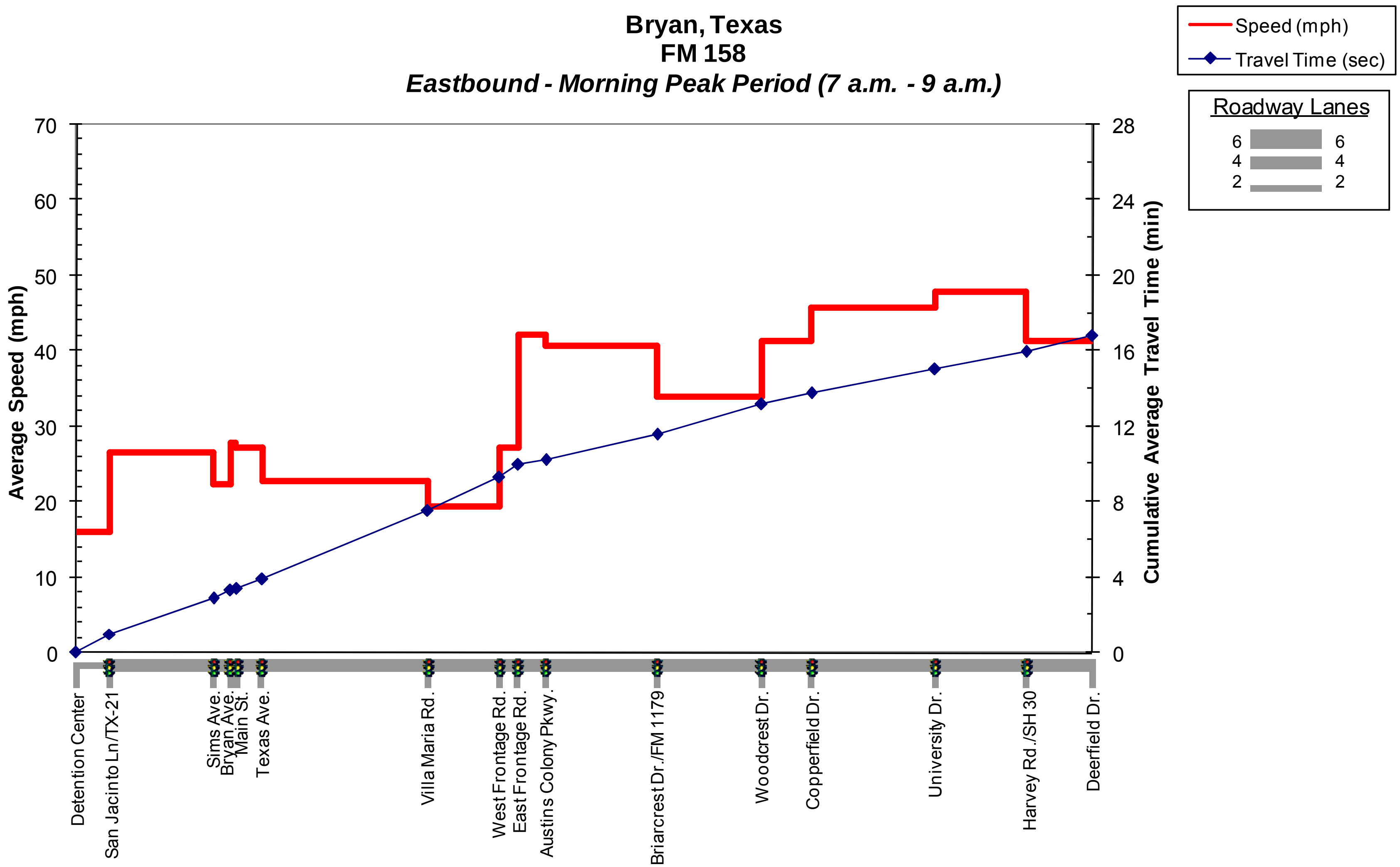


Figure D-101. Average Speed and Cumulative Average Travel Time for FM 158, Eastbound - Morning

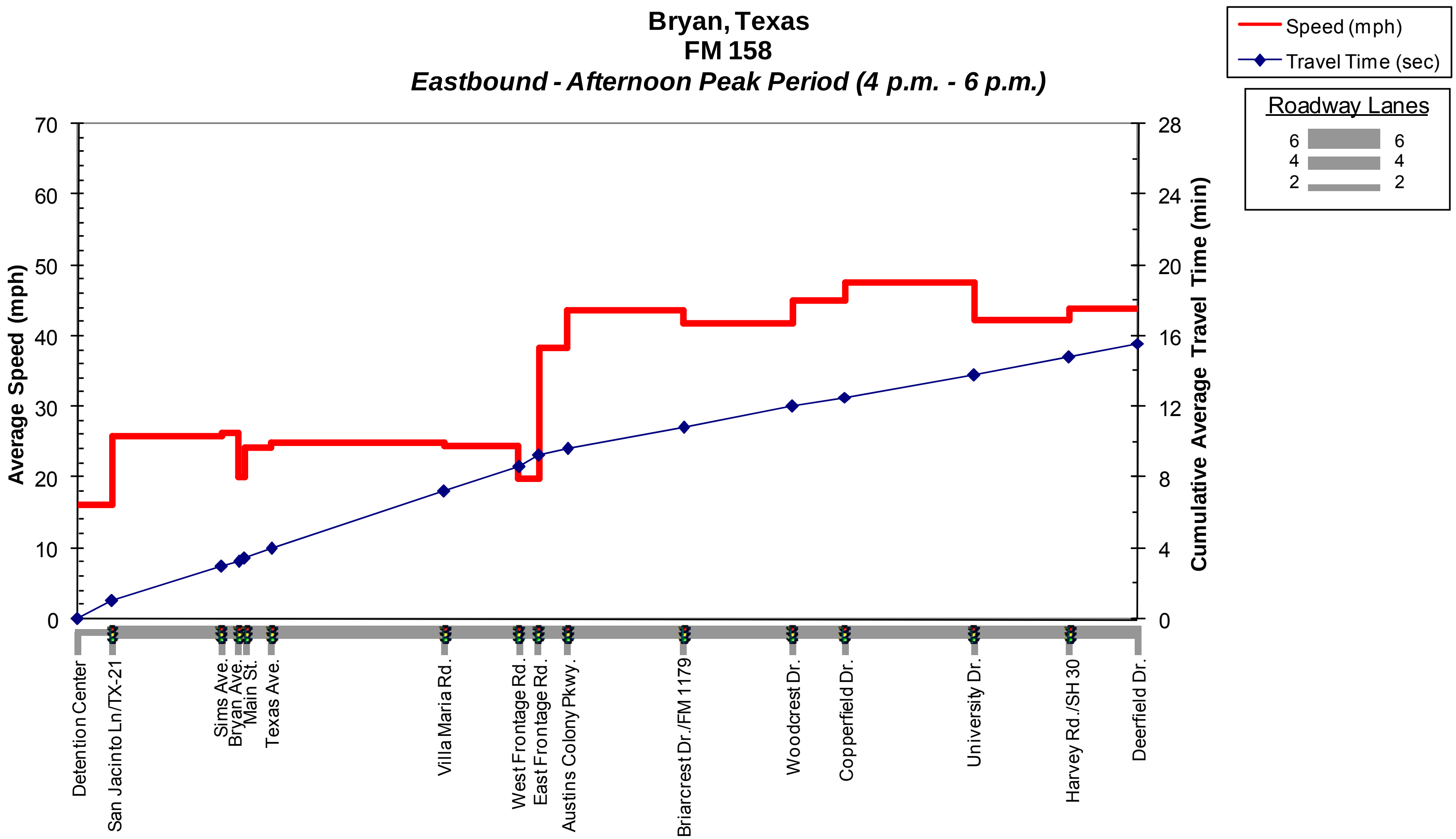


Figure D-102. Average Speed and Cumulative Average Travel Time for FM 158, Eastbound - Afternoon.

