

9 Transit: Keeping Pace

Measuring the Effects of Traffic Congestion On Transit Signal Priority Call Distances

Matt Dorado

Erin Qureshi

River Hwang

Robert L. Bertini

Department of Civil & Environmental Engineering

Portland State University

P.O. Box 751

Portland, Oregon 97207-0751

Phone: 503-725-4285

Fax: 503-725-5950

Email: doradom@cecs.pdx.edu

Peter Koonce

Kittelson & Associates, Inc.

610 SW Alder St., Suite 700

Portland, OR 97205

Phone: 503-228-5230

Fax: 503-273-8169

Email: pkoonce@kittelson.com

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ABSTRACT

The city of Portland, Oregon has deployed Transit Signal Priority (TSP) at more than 300 intersections, in cooperation with TriMet, the regional transit operator. TSP is used on particular routes and only within the city limits. Benefiting from TriMet's "smart" buses, using global positioning systems (GPS), each vehicle "knows" whether it is on route and on schedule. Therefore, using the on-board technology, TSP is only activated when it is needed—when a bus is late. For each intersection there is a predetermined distance at which the TSP call is made. While this distance is particular to each intersection, it does not vary throughout the day in coordination with traffic flow patterns. Of the numerous factors that contribute to varying dwell times, one of the most important is the magnitude of traffic congestion on the street being traveled. The purpose of this paper is to describe the relationship between the effective call distance and the traffic congestion on the bus route. It is believed that by coordinating the call distance with the amount of roadway congestion will improve transit performance as well as a decrease the proportion of TSP calls that are not fully utilized. The analysis uses varying approach volume to capacity (v/c) ratios while measuring bus delay. Using a hardware-in-the-loop simulation system for evaluating TSP in Portland, this research has been performed by modeling intersections using VISSIM traffic modeling software and varying the call distances over various v/c ratios.

Introduction

Transit Signal Priority (TSP) is adopted as one of the operational strategies to increase the efficiency of in-service vehicle movement in traffic stream by TriMet and the City of Portland, Oregon in an on-going attempt to improve the overall performance of the bus fleet to meet ever-increasing customer demands. It has been shown that through the application of TSP, the overall travel time and travel time variability can be reduced and thus reducing rider travel time and transit operating costs (1). It has also been shown that TSP can reduce overall delay at the intersection on a per-person basis (2).

As part of the Streamline program, the City of Portland, the Oregon Department of Transportation (ODOT), and TriMet, the regional transit service provider for Portland, implemented TSP at over 240 intersections on seven transit routes. The ultimate goal of the Streamline program is to increase overall efficiency of the transit system by reducing run time and increase the reliability of the transit system by adhering to the transit schedule. To achieve this, preferential treatments are given to transit buses; among the implementations are TSP, an Automatic Vehicle Location (AVL) system, improved scheduling and low-cost stop improvement.

The priority treatments given to vehicles in this study are consistent with the signal controller hardware and software that are adopted by the City of Portland. Wapiti Microsystems Software, the traffic signal software used by City of Portland, provides a range of priority options. Priority can be requested on any of the legs of the intersection, and can include red truncation, green extension, or a combination of the two. Priority is implemented by modifying coordination timing plans and adjusting forceoffs (green times) for the vehicle movements while remaining in coordination.

The maximum green extension ranges from 0 to 40 seconds, and is constrained by intersection elements. The red truncation also depends on the configuration of the intersection. The choice of a particular priority strategy depends upon where in the cycle the priority is requested

AVL SYSTEM AND TSP

The AVL system used by TriMet uses the Global Positioning System (GPS) and radio communications and is part of an overall operations management system. This system monitors the real time position of all buses in the TriMet fleet. The AVL system provides the central command center, via radio transmission, with time stamped location data for all the buses at each stop. Since the distance between stops is known, the travel time between stops can be calculated, and then integrated into the scheduling process. The AVL system is also important in determining one of the major TSP parameters, whether a bus is behind schedule. If a bus is late, on route, and at an intersection that has a TSP plan, a call goes into the controller, via infra-red, to alter the phase timing accordingly. If a call comes in on a green the green time is then extended. If the call comes in on a red, the red time is shortened in favor of the bus.

