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NE MULTNOMAH STREET OPTICOM BUS SIGNAL PRIORITY PILOT STUDY

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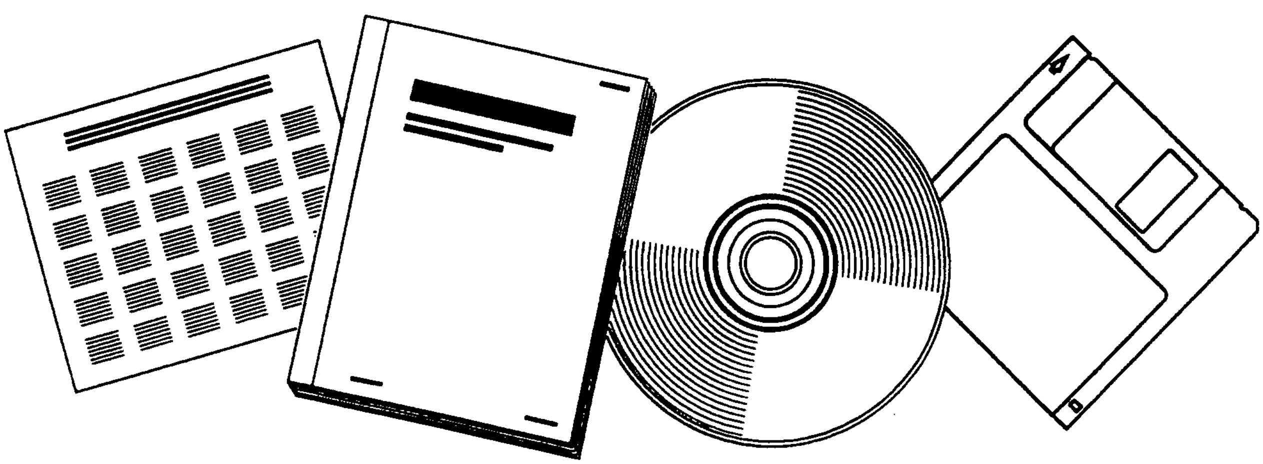

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NE Multnomah Street Opticom Bus Signal Priority Pilot Study

by

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16. Abstract

Bus Pre-emption systems will be installed at a number of "critical" intersections on the Powell Boulevard Arterial in Portland, Oregon. TRI-MET will be establishing a Fastlink express bus service along this arterial in the future. This project will continue the analysis that was begun with a previous project that examined two different bus signal pre-emption technologies at four intersections on a short stretch of Powell Boulevard. The first study examined the effects of bus pre-emption on cross streets and turning movements. The new study will examine the site specific characteristics of several critical intersections. The new study will also include a field validation of a bus signal pre-emption simulation that has been developed.

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Introduction

INTRODUCTION

1.1 TRI-MET BUS SIGNAL PRIORITY DEVELOPMENT PROGRAM

Since 1993, Tri-Met has had a bus signal priority development program. The program originated after an intergovernmental agreement between Tri-Met and the City of Portland was executed to evaluate the bus signal priority concept in the City, where most of Tri-Met's bus service is located. The focus of this program is to identify the most appropriate priority technology, and apply a selected technology at a number of locations in the Portland area in a widespread application of bus signal priority. The priority system must be compatible with the bus Automatic Vehicle Location (AVL) system being developed as part of an upgrade to the Tri-Met Bus Dispatch Center.

In 1994, Tri-Met, in conjunction with the City of Portland (in particular the Bureau of Traffic Management), sponsored a study to assess two potential bus signal priority technologies: 1) the TOTE system developed by McCain Traffic Supply and 2) the LoopComm system developed by Detector Systems. A two-mile section of Powell Blvd. in southeast Portland between Milwaukie and 52nd Avenues was chosen as the test corridor, with the TOTE system installed at two signalized intersections and the LoopComm system at another two signalized intersections. Besides an assessment of the equipment performance, traffic surveys were undertaken to assess the impact of bus signal priority on bus travel time, general vehicle delay and cross street bus delay, and overall intersection person delay.