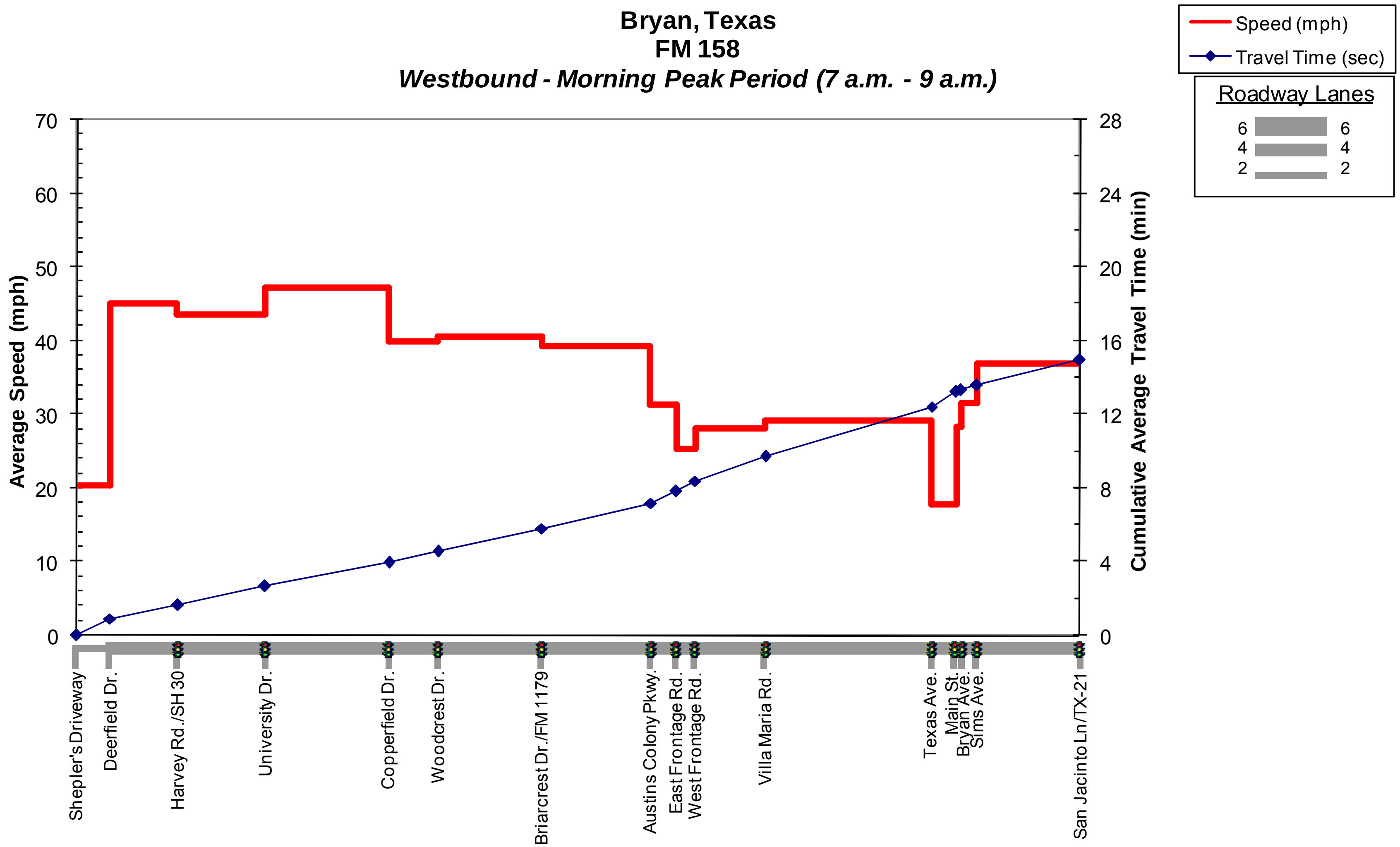


Figure D-103. Average Speed and Cumulative Average Travel Time for FM 158, Westbound - Morning

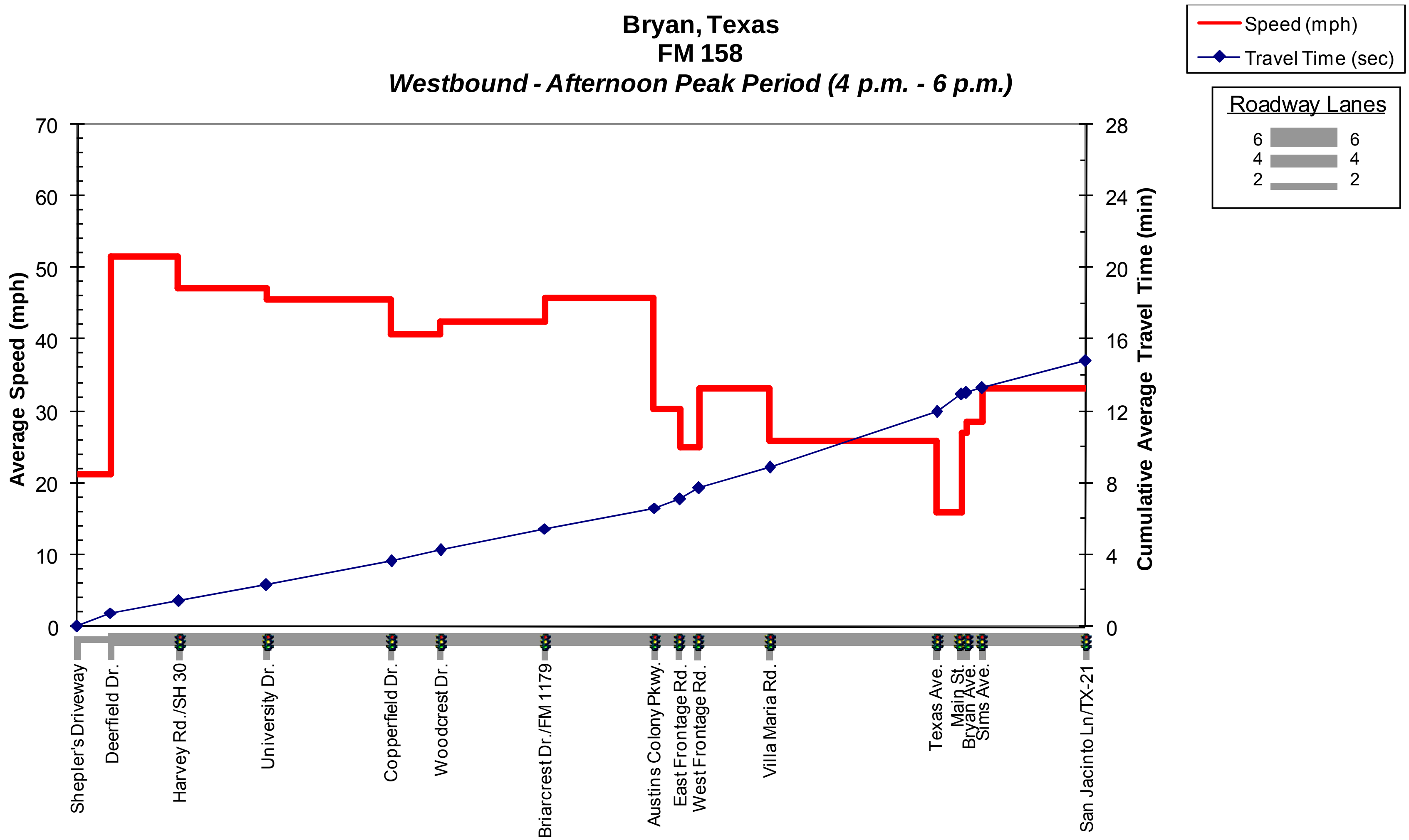


Figure D-104. Average Speed and Cumulative Average Travel Time for FM 158, Westbound - Afternoon.

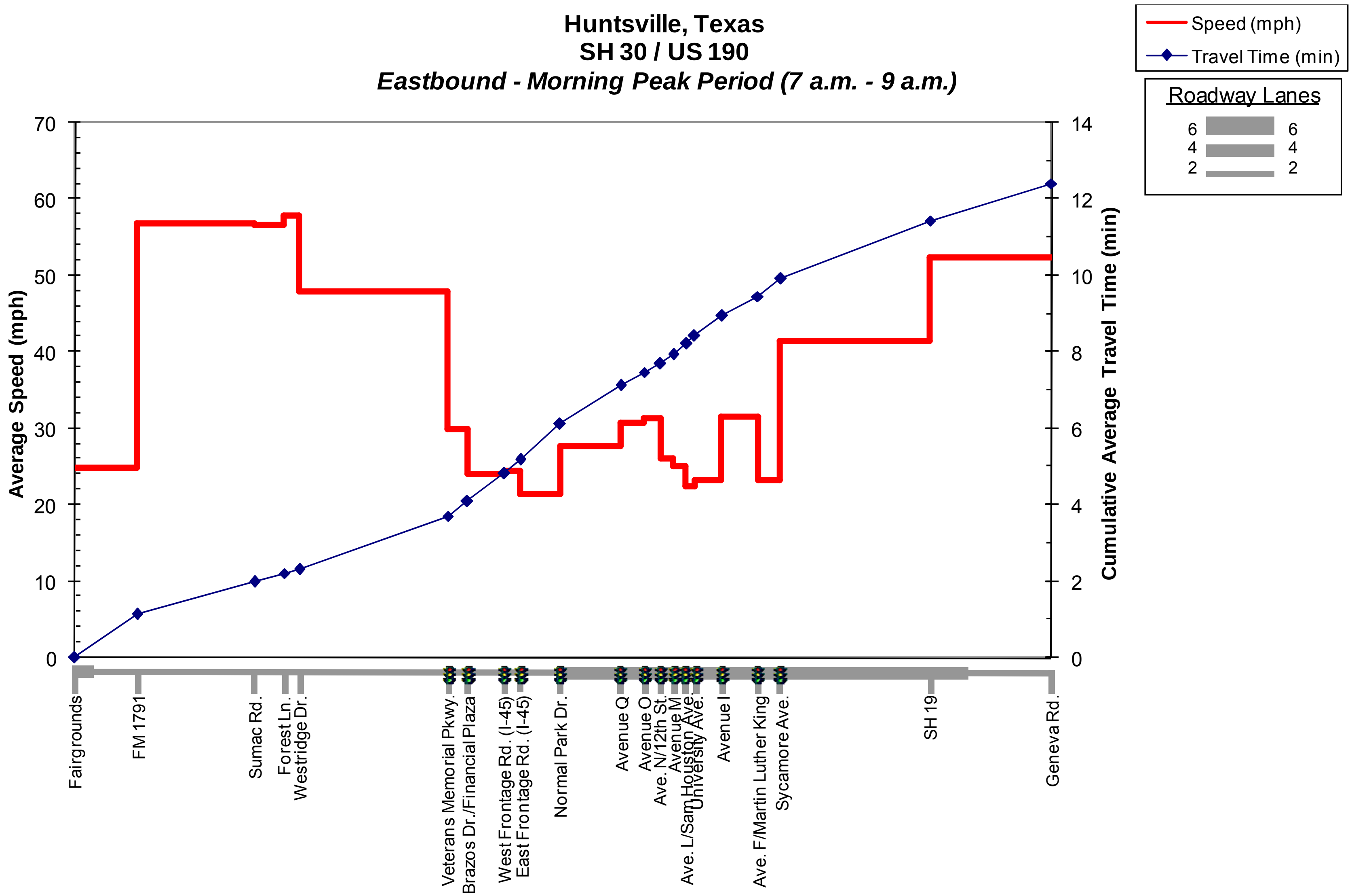


Figure D-105. Average Speed and Cumulative Average Travel Time for SH 30/US 190, Eastbound - Morning