HARDWARE IN THE LOOP

The simulation set up used for this project used a microscopic simulation software program on a desktop PC. This program was then linked to a City of Portland 170E controller unit (programmed with Wapiti Microsystems Software) via a Controller Device Interface (CID) developed through a collaboration of the Federal Highway Administration, the National Institute for Advanced Transportation Technology, and Darcy Bullock of Purdue University. This setup allows for the realistic evaluation of the traffic control parameters with out disturbing real traffic flow and gives the added benefit of letting students become familiar with traffic signal controllers currently in use in and around the city of Portland.

STUDY DESIGN

The intersection of Sandy Boulevard and 33rd Avenue has unique characteristics that made it a good candidate for this project. The Number 12 bus services Sandy Boulevard with approximately fifteen-minute headway. The intersection of Sandy/33rd has both a near side (westbound) and a far side (eastbound) bus stop, a fixed time-two phase signal with a 70 second cycle time, and is a major arterial with high fluctuations in volume depending on the time of day. These characteristics gave the opportunity to study the not only the effects of the congestion but also how that relates to near and far side stops.

Data for this project was collected using a combination of VISSIM and SYNCHRO software and a "Hardware in the Loop" configuration. SYNCHRO was used to establish the approach volume to capacity (v/c) ratios for eastbound and westbound traffic. VISSIM was then used to perform the actual simulation and produce the data for analysis.

The signal-timing plan for Sandy/33rd was acquired from the City of Portland and input into the SYCHRO software. The split time for this intersection is 32 seconds of green, 4 seconds of amber, and 1.5 seconds of all clear for Sandy. 33rd receives 27.5 seconds of green, 3.5 seconds of amber, and 1.5 seconds of all red. For the green extension on Sandy the phase receives 7 seconds of extra green time. The minimum green time for this intersection is 10 seconds. There are time-of-day plans for Sandy/33rd to accommodate the morning and evening commutes. These plans were not used in the simulations. The volumes on Sandy were adjusted until the selected *approach* v/c ratios were displayed. Because there was no interest in the delay effect of the side streets for this experiment, the v/c ratios for the side streets were ignored. The v/c ratios used were 1.1, 0.9, 0.7, and 0.5. These equated to volumes per hour of 1640, 1330, 1040, and 735, respectively.

These volumes were then input into the VISSIM simulation software. Simulations were run using each volume in conjunction with each detector call distance of 420ft, 350ft, and 280ft from stop bar. Each simulation was run for 12 hours (43,200 seconds) with a 900 second warm up time. Buses were deployed every fifteen minutes on each line. This is the approximate headway for buses currently servicing Sandy Boulevard. The bus dispatch times were staggered per direction to produce a bus on the system every seven and one half minutes. This made it easy to identify the direction of the bus in the data. For the purposes of this study, the buses were assumed to always be late and served the stop each time. These conditions created an environment where TSP was implemented for each bus entering the system.

The data collected from the simulation was collated into three categories; Travel Time (**Figures 1-2**), Waiting Time (**Figures 3-4**) and Delay (**Figures 5-6**). Travel times were collected over a fixed 1000 ft distance that included the intersection, bus stop, and the detector. Waiting time is defined as all the time that a bus was stopped with the exception of when a bus was serving passengers. Delay data was collected for the buses only. Each category was separated out for both eastbound and westbound buses giving the added data for near and far side stops. Each category was then averaged for comparison. The results are shown in the **Tables 1-3**.

A Signal Controller Detection Record was also generated from the simulation models. This is a record of the phase changes and the time that the bus was in the detection zone. This gives the opportunity to see when the call came into the controller, whether it was on a main line green or red, and how the controller handled the call. The other feature of this report is that it can be easily seen if a bus used the TSP call or if the bus was caught at a red light anyway. See **Figure 7**

ANALYSIS

The bus delay was simulated using a traffic controller as part of a “hardware in the loop” simulation. Due to the different bus stop locations the results of this project are broken into near and far side stops. At Sandy/33rd the westbound route has a near side stop and the eastbound has a far side stop.