A third bus signal priority technology, the Opticom system, by the 3M Company, was not tested in the 1994 study. This system, with recent enhancements by 3M, was the subject of a study in 1995 along NE Multnomah Street in the Lloyd District area of Portland. The Opticom system was tested in light of the fairly extensive application of Opticom signal equipment associated with fire vehicle signal preemption in Portland and elsewhere in the metro area.

1.2 PILOT PROJECT IDENTIFICATION/RATIONALE

The 1995 Opticom bus signal priority test focused on a location in the City of Portland due to the current agreement between the City and Tri-Met to evaluate the bus signal priority concept on city streets. The study area focused on the Lloyd District area due to the concentration of existing Opticom signal preemption equipment in Portland being located in this area, in particular along NE Multnomah Street, NE Broadway, and NE Weidler Street between 1st and 16th Avenues.

In the summer of 1994, a bus travel time and delay survey was conducted during the weekday midday and PM peak hours along Multnomah, Broadway and Weidler streets between 1st and 16th Avenues. This survey was used to assess existing bus operating characteristics along these corridors and to identify in which corridor bus operations could most benefit from signal priority. The results of this study are shown in Table B-1. Due to the one-way street nature and hence greater capacity of Broadway and Weidler, it was not that surprising that relatively low bus travel time and delay is being experienced on the one-way couplet, and that Multnomah, of the three streets, would probably be the best corridor for the Opticom study. Even the Multnomah corridor between 1st and 16th was not considered to be an ideal corridor for two reasons. First, the limited length of test area (only about 0.75 miles) experiences low travel times and thus random changes in delay can affect the data significantly. Secondly, Multnomah has lower traffic volumes than the 1994 test street (Powell Blvd.). There is not another longer and/or more congested corridor, however, within the City of Portland that has the level of Opticom signal preemption equipment as Multnomah. All nine of the signals on Multnomah between 1st and 16th have existing Opticom equipment. Thus, Multnomah between 1st and 16th was chosen as the test area for the study as shown in Figure 1.