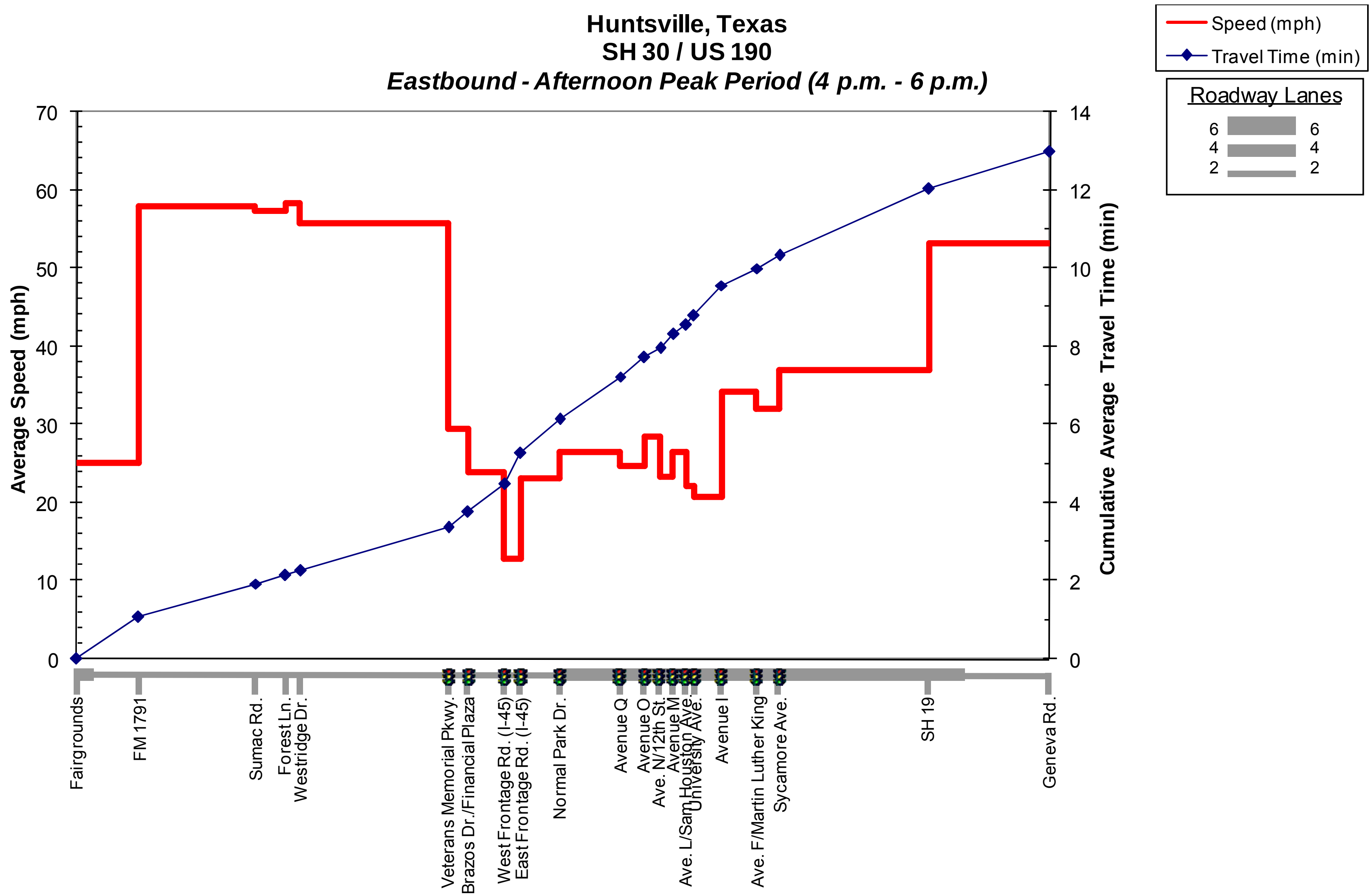


Figure D-106. Average Speed and Cumulative Average Travel Time for SH 30/US 190, Eastbound - Afternoon.

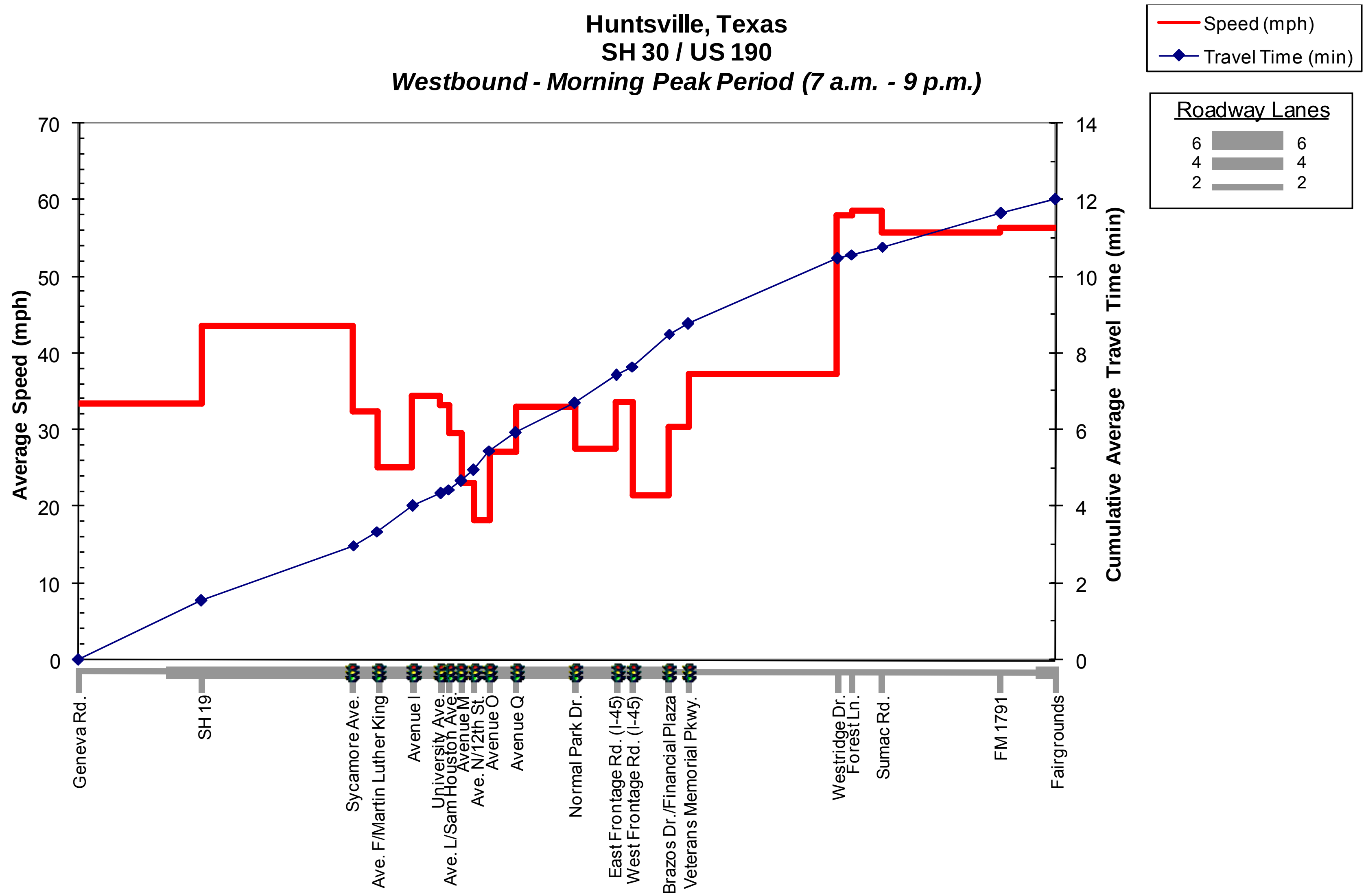


Figure D-107. Average Speed and Cumulative Average Travel Time for SH 30/US 190, Westbound - Morning