Far Side Stops/Eastbound

For buses serving a far side stop the most important element is to get the bus through the intersection. The average travel time curve for each call distance is shown in **Figure 1**. The figure shows that for each level of v/c there is a definite advantage to having a longer call distance. The difference in average travel times of the 420ft call distance over the 350ft distance was 1.1 seconds and 1.9 second less than the 280ft call distance. The average delay experienced by the bus was increased by 1.1 seconds at 350ft and 2.1 seconds at 280ft. There was also a 1 second advantage in average stopped time over the 350ft call distance and a 2.2 second advantage over the 280ft call distance.

Each simulation recorded the movement of 47 buses, over 12 scenarios. That equals 564 buses in each direction that entered the system. Of these 564 buses there was a total of 219 (39%) buses that had wait time recorded. There was again an advantage to having the longer call distance, the percentage of buses that experienced wait time went down from 35% at 280ft to 31% at 420ft.

Near Side Stops/Westbound

Near side stops have the added complication of the bus needing service passengers at the stop bar of an intersection. This creates a different set of circumstances that result in an optimum call distance that is related more to the travel time than anything else. The call distance for this intersection is currently 350ft. This distance was determined by taking the green time extension in seconds (7) and calculating the distance that can be traveled at the posted speed.

From the average travel time curve (**Figure 2**) there is a time advantage to using the call distance as related to the green time extension. This holds true for the waiting time and the average delay experienced. The difference in average travel times of the 350ft call distance over the 420ft distance was 2.8 seconds and 1.6 second less than the 280ft call distance. The average delay experienced by the buses was 1.4 seconds at 420ft and 3.0 seconds at 280ft. There was also a 2.3 second advantage in average stopped time over the 420ft call distance and a 1.9 second advantage over the 280ft call distance. As expected there were a much higher number of buses that experienced a wait time. Of the 564 buses on the system 420 (74%) of them experienced wait times. However, the 350ft call distance provided the best results with 32% of the stopped buses compared to 35% at 280ft and 33% at 420ft.

CONCLUSION

This project shows that the benefits associated with extending or shortening the call distance for TSP varies depending on the position of the stop. Furthermore, the relationship of the congestion in a given intersection and the call distance worked best up to a v/c of approximately 0.9 with the optimal benefits at a v/c of approximately 0.7. It was also shown that a further call distance had benefits for far side stops only. The best call distance for near side stops was shown to be a distance related to the green time extension. It would seem that an incorporation of a congestion factor in the call distance calculation would be advantageous.