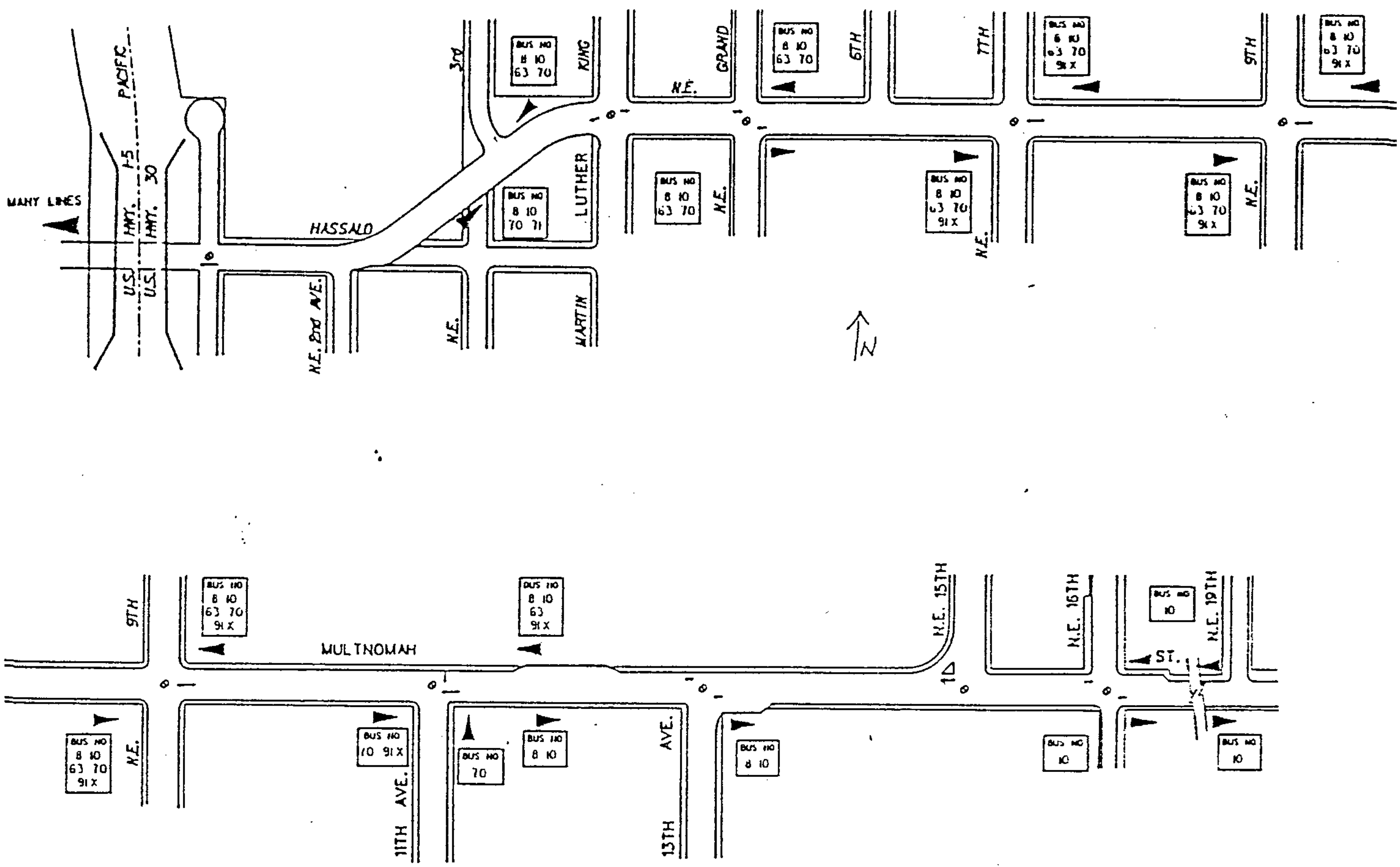
1.3 PROJECT ORGANIZATION

Similar to the Powell Blvd. test project in 1994, the 1995 Opticom test was a collaborative effort involving Tri-Met, the City of Portland and the Oregon State University (OSU) Transportation Research Institute. Kittelson & Associates, Inc. provided much of the study project management and technical analysis direction. Tri-Met leased 75 Opticom bus signal priority emitters from the 3M Company for a one-year period (July 1, 1994 through June 30, 1995) to conduct the test.

Tri-Met staff involvement in the project focused on installing the Opticom emitters on all 75 900 series buses in their fleet, and providing communications and training to operators on the proper use of the signal priority system during the test period. The City of Portland, led by the Bureau of Traffic Management supported by the Bureau of Maintenance, was responsible for making signal timing modifications to optimize bus operations during the priority equipment test period.

The OSU Transportation Research Institute lead the data tabulation and analysis associated with the traffic surveys performed during the test period. Gargan Research and Traffic Smithy, two traffic survey firms, were responsible for all field traffic surveys. Gargan Research measured bus travel times and delays, while Traffic Smithy obtained traffic counts and conducted vehicle queue measurements (which were translated into delay estimates).

Figure 1. NE Multnomah Opticom Bus Signal Priority Pilot Project



Section 2

Opticom System Description

OPTICOM SYSTEM DESCRIPTION

2.1 HARDWARE COMPONENTS

The primary hardware components include the Opticom emitter, which is mounted on the bus, and the intersection equipment, which includes the Opticom detector and discriminator.

The Opticom emitter for transit use is similar to the emitters used by emergency vehicles, except for two points:

- the transit emitter has a 6.25 HZ frequency versus a 14 HZ frequency for emergency vehicles; and
- the transit emitter has a visible light shield, allowing only the appropriate infra-red radiation to activate the Opticom detector.

The emitter also transmits a single-digit class code and a five-digit ID code, similar to the emergency vehicles.

The intersection equipment required for Opticom use are exactly the same devices as used for emergency vehicle preempt, an Opticom detector and an Opticom discriminator. For this project the City of Portland used 3M's new 500-Series Discriminators. These discriminators are programmed via a PC and are able to detect, verify, and log the ID codes transmitted by the 500-Series emitters. These discriminators also have a simplified method for selecting the desired detection range for each detector.

2.2 SOFTWARE CONFIGURATION

All nine signalized intersections included in this project have Type 170 controllers with Wapiti W4IKS firmware. The "bus preempt" module in this firmware was the method used to provide priority. The "bus preempt" module provides a "green extension / early green return" type of priority for the transit vehicle, which does not take the intersection out of its normal signal coordination cycle.