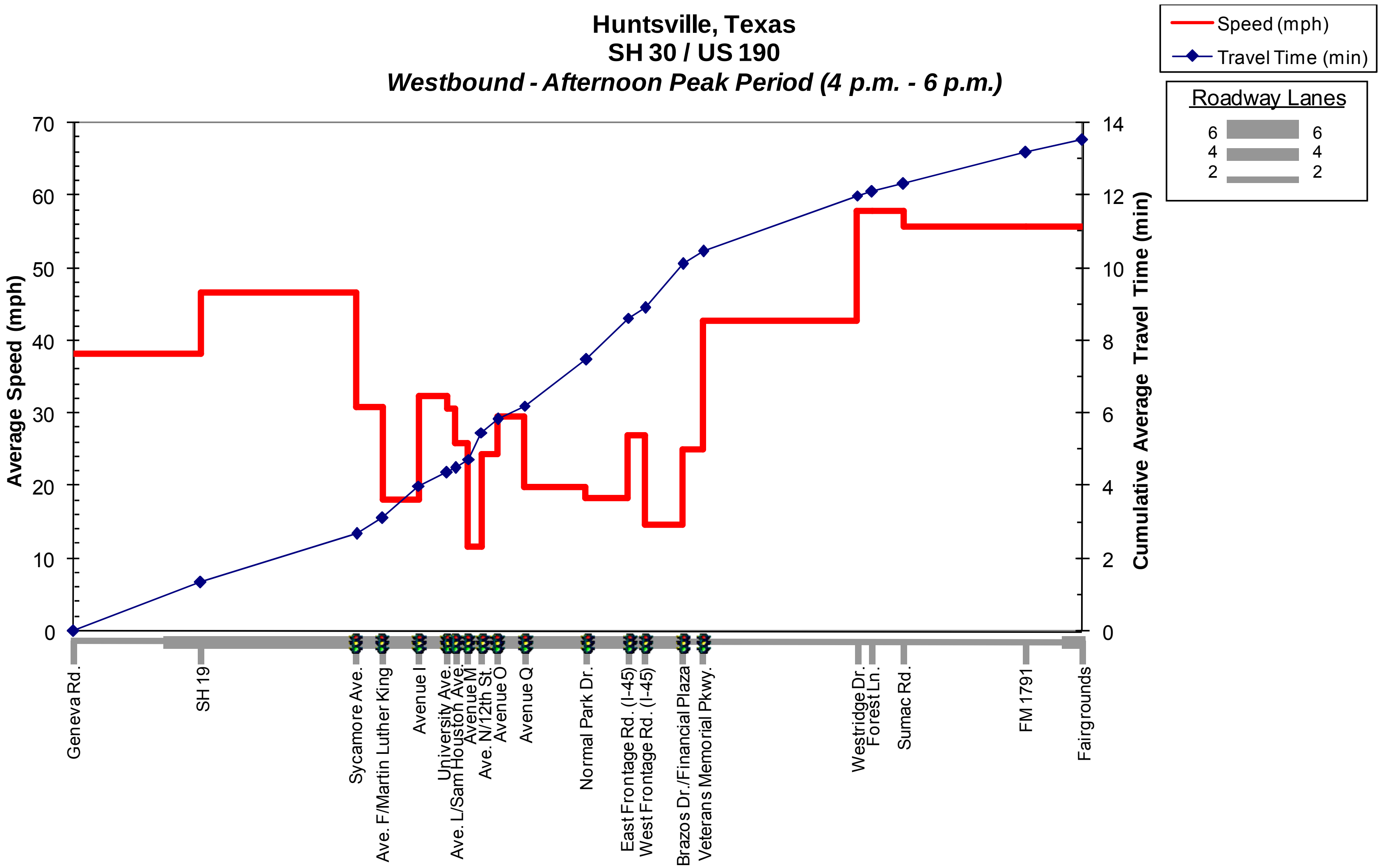


Figure D-108. Average Speed and Cumulative Average Travel Time for SH 30/US 190, Westbound - Afternoon.

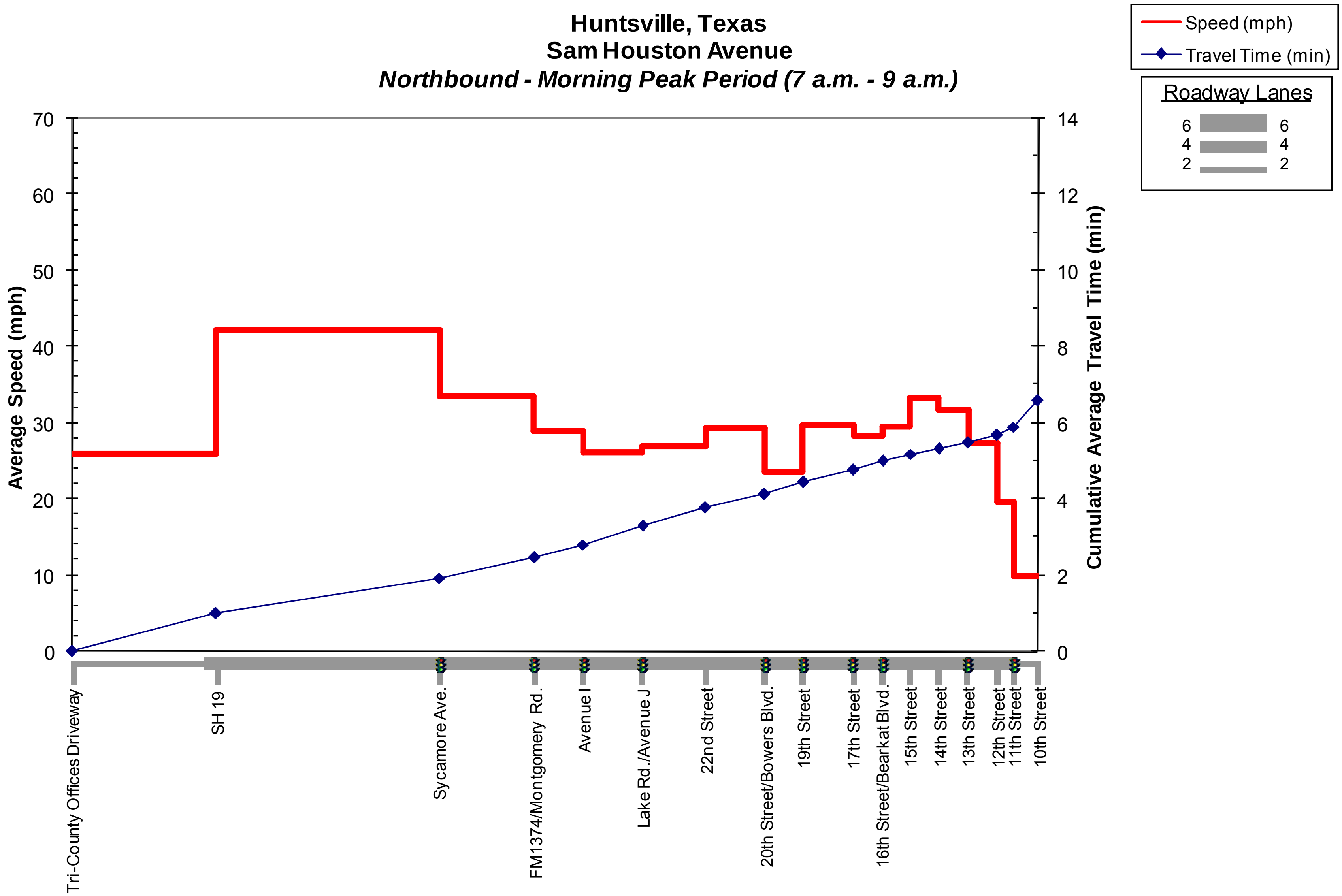


Figure D-109. Average Speed and Cumulative Average Travel Time for Sam Houston Avenue, Northbound - Morning