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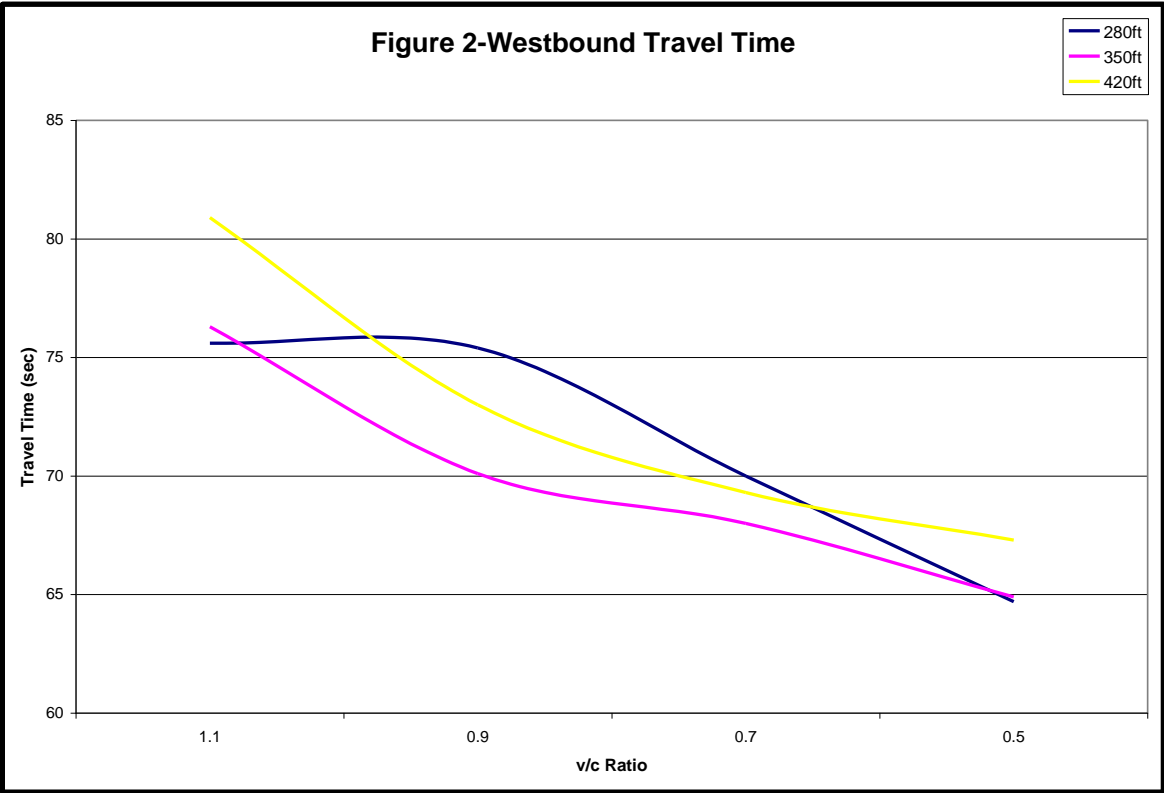
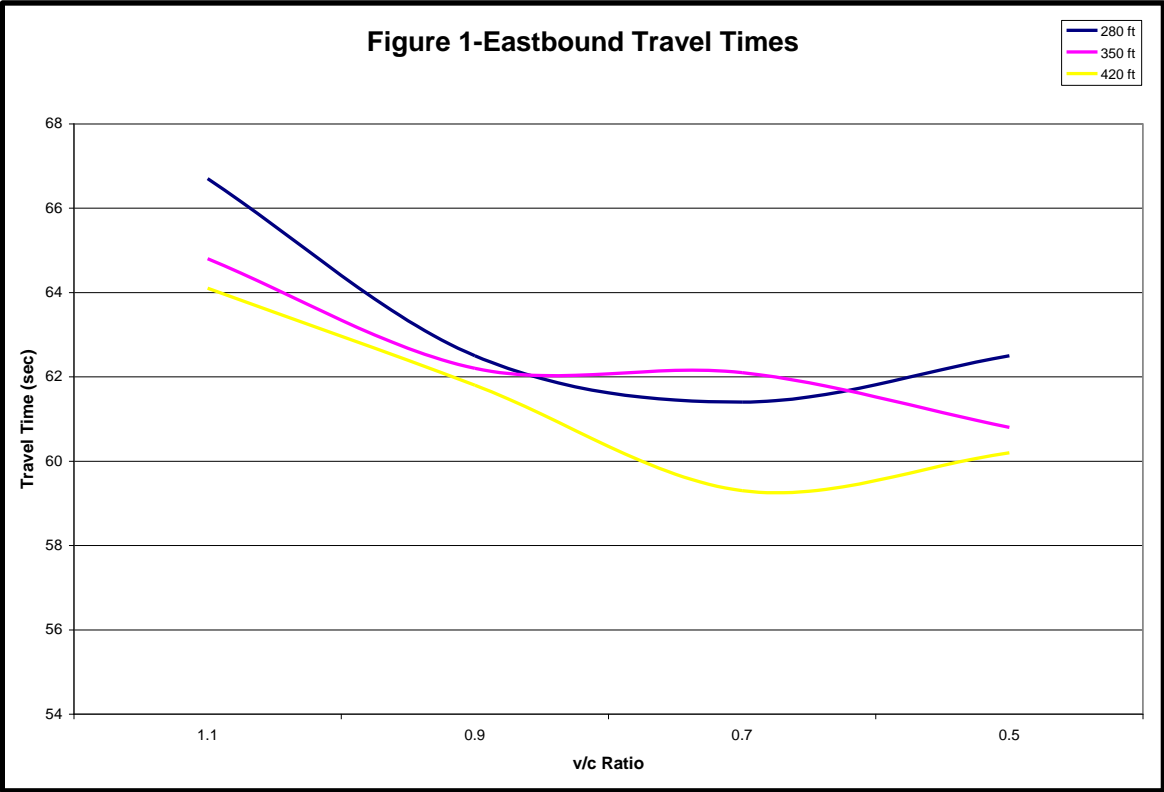
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