Table 1 summarizes the basic features of the Opticom system. As a comparison, this table also includes similar information for the TOTE and LoopComm detection systems, as applied during the Powell Boulevard Pilot Project.

TABLE 1

COMPARISON OF TOTE, LOOPCOMM, AND OPTICOM EQUIPMENT POWELL AND MULTNOMAH BUS SIGNAL PRIORITY STUDIES

	General Description	Vehicle Tag/Transmitter Information			Wayside Cost per Intersection*	Interface with traffic controller	Data Logging Capabilities
		Type	Equip. Cost/Bus	Mounting Method			
TOTE (Powell)	Radio frequency activated tags on the buses with special RF readers installed along the wayside. Includes a master unit for interfacing with traffic controller and logging reader data.	RF Tag 9.3"L x 2.4"W x 0.75"H	$40	-Tag is mounted on the outside front of the bus above the reader board. No power supply is required.	$29,000 (hardware) $2,000 (labor)	The master TOTE controller receives info from all readers. TOTE controller provides 6.25 Hz priority call to traffic controller.	The master should store data for up to 7,000 buses. Data includes time arrived, time departed, active phases at preempt call, and start / stop times of priority phase "green".
Loop Comm (Powell)	Special transmitter on bus that transmits ID code that is read through a standard vehicle loop imbedded in the pavement. A Model 630 detector reads the ID code and also acts as standard loop detector amplifier.	Transmitter 4.5" diameter x 0.75"H	$75	Transmitter is mounted under bus, 2' behind front bumper. Transmitter requires power source.	$15,000 (hardware) $3,500 (labor, inc. new loops)	Individual Model 630 detectors tied to City external logic package. Logic package provides 6.25 Hz priority call to traffic controller.	Each Model 630 unit should store approx. 9,000 bus observations. Data must be retrieved from each Model 630.
Opti-com (Mult-nomah)	Special optical emitter on bus that transmits ID code that is read through a standard Opticom detector used for emergency vehicle. A discriminator reads the ID code.	Optical Emitter (Non-visible light for transit use)	$1,600	Tag is mounted on the front of the bus inside the reader board. The power supply is located in reader board. The on/off switch located by operator's left knee.	$6,000 (hardware) $2,000 (labor, inc. wire to detector)	Discriminator plugs into standard slot in controller cabinet. Discriminator supplies low priority call directly into controller.	Each 500 Series Discriminator stores only 100 bus observations. Data must be periodically retrieved from each discriminator.

* approximate cost for a typical intersection with "green extension" on two approaches (based on prices of equipment purchased for this pilot)

2.3 FIELD INSTALLATION / TEST

One of the reasons for selecting NE Multnomah Street as the Opticom test site was the presence of existing Opticom field hardware at each intersection. Primary tasks to make the signalized intersections ready for bus priority control included:

- installation of new 500-Series Discriminators;
- determination of appropriate detector range factors;
- input of allowable emitter IDs; and
- determination and installation of the controllers' bus priority parameters

During testing of the controller firmware, City of Portland staff discovered a "bug" relating to the deactivation of the priority feature. Basically, the disable feature did not operate correctly. The firmware supplier was notified and had a correction sent to the City of Portland within a week.

Section 3

Signal Operations Plan

SIGNAL OPERATIONS PLAN

3.1 BUS PRIORITY LOCATIONS

This study included the nine traffic signals on NE Multnomah Street from NE 1st through NE 16th Avenues as shown earlier in Figure 1. The total travel distance is approximately 4,000 feet.

3.2 SIGNAL PRIORITY OPERATION

All nine signalized intersections included in this study have Type 170 controllers with Wapiti W4IKS firmware. The "bus preempt" module in this firmware was the method used to provide bus priority for seven of the nine signalized intersections. The "bus preempt" module provides a "green extension / early green return" type of priority for the transit vehicle, which does not take the intersection out of its normal signal coordination cycle. The other two intersections, NE Multnomah at Grand and at MLK, did not receive any priority since the Multnomah movement is not the coordinated movement and the W4IKS firmware only allows priority for the coordinated movement.