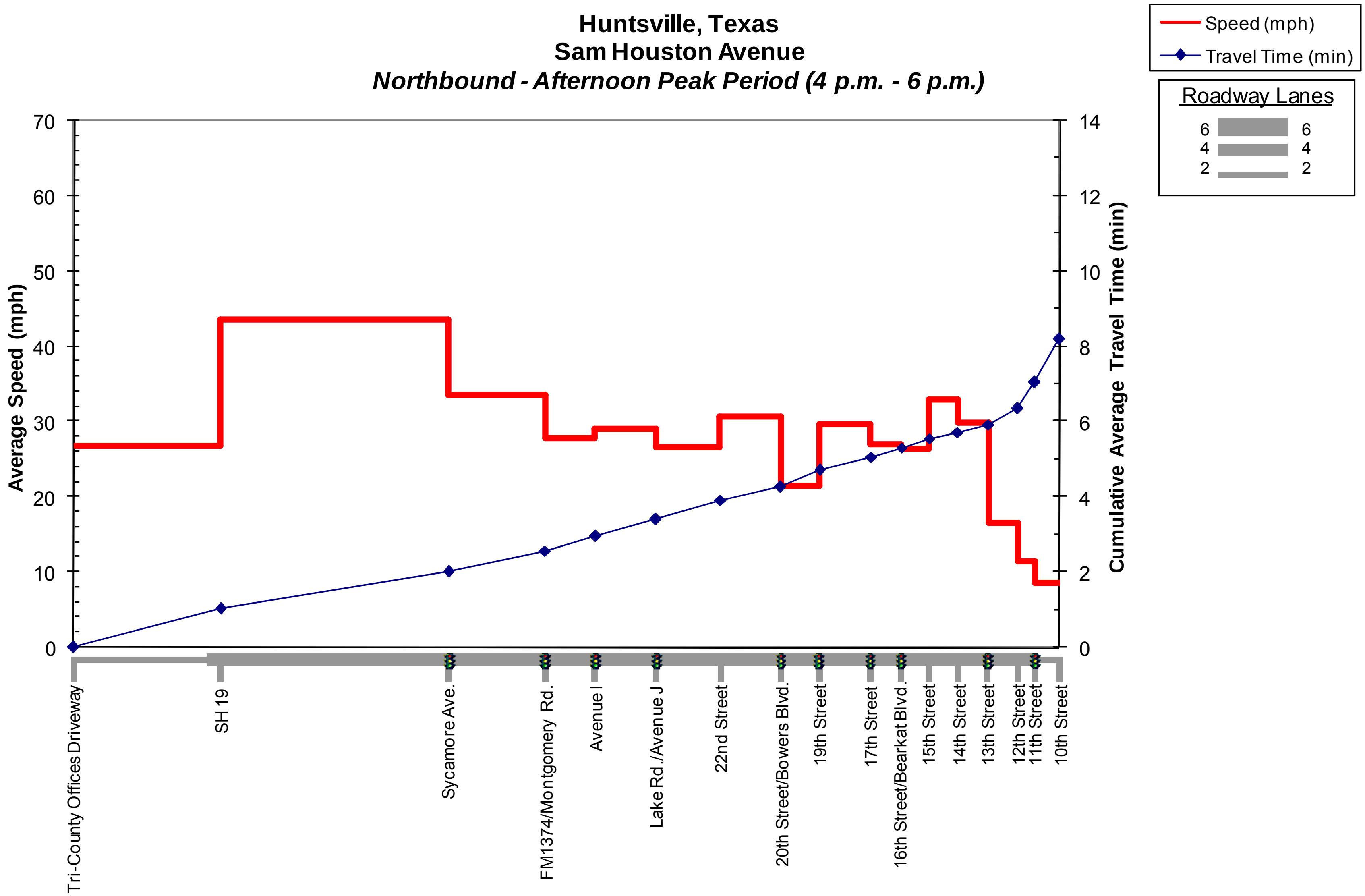


Figure D-110. Average Speed and Cumulative Average Travel Time for Sam Houston Avenue, Northbound - Afternoon.

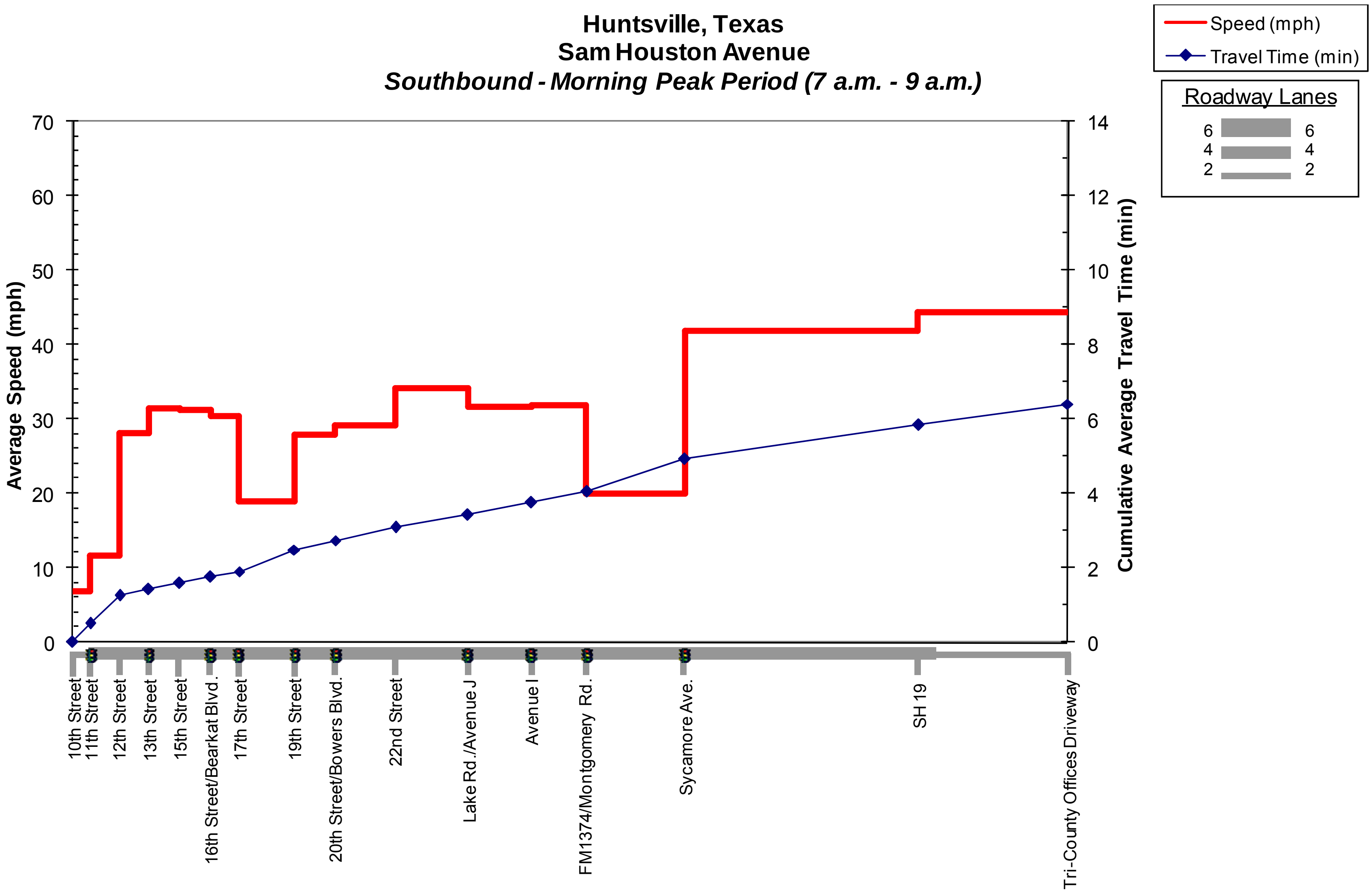


Figure D-111. Average Speed and Cumulative Average Travel Time for Sam Houston Avenue, Southbound - Morning

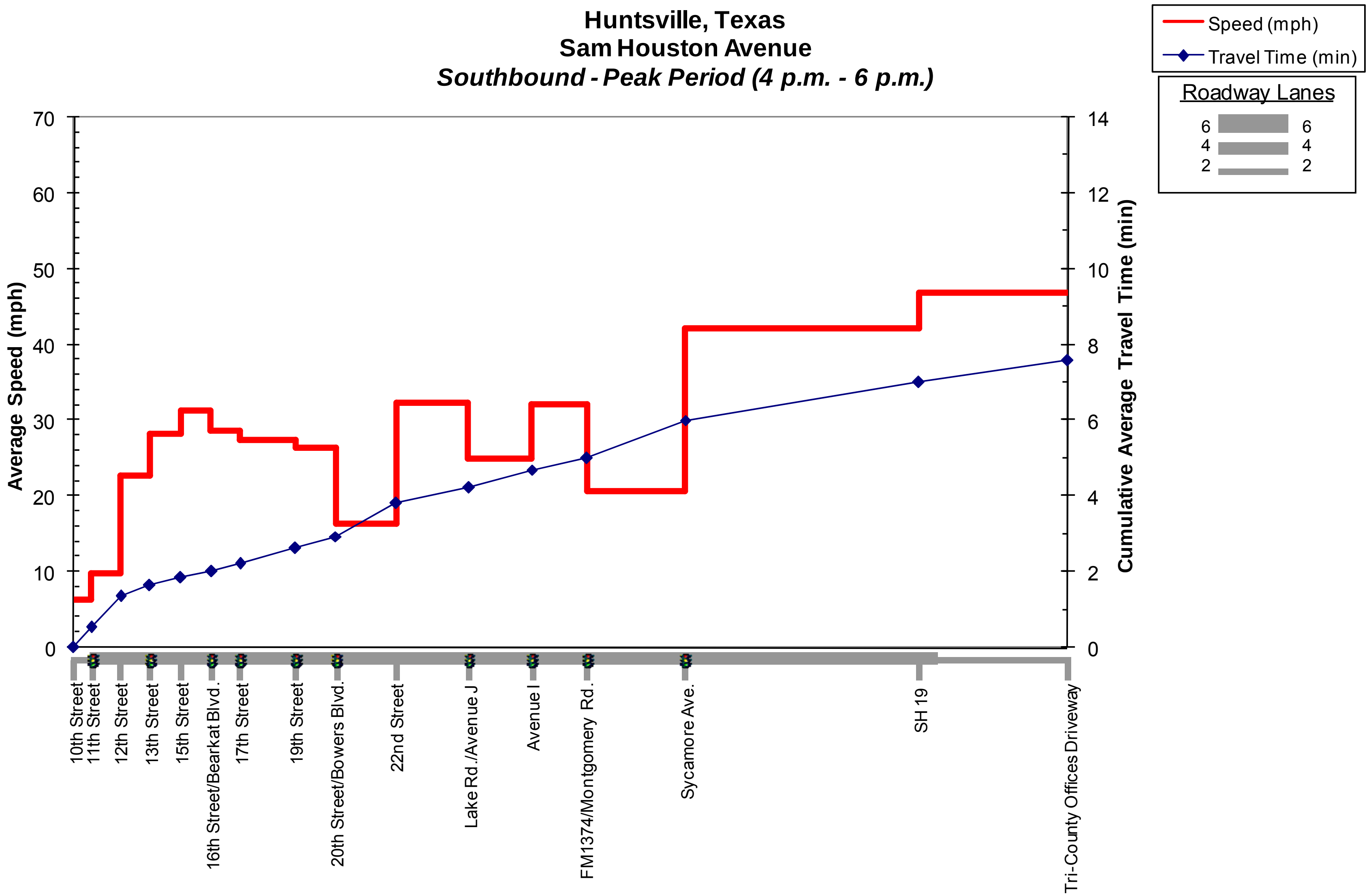


Figure D-112. Average Speed and Cumulative Average Travel Time for Sam Houston Avenue, Southbound - Afternoon.