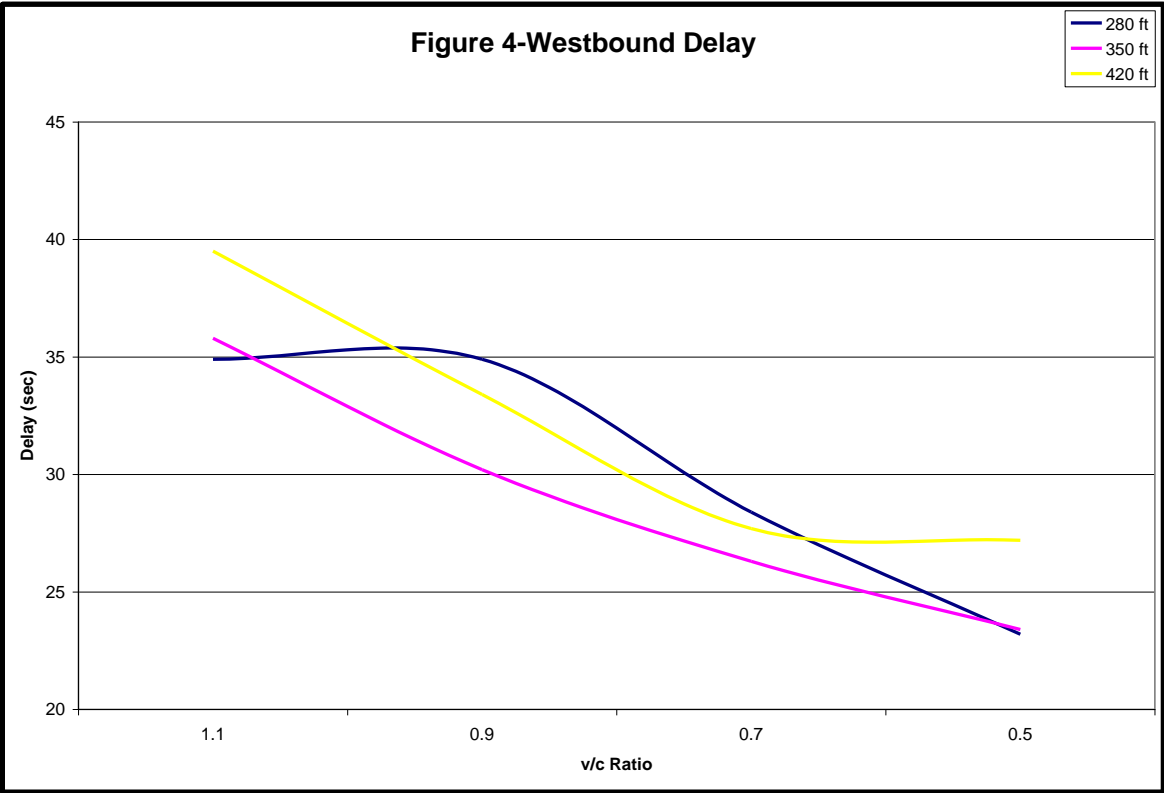
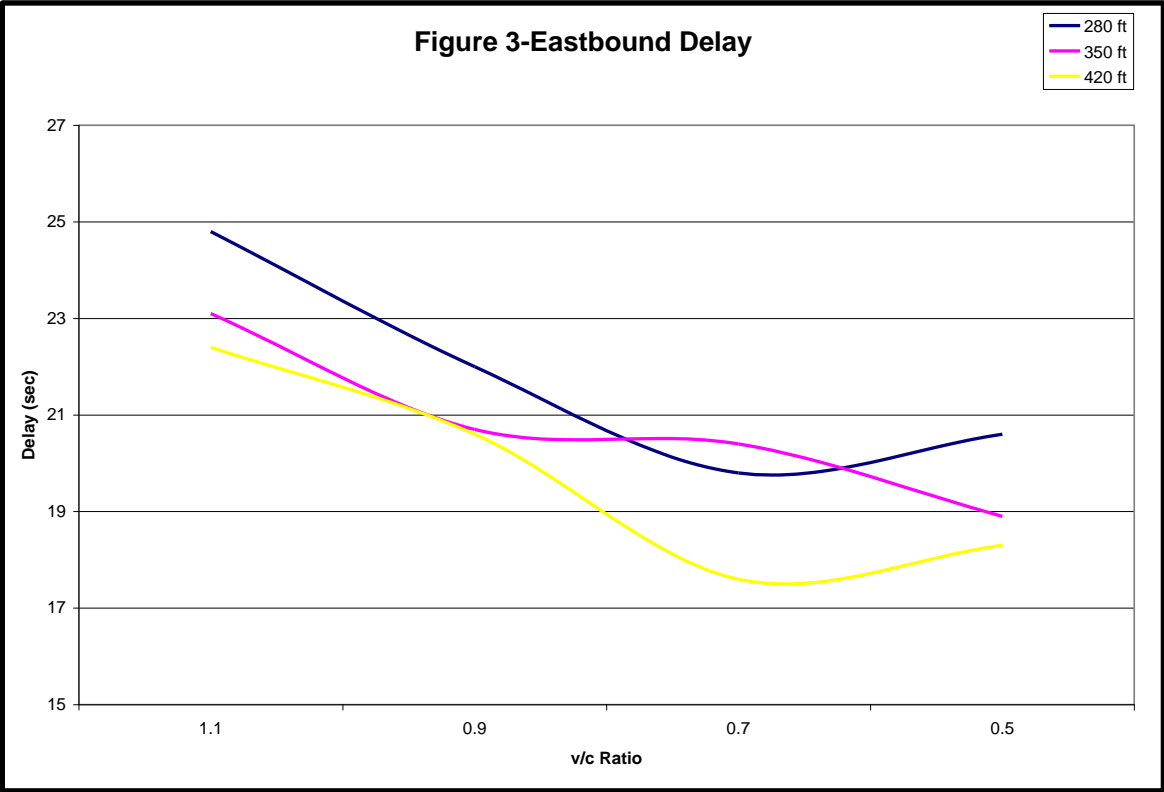
Table 1 Average Travel Times				
	Direction	Detector Length		
		280 ft	350 ft	420 ft
1.1	East	66.7	64.8	64.1
	West	75.6	76.3	80.9
0.9	East	62.5	62.2	61.8
	West	75.4	70.1	73.0
0.7	East	61.4	62.1	59.3
	West	70.0	68.0	69.3
0.5	East	62.5	60.8	60.2
	West	64.7	64.9	67.3