All intersection controllers must have their Opticom detector reception distances set to only detect buses that have cleared their previous stop. These zones were set in the field via the test emitter used by the City of Portland Bureau of Maintenance staff.

The descriptions of each intersection operation under the bus signal priority tests are listed below.

1st - Since this intersection operates in an uncoordinated mode and operates in a simple three-phase operation, a bus requesting priority will receive quick response. If the controller is servicing 1st Avenue, it will attempt to move immediately to the Multnomah Street green providing no pedestrian phases are in operation. If the controller is green for Multnomah Street, it should remain green until the bus clears the intersection.

MLK/ - Grand: No priority was used for these intersections. One option considered was using the Opticom input to put a constant vehicle call for the east / westbound movement via the Wapiti Command Box. However, due to the existing timing parameters, this would provide only a minor benefit for buses, and therefore, was not implemented.

7th/9th - These intersections operate on coordinated 70-second cycle lengths and have near side bus stops in both directions. If the bus operator needed to load or discharge passengers, the emitter had to be de-energized, then energized again within five to 10 seconds of being ready to depart the intersection. If the operator saw that no stop was required, then the emitter would be energized as soon as practicable. The green extension allowed up to 20 seconds additional Multnomah green. The early green return was only able to return six or seven seconds earlier. The westbound near side stops at both intersections were relocated 50' from the stop bar due to the Opticom detector being located on the near side signal span.

11th - This intersection operates on a coordinated 70-second cycle length. East bound Multnomah has a far side bus stop. Westbound Multnomah has a near side bus pullout approximately 150' from the stop bar. The green extension allowed up to 20 seconds additional Multnomah green. The early green return was only able to return to the Multnomah green up to six seconds earlier than normal.

13th - This intersection operates in an uncoordinated mode and operates in a standard eight-phase operation. As with 1st Avenue, a bus requesting priority received quick response. However, the added left turn phases did delay the early green return option.

15th - This intersection operates on a coordinated 70-second cycle length. No bus stops are located nearby. The green extension allowed up to 25 seconds additional Multnomah green. The early green return was only able to return six seconds earlier.

16th - This intersection operates on a coordinated 70-second cycle length. The eastbound near side stop was temporarily relocated to the far side of the intersection. Due to the added left turn phase, the green extension would only allow up to 15 seconds additional Multnomah green. The early green return was be able to return 15 seconds earlier.

3.3 BUS STOP MODIFICATIONS

The use of the "green extension / early green return" function usually requires that the bus stop be on the far side of the signalized intersection. However, this study had five locations where near side stops remained in place (eastbound and westbound stops at 7th and 9th Avenues; and westbound Grand Avenue). Two other near side locations (eastbound Grand and eastbound 16th Avenues) were temporarily relocated to far side stops during the test period. At the five near side locations, the bus operator instructions were clear that the emitter must first be disengaged when loading or discharging passengers at these stops.

Section 4

Equipment Performance Evaluation

EQUIPMENT PERFORMANCE EVALUATION

4.1 EMITTERS

The emitter installation was fairly straight forward, although Tri-Met Bus Maintenance staff did need to try various options for optimum emitter placement. The emitter was eventually installed inside the reader board on the 900-series GMC buses.

The operators' on/off switch was located on the lower left of the front dashboard of the bus, near the operators' left knee. An on/off indicator was placed on the dashboard.

No emitters failed during the testing period. One emitter was found to have a loose ground wire, which was easily repaired. Another emitter was found to have an incorrectly programmed ID code, which was an installation error.

Bus maintenance staff found the emitter to operate satisfactorily with reasonable installation requirements. Maintenance staff did request that if Opticom use is continued, then maintenance staff should have an Opticom detector and discriminator installed in the bus maintenance yard to better facilitate emitter testing and ID code verification.

4.2 CONTROLLER EQUIPMENT

Since this was the City of Portland's staff first use of the Series 500 Opticom Discriminators, some familiarization was required.