APPENDIX E

Preliminary Workshop Lesson Plans

Workshop on Mobility Monitoring for Small and Medium-Sized Communities

Lesson Plan

August 2007

Prepared by:

Texas Transportation Institute

INTRODUCTION

The Workshop on Mobility Monitoring for Small and Medium-Sized Communities was developed by the Texas Transportation Institute (TTI) for the Texas Department of Transportation (TxDOT). The course is delivered by either a qualified instruction team or TxDOT staff from the Transportation Planning and Programming Division (TPP).

The workshop serves as an introduction to establishing a mobility monitoring process in small and medium-sized communities with less than 250,000 population. Participants will learn the six framework steps and key considerations within each step.

The workshop is intended for public sector transportation professionals involved in transportation planning. It is designed to present a broad array of information and planning tools regarding mobility monitoring to prepare workshop participants for the tasks required to plan and perform mobility monitoring.

COURSE ORGANIZATION

The one-day course will be presented by qualified instructors using the curriculum materials including an Instructor Manual, a Participant Notebook, *Guidebook for Mobility Monitoring in Small to Medium-Sized Communities: A How To Guide*, and supporting visual aids and exercises.

All participants receive a copy of the Participant Notebook containing copies of all presentation slides and charts at the workshop. Participants will also receive a copy of *Guidebook for Mobility Monitoring in Small to Medium-Sized Communities: A How To Guide* at the workshop supplied by TxDOT. The notebook and guide will be used extensively during the workshop learning modules.

The course is divided into 9 lessons. An agenda is included in the Participant Notebook and shown on page 2.

The course is designed to run from 8:00 a.m. to 4:30 p.m. It can be modified to allow for two half-days of instruction, if needed. In this case, time must be allotted on the second half-day for review of the previous day’s material.

Day 1

Lesson	Title	Min	Start	End
	Workshop Introduction	30	8:00 AM	8:30 AM
1	Congestion Trends	20	8:30 AM	8:50 AM
2	Introduction to Performance Measures	40	8:50 AM	9:30 AM
3	Importance of Monitoring	20	9:30 AM	9:50 AM
	Break	10	9:50 AM	10:00 AM
4	Step 1: Identify the Needs and Opportunities	60	10:00 AM	11:00 AM
5	Step 2: Make the Monitoring Plan	60	11:00 AM	12:00 PM
	Lunch	60	12:00 PM	1:00 PM
6	Step 3: Monitor the System	15	1:00 PM	1:15 PM
7	Step 4: Analyze the Data	75	1:15 PM	2:30 PM
	Break	10	2:30 PM	2:40 PM
8	Step 5: Package and Distribute the Results	60	2:40 PM	3:40 PM
9	Step 6: Move Forward with Improvements and Continue the Monitoring	20	3:40 PM	4:00 PM
	Self-Assessment and Workshop Assessment	30	4:00 PM	4:30 PM

COURSE COORDINATION

Facilities, equipment, and scheduling should be coordinated through the instruction team and the TxDOT Transportation Planning and Programming Division.

CLASS SIZE

The maximum class size to achieve the learning objectives of the workshop is 30 people. TxDOT will ship 30 copies of the Participant Notebook and, if needed, an equal number of *Guidebook for Mobility Monitoring in Small to Medium-Sized Communities: A How To Guide* to the name and address of the designated training location, in care of the instruction team.

WORKSHOP EQUIPMENT REQUIREMENTS

Audio/Visual Equipment Requirements

Workshop visual aids will be delivered through computerized slides projected by an LCD projector and the use of wall charts. The following equipment is needed for presenting the visual aids:

- Computer (LCD) projector with minimum 1024x768 resolution, located so that the image fills the screen without obstructions. A backup projector should be available;
- Large projection screen (7 ft width minimum);
- Pointing device (electronic or mechanical);
- Several (4-6) large, black marking pens for student name tents;
- Blackboard or whiteboard or flipcharts, with appropriate markers; and
- Mounting tape and/or thumb tacks for the wall charts.

The equipment should be placed in the designated room and available to be checked by an instructor before the workshop begins.

Instructor's Workstation Requirements

The instructor's workstation must meet all the requirements listed:

- Computer with at least: 300MHz CPU, 32MB RAM, 100MB hard-disk space available, sound card, speakers, and external mouse;
- MS PowerPoint 2000 or later; and
- World Wide Web access (desirable, but not essential).

Classroom Requirements

The classroom should be a large room, a conference room, or similar room, preferably with a flat floor. It must contain sufficient tables and chairs for the number of expected participants plus two instructors. Ceiling height must be adequate to permit visual aids to clearly be seen from all points in the room. There must be enough desktop space for each student to lay a 3-ring binder flat and to flip the pages and take notes on the pages in the binders. Whenever possible, the tables and chairs should be arranged in "classroom" style, with all students facing the front of the room, but arranged in a manner to allow easy rearrangement for group exercises. Preferably, there should be a clear aisle in the middle of the room and on each side of the room to permit the instructor to move among the students for a high level of interaction.

All students should face the front of the room. A presentation table/podium must be placed at the front of the room. A table or cart with the electronic projector and the instructor's computer workstation must be positioned so that the image fills the screen without distortion. A large projection screen (7 ft width minimum) that is entirely visible from every seat must be placed in the front of the room.

There must be no visual obstructions. It is essential that all students can see both the entire project screen and the upper half of the instructor, from a comfortable seated position.

Heating, ventilation, and air conditioning (HVAC) should be sufficient to handle the needs of the participants without creating excessive noise. The students should be able to hear normal speech across the full length of the room while the HVAC system is operating at the highest speed.

The room must have a lighting system that does not directly illuminate the projection screen. Preferably, it should also permit convenient dimming of the lights, especially in the area of the room near the projection screen.

Participant Requirements

Participants will be required to bring a tablet for note taking, a pen/pencil, and a calculator.

Target Audience

The workshop is intended for new and experienced technical staff in TxDOT headquarters, district, and area offices, as well as technical staff of cities, counties, and metropolitan planning organizations to better understand the need and process of monitoring mobility in small and medium-sized communities. The workshop provides an overview of mobility, its measurement, and the application of a six-step monitoring framework.

WORKSHOP LEARNING OBJECTIVES

Upon completion of the workshop, participants will be able to:

- Describe general mobility trends and causes of congestion in small and medium-size communities.
- List and describe six steps of the mobility monitoring framework.
- Identify a range of mobility performance measures and their application.
- Describe the development and application of performance thresholds.
- Develop and execute a mobility monitoring plan for their community.
- Calculate basic mobility performance measures.
- Describe reader-friendly writing and use of graphics to convey measured performance.
- Explain the benefits from continued improvement of the mobility monitoring process.
- Describe the contents and application of the guide, *Guidebook for Mobility Monitoring in Small to Medium-Sized Communities: A How To Guide.*

AGENDA

Day 1

Lesson	Title	Min	Start	End
	Workshop Introduction	30	8:00 AM	8:30 AM
1	Congestion Trends	20	8:30 AM	8:50 AM
2	Introduction to Performance Measures	40	8:50 AM	9:30 AM
3	Importance of Monitoring	20	9:30 AM	9:50 AM
	Break	10	9:50 AM	10:00 AM
4	Step 1: Identify the Needs and Opportunities	60	10:00 AM	11:00 AM
5	Step 2: Make the Monitoring Plan	60	11:00 AM	12:00 PM
	Lunch	60	12:00 PM	1:00 PM
6	Step 3: Monitor the System	15	1:00 PM	1:15 PM
7	Step 4: Analyze the Data	75	1:15 PM	2:30 PM
	Break	10	2:30 PM	2:40 PM
8	Step 5: Package and Distribute the Results	60	2:40 PM	3:40 PM
9	Step 6: Move Forward with Improvements and Continue the Monitoring	20	3:40 PM	4:00 PM
	Self-Assessment and Workshop Assessment	30	4:00 PM	4:30 PM

Lesson Number:	NA
Lesson Title:	Workshop Introduction
Learning Objectives:	None
Instructional Method:	This opening session acquaints instructors and participants with each other, covers ground rules, and concludes by explaining the workshop objectives. The instructors introduce themselves. The participants introduce themselves and share information about their work responsibilities and expectations for this workshop. Instructors will capture these expectations on a flip chart for review at the end of the workshop. The expectations will be posted in the room for the duration of the workshop. Instructors cover the workshop ground rules, i.e., discussion etiquette, breaks, cell phones. Instructors will direct participants to location of restrooms and water fountain. Instructors will stress timely breaks be observed by participants to keep to the agenda. Instructors will encourage the participants to actively engage in the discussion. Instructors identify and explain the workshop materials workshop notebook and guidebook. Instructors will review the workshop learning objectives and the workshop agenda.
Instructional Day:	Day 1 - AM
Time Allocation:	Introductions 15 minutes Ground Rules, Objectives 15 minutes workshop materials and resources Total: 30 minutes
Evaluation Plan:	Not applicable

Lesson Number:	1
Lesson Title:	Congestion Trends
Learning Objectives:	Participants will be able to: • Discuss recent small and medium-sized community congestion trends • Explain common causes of congestion
Instructional Method:	Participants receive an introduction to congestion trends in small and medium-sized communities, and a discussion of how communities prioritize mobility needs. Trends from the TTI Urban Mobility Report will be introduced. Instructors will discuss with the class the common causes of congestion by polling participants for their experiences. The instructor will use question and answer techniques to draw additional information from participants. The instructor will initiate discussion of the exercise when completed.
Instructional Day:	Day 1 - AM
Time Allocation:	Lecture 15 minutes Discussion 5 minutes Total: 20 minutes
Evaluation Plan:	Instructors will ask questions of the participants to gauge their comprehension of the lesson material. Participants should express commonalities and differences of congestion causes with other participants. Encourage the participant to describe why causes may be different.

Lesson Number: 2

Lesson Title: Introduction to Performance Measures

Learning Objectives: Participants will be able to:

- Identify and describe mobility performance measures and contrast their application to varying analysis levels
- Describe the attributes of good performance measures
- Discuss the importance of performance thresholds
- Calculate travel rate indices.

Instructional Method: Introduce the participants to the various mobility performance measures included in the guidebook. Discuss how each measure describes mobility and its applicability for various analysis levels. Present the attributes of good performance measures. Ask the participants if they measure mobility in any of these or other ways. Ask the participants which measures they find most important or relevant for their community. Discuss how the different measures communicate to various audiences.

Discuss why performance thresholds are important, and how the thresholds can be defined. Engage the participants in discussing how they would define performance thresholds and the reasons for their selections. Ask the participants when they would consider action – measurements beyond the threshold or frequently beyond the threshold. Ask the participants what actions they would consider.

Instructors will step through the calculation of a travel rate index. Lesson 7 will provide greater detail within the calculation. The presentation at this time should be very general.

Instructional Day: Day 1 - AM

Time Allocation:

Lecture	20 minutes
Discussion	10 minutes
Exercise	10 minutes
Total:	40 minutes

Evaluation Plan: A written exercise will gauge the participant's comprehension. The written exercise will have participants list and describe 3 to 5 mobility performance measures, identify three attributes of good performance measures, write why performance thresholds are important and provide an example that would apply to their community, and compute a travel rate index for a corridor from data supplied in the written exercise.

Lesson Number:	3
Lesson Title:	Importance of Monitoring
Learning Objectives:	Participants will be able to: • Describe the benefits of mobility monitoring • Discuss the benefits of repeated monitoring
Instructional Method:	Instructors will present the general benefits of a mobility monitoring program. Gather participants' experiences from any past monitoring they conducted. Lead into the benefits of repeated monitoring. Stress that infrequent measurement does not facilitate swift recognition of trends and congestion countermeasures.
Instructional Day:	Day 1 - AM
Time Allocation:	Lecture 15 minutes Discussion 5 minutes Total: 20 minutes
Evaluation Plan:	Participants will participate in open discussion at the end of the lesson, led by the instructor. The instructor will gauge participant comprehension from their responses.

Lesson Number: 4

Lesson Title: Step 1: Identify the Needs and Opportunities

Learning Objectives: Participants will be able to:

- Discuss the importance of identifying public cares and concerns
- Identify the primary users of mobility monitoring
- Explain and contrast how congestion is defined
- Describe key early considerations for developing a monitoring plan
- Describe considerations for the mobility monitoring outcomes
- Discuss appropriate congestion reduction strategies agreeable to their community

Instructional Method: Instructors will introduce the six-step monitoring framework at the beginning of this lesson. Using the guide structure for each step, instructors will address the learning objectives.

Engage participants to share their thoughts of including the public cares and concerns. Tie the primary users of the mobility monitoring process to the public and elected officials. Lead to diverse definitions of congestion that are community specific – not big vs. small but small vs. medium. Citizens have expectations for mobility and small and medium-sized communities are more sensitive to decreased performance.

Present the early considerations for developing a monitoring plan. Stress that the plan should begin with an expectation of what outcomes will be communicated. Conclude with discussion of congestion reduction strategies. Gauge participants' experience with these strategies, leading them to contrast which strategies are likely for their community and those that are not.

Introduce the Fender Falls case study. Ask participants how the case study is alike and different from their own communities.

Instructional Day: Day 1 - AM

Time Allocation:

Lecture	50 minutes
Exercise/Discussion	10 minutes
Total:	60 minutes

Evaluation Plan: A written exercise will measure the participants' comprehension of the lesson material. A multiple choice and brief writing format will be used.

Lesson Number:	5
Lesson Title:	Step 2: Make the Monitoring Plan

Learning Objectives: Participants will be able to:

- Identify common available data sources
- Describe and contrast data collection methods
- Describe quality assurance checks
- Discuss the importance of repeated mobility monitoring
- Develop a sketch monitoring plan

Instructional Method: Present participants with commonly available data sources. Ask participants what sources they know are available to them, and who they would contact for information.

Present and discuss types of data collection methodologies. Contrast the costs, skill required, data detail, data accuracy, and automation potential of travel time data collection methods.

Introduce simple quality assurance checks used to validate the plan. Conclude with a discussion of repeated monitoring, its importance and challenges.

Instructional Day: Day 1 - AM

Time Allocation:

Lecture	35 minutes
Group Exercise	25 minutes
Total:	60 minutes

Evaluation Plan: Divide participants into small groups and ask them to develop a sketch monitoring plan for Fender Falls. Provide enough detail on the physical extent of interest, but allow the participants to ask clarification for other considerations. When other considerations are asked, address the group with the question and answer. Have a leader from each group present the sketch monitoring plan. During presentations, ask questions and encourage other participants to ask questions.

Lesson Number:	6
Lesson Title:	Step 3: Monitor the System
Learning Objectives:	Participants will be able to: • Describe considerations and management contingencies to mitigate data collection problems and negative issues
Instructional Method:	Instructors will discuss tips to ensure data collection success and avoid frustration. Ask participants to share their own experiences to ensure successful data collection. Discuss the importance of videologging.
Instructional Day:	Day 1 - PM
Time Allocation:	Lecture 15 minutes Total: 15 minutes
Evaluation Plan:	The instructor will review a summary slide of the tips asking participants to read aloud from the visual aid.

Lesson Number:	7
Lesson Title:	Step 4: Analyze the Data

Learning Objectives: Participants will be able to:

- Explain how mobility performance measures are calculated
- Describe procedures for calculating travel rate indices
- Describe a method for calculating free-flow travel rate
- Interpret a link travel rate index graph
- Describe a method for calculating corridor delay
- Explain the benefits of community targets and how these targets are developed
- List quality control actions

Instructional Method: Present the basic mobility measures and explain how they are calculated. Explain how travel rate indices are calculated. Explain one method for calculating free-flow travel rate (median 15th percentile); contrast other methods. Explain how the median is an appropriate measure and how the 15th percentile eliminates outlier travel time measurements.

Present a link travel rate index graph. Ask participants to interpret the graph. The instructor may need to lead the interpretation.

Present a method for combining simple volume and travel time data to calculate corridor delay. Show how the delay can be transformed from a modal representation to impacts on person flow.

Refer back to Step 1 discussion of mobility performance targets. Explain how these are used and note the flexibility to meet the needs of each community.

Conclude the lesson by identifying quality control actions in the data analysis. Stress the importance of quality control to ensure accurate reporting. Inaccurate reports can result in a reduction or loss of confidence in the monitoring process.

Instructional Day: Day 1 - AM

Time Allocation:

Lecture	45 minutes
Exercise	30 minutes
Total:	60 minutes

Evaluation Plan: Present participants with a worksheet to calculate and graph mobility measures. Have participants develop a link travel rate index graph from data supplied to them. Participants will calculate corridor delay from data provided in the exercise. List two quality control techniques.

Lesson Number: 8

Lesson Title: Step 5: Package and Distribute the Results

Learning Objectives: Participants will be able to:

- Contrast use of tabular and graphical data
- Explain considerations of color and scale
- Describe considerations for developing mobility improvement strategies and action plan
- Explain the concept of reader-friendly writing
- List and describe effective documentation tips
- List components of a press release
- List and describe effective press release tips

Instructional Method: Instructors will discuss the overuse of tabular data and demonstrate difficulty in identifying trends or key aspects of data as opposed to use of graphical techniques. Present several alternative graphic formats. Reference Edward Tufte and William Cleveland for data visualization. Cover considerations in use of color in graphics and importance of scale.