Table 2 Average Delay Times				
	Direction	Detector Length		
		280 ft	350 ft	420 ft
1.1	East	24.8	23.1	22.4
	West	34.9	35.8	39.5
0.9	East	22.0	20.7	20.6
	West	34.9	30.2	33.4
0.7	East	19.8	20.4	17.6
	West	28.4	26.3	27.7
0.5	East	20.6	18.9	18.3
	West	23.2	23.4	27.2

Table 3 Average Time Stopped				
	Direction	Detector Length		
		280 ft	350 ft	420 ft
1.1	East	10.1	8.5	9.3
	West	17.7	17.0	19.9
0.9	East	9.6	10.0	7.0
	West	17.5	17.5	17.1
0.7	East	11.1	8.9	6.9
	West	20.3	13.8	16.0
0.5	East	10.0	8.4	8.6
	West	13.3	13.0	17.5

*Shaded cells are lowest row value





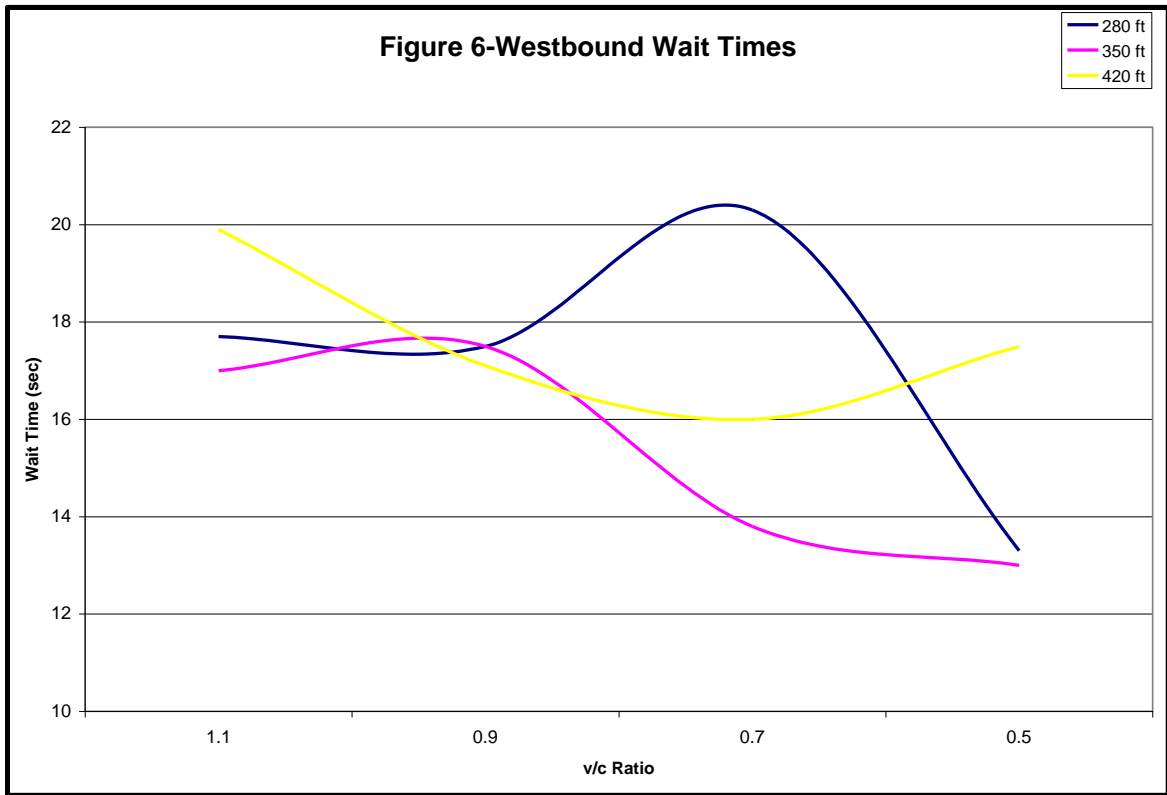
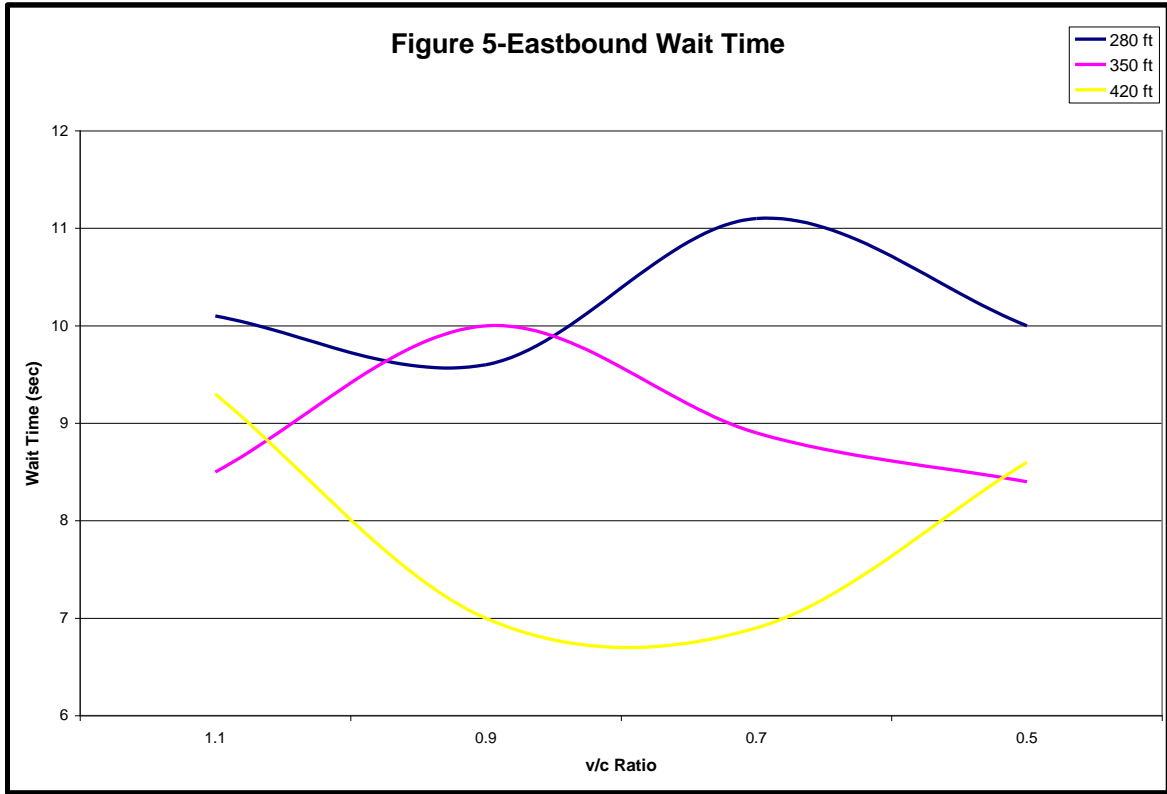