Issues with the discriminators included:

- The discriminators only logs allowable ID codes. The unit should also log non-allowable codes so that the agency can detect attempts of improper activation of the Opticom.
- The discriminators real time clock has poor accuracy. The discriminators' clocks could drift by several seconds each day, hindering the use of the discriminator log data to determine bus travel time.
- The PC software was less than fully user-friendly. The PC has to be connected to an actual discriminator before being able to even check any settings in the PC database.

These issues have been communicated to 3M.

Table 2 below summarizes the equipment evaluation results for Opticom as compared with earlier results for the TOTE and LoopComm equipment in the Powell Blvd. study.

TABLE 2
EQUIPMENT PERFORMANCE EVALUATION
POWELL & MULTNOMAH BUS SIGNAL PRIORITY STUDIES

	Detection Location Issues	Ease of Installation	Bus Reading Accuracy	Equipment/ System Reliability	Data Logging Issues	User Interface
TOTE (Powell)	Generally limited to existing pole locations, unless willing to install new poles. May constrain getting desired detection point.	Used existing poles for antennas and readers. Required power and comm. cable from controller to readers. Requires fine tuning of antenna orientation.	Generally 96% to 99%.	Overall poor performance on this pilot project. The equipment was still under development during our testing. Various errors occurred with all components.	The TOTE master did not have specified capacity. Often staff were unable to retrieve data (Some records were lost).	Generally easy to use. Unable to view the existing settings in an operating master.
Loop Comm (Powell)	Must make sure that the loop is in bus travel lane (may be problem where bus tends to use more than one specific lane). No easy way to "fine tune" loop location.	Generally will require installation of new vehicle loops at proper locations. Requires power and comm. cable for remote amplifier. Overall installation like standard vehicle detector.	Generally 97% to 99%, although had 90% to 95% with larger loops (i.e. 6x17).	The Model 630 detectors worked reliably during the test period.	The Model 630s appeared to properly record the bus data. Since there is no central master, the data had to be retrieved from each individual 630 (i.e. 4 different places at 39th).	Intuitive interface that was easily mastered by staff. Issue of needing to verify PC time before connecting to the 630.
Opticom (Multnomah)	Range is set within the discriminator. Value is easily determined and modified. However, may change as detector gets dirty.	If intersection already has Opticom, then installation is simple, requiring only field setup of discriminator database.	Unsure on direct reliability. Only 50% of buses logged at all points, although believed to be largely due to improper operation of emitter by bus operators.	The emitters and discriminators worked reliably during the test period.	The discriminator logs only 100 entries, requiring daily retrieval of data.	PC requires connection to actual discriminator to read existing PC database (inconvenient).

One of the most advantageous aspects of the Opticom system is that any intersection with Opticom already installed for emergency vehicle priority can be potentially used for transit priority with little additional cost. Related to this advantage is the fact that by using Opticom, the maintaining road agency does not have to maintain any additional intersection equipment in order to provide transit priority.

Section 5

Traffic Surveys

TRAFFIC SURVEYS

5.1 SCOPE AND METHODOLOGY

The type of traffic surveys conducted for the Multnomah bus signal priority study, and the methodologies for such surveys, were similar to those undertaken for the Powell Blvd. study in 1994. The focus of the data collection effort was to identify the impact of signal priority on:

1. The reduction in bus travel time in the study corridor;

2. the effect on delay to other vehicles on Multnomah Street and to side street traffic; and

3. the change in total person delay at the intersections studied.

A two week "before" and "after" data collection effort was undertaken. For the first week, traffic and vehicle occupancy counts, vehicle queue measurements, and bus travel time and delay surveys were undertaken without the bus signal priority turned on. The second week, the priority equipment became operational with the same traffic data collected to identify the impact of the priority on traffic conditions. The intersections surveyed were all cross streets of Multnomah Street and included 9th, 11th, 13th, and 16th Avenues. The traffic surveys each week were conducted on Tuesday, Wednesday, and Thursday (March 14-16, 1995 for the "before" survey, and March 21-23 for the "after" survey) during the midday peak period (11 AM to 1 PM) and PM peak period (4-6 PM). Over 25 traffic survey personnel were involved in the data collection effort.

Bus Travel Time and Delay Study

Bus travel time and delay data for the #10 NE 33rd Avenue line