Ask participants to relate considerations they have encountered developing mobility improvement strategies for their communities. Discuss the importance of an action plan.

Describe the reader-friendly writing concept. Discuss effective documentation tips. Ask participants to describe their writing style and describe their intended audience.

Conclude by discussing components of a press release. This is the end or outcome of the monitoring. Have the participants see that this is where they were being led from Step 1. Discuss effective press releases. Ask participants to share their experiences.

Instructional Day: Day 1 - PM

Time Allocation:

Lecture	40 minutes
Exercise	20 minutes
Total	60 minutes

Evaluation Plan: Distribute an exercise to students that will have them list the four main concepts for reader-friendly writing. Have them write a brief press release for their community and ask for volunteers to share their release with the group.

Lesson Number:	9
Lesson Title:	Step 6: Move Forward with Improvements and Continue the Monitoring
Learning Objectives:	Participants will be able to: • Explain the importance of regular mobility monitoring contrasting cycle frequencies • Describe techniques and considerations for improving the mobility monitoring process
Instructional Method:	Instructors will engage participants in open discussion on the potential impacts of infrequent monitoring. Probe the participants for what cycle frequency they would consider reasonable and the basis for its reasonableness. Query participants for methods they use on their job to improve their own processes. Ask how they can modify or implement those techniques to a mobility monitoring process.
Instructional Day:	Day 1 - PM
Time Allocation:	Lecture 10 minutes Discussion 10 minutes Total 20 minutes
Evaluation Plan:	Instructors will ask the participants to collectively summarize the lesson based around the two lesson learning objectives.

Lesson Number:	NA
Lesson Title:	Self-Assessment Exercise and Workshop Assessment
Learning Objectives:	None
Instructional Method:	Participants will directly measure their individual knowledge retention from the workshop. An instructor explains the final exercise, hands them out, and collects them from participants when they finish. If time remains, instructors initiate a short discussion on the results, allowing the group to gauge their progress in the workshop collectively. An instructor reviews the importance of the workshop assessment, answers any questions regarding it, and collects them from participants after they are finished.
Instructional Day:	Day 1 - PM
Time Allocation:	Skills assessment 20 minutes Workshop assessment 10 minutes Total 30 minutes
Evaluation Plan:	Participants take a skills assessment exercise on mobility monitoring in small and medium-sized communities. The skills assessment should pull from previous exercises and discussion topics. There should be no surprises! Participants are asked to fill out a questionnaire regarding the various aspects of the workshop, its usefulness to the participant, and the effectiveness of the instructor(s).

APPENDIX F

Calculations of Travel Time Data Collection Costs
(*Note: Electronic File in Attached CD*)

The Microsoft Excel file in the directory "Appendix F" of the CD at the end of this report contains the data used to create the travel time data collection cost estimates in Section 7.4 of this report. The user can use the Travel Time Data Collection Cost Calculator, v 1.0 in the attached Excel spreadsheet to edit inputs and estimate costs for specific data collection efforts.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Method**		**Sunk Costs (Capital)**						**Recurring Costs**					
2			Item	Cost	Unit	Amount	Extension		Item	Cost	Unit	Amount	Extension	
3	**Manual**		Stopwatches	$25	ea	2	$50		Route planning	$40-80	MH	1	$60	
4			Office computer	$1,000	ea	1	$1,000		Data Collection Sheet Preparation	$40-80	MH	0.5	$30	
5			(2) clipboards	$3	ea	1	$3		Test Vehicle Driver (training)	$15-40	MH	4	$120	
6									Test Vehicle Driver (collection)	$15-40	MH	12	$360	
7									Data Entry/Reduction Personnel	$15-30	MH	15	$450	
8									Supervision and Management (collection)	$40-80	MH	2	$120	
9									Supervision and Management (analysis)	$40-80	MH	4	$240	
10									Reimbursed Vehicle Mileage	$ 0.485	mi	110	$53	
11														
12							***$1,053***						***$1,433***	
13														
14	**DMI**		DMI	$600-1200	ea	2	$1,800		Route planning	$40-80	MH	1	$60	
15			DMI Installation	$60	ea	2	$120		Data Collection Sheet Preparation	$40-80	MH	0.25	$15	
16			Laptop computer	$600	ea	2	$1,200		Test Vehicle Driver (training)	$15-40	MH	4	$120	
17			Coll./Office software	$150	ea	2	$300		Test Vehicle Driver (collection)	$15-40	MH	12	$360	
18			Office computer	$1,000	ea	1	$1,000		Data Reduction Personnel	$15-30	MH	10	$300	
19			(2) clipboards	$3	ea	1	$3		Supervision and Management (collection)	$40-80	MH	2	$120	
20									Supervision and Management (analysis)	$40-80	MH	2	$120	
21									Reimbursed Vehicle Mileage	$ 0.485	mi	110	$53	
22														
23							***$4,423***						***$1,148***	
24														
25	**GPS (laptop)**		GPS	$75	ea	2	$150		Route planning	$40-80	MH	1	$60	
26			Collection Software	$700	ea	2	$1,400		Data Collection Sheet Preparation	$40-80	MH	0.25	$15	
27			Office Software	$1,100	ea	1	$1,100		Test Vehicle Driver (training)	$15-40	MH	2	$60	
28			Laptop computer	$600	ea	2	$1,200		Test Vehicle Driver (collection)	$15-40	MH	6	$180	
29			Power inverter	$50	ea	2	$100		Data Reduction Personnel	$15-30	MH	10	$300	
30			Office computer	$1,000	ea	1	$1,000		Supervision and Management (collection)	$40-80	MH	2	$120	
31			(2) clipboards	$3	ea	1	$3		Supervision and Management (analysis)	$40-80	MH	2	$120	
32									Reimbursed Vehicle Mileage	$ 0.485	mi	120	$58	
33														
34							***$4,953***						***$913***	
35														
36	**GPS (no laptop)**		GPS	$500	ea	2	$1,000		Route planning	$40-80	MH	1	$60	
37			Office software	$2,000	ea	1	$2,000		Data Collection Sheet Preparation	$40-80	MH	0.25	$15	
38			Office computer	$1,000	ea	1	$1,000		Test Vehicle Driver (training)	$15-40	MH	2	$60	
39			(2) clipboards	$3	ea	1	$3		Test Vehicle Driver (collection)	$15-40	MH	6	$180	
40									Data Reduction Personnel	$15-30	MH	10	$300	
41									Supervision and Management (collection)	$40-80	MH	2	$120	
42									Supervision and Management (analysis)	$40-80	MH	2	$120	
43									Reimbursed Vehicle Mileage	$ 0.485	mi	110	$53	
44														
45							***$4,003***						***$908***	
46														
47	**General**		Office computer	$1,000	ea	1	$1,000							
48			(2) clipboards	$3	ea	1	$3							
49														
50							***$1,003***							

Figure F-1. Travel Time Data Collection Costs.

	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
1	**Total Cost (Annual, 1 route)**							**Total Cost (bi-annual, 1 route)**					
2	Year 1	Year 2	Year 3	Year 4	Sub-Total	NPV		Year 1	Year 2	Year 3	Year 4	Sub-Total	NPV
3													
4													
5													
6													
7													
8													
9													
10													
11													
12	$2,486	$1,476	$1,521	$1,566	$7,000	$6,600		$2,486	$0	$1,521	$0	$4,000	$3,800
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23	$5,571	$1,183	$1,218	$1,255	$9,200	$8,800		$5,571	$0	$1,218	$0	$6,800	$6,500
24													
25													
26													
27													
28													
29													
30													
31													
32													
33													
34	$5,866	$941	$969	$998	$8,800	$8,400		$5,866	$0	$969	$0	$6,800	$6,600
35													
36													
37													
38													
39													
40													
41													
42													
43													
44													
45	$4,911	$936	$964	$993	$7,800	$7,400		$4,911	$0	$964	$0	$5,900	$5,700
46													
47													
48													
49													
50	$1,003												

Figure F-1. Travel Time Data Collection Costs, continued.

	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
1	**Total Cost (Annual, 4 routes)**							**Total Cost (bi-annual, 4 routes)**					
2	Year 1	Year 2	Year 3	Year 4	Sub-Total	NPV		Year 1	Year 2	Year 3	Year 4	Sub-Total	NPV
3													
4													
5													
6													
7													
8													
9													
10													
11													
12	$6,786	$5,905	$6,083	$6,265	$25,000	$23,300		$6,786	$0	$6,083	$0	$12,900	$12,200
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23	$9,016	$4,731	$4,873	$5,019	$23,600	$22,100		$9,016	$0	$4,873	$0	$13,900	$13,200
24													
25													
26													
27													
28													
29													
30													
31													
32													
33													
34	$8,606	$3,762	$3,875	$3,992	$20,200	$19,000		$8,606	$0	$3,875	$0	$12,500	$11,900
35													
36													
37													
38													
39													
40													
41													
42													
43													
44													
45	$7,636	$3,742	$3,855	$3,970	$19,200	$18,000		$7,636	$0	$3,855	$0	$11,500	$10,900
46													
47													
48													
49													
50													

Figure F-1. Travel Time Data Collection Costs, continued.