Table 4

Eastbound

Average Travel Times				
v/c		Detector Length		
		280 ft	350 ft	420 ft
1.1	East	66.7	64.8	64.1
0.9	East	62.5	62.2	61.8
0.7	East	61.4	62.1	59.3
0.5	East	62.5	60.8	60.2
Avg		63.3	62.5	61.4
Difference		1.9	1.1	

Westbound

Average Travel Times				
v/c		Detector Length		
		280 ft	350 ft	420 ft
1.1	West	75.6	76.3	80.9
0.9	West	75.4	70.1	73
0.7	West	70	68	69.3
0.5	West	64.7	64.9	67.3
Avg		71.4	69.8	72.6
Difference		1.6		2.8

Average Delay Times

Average Delay Times				
v/c		Detector Length		
		280 ft	350 ft	420 ft
1.1	East	24.8	23.1	22.4
0.9	East	22	20.7	20.6
0.7	East	19.8	20.4	17.6
0.5	East	20.6	18.9	18.3
Avg		21.8	20.8	19.7
Difference		2.1	1.1	

Average Delay Times

Average Delay Times				
v/c		Detector Length		
		280 ft	350 ft	420 ft
1.1	West	34.9	35.8	39.5
0.9	West	34.9	30.2	33.4
0.7	West	28.4	26.3	27.7
0.5	West	23.2	23.4	27.2
Avg		30.4	28.9	32.0
Difference		1.4		3.0

Average Wait Time

Average Wait Time				
v/c		Detector Length		
		280 ft	350 ft	420 ft
1.1	East	10.1	8.5	9.3
0.9	East	9.6	10	7
0.7	East	11.1	8.9	6.9
0.5	East	10	8.4	8.6
Avg		10.2	9.0	8.0
Difference		2.3	1.0	

Average Wait Time

Average Wait Time				
v/c		Detector Length		
		280 ft	350 ft	420 ft
1.1	West	17.7	17	19.9
0.9	West	17.5	17.5	17.1
0.7	West	20.3	13.8	16
0.5	West	13.3	13	17.5
Avg		17.2	15.3	17.6
Difference		1.9		2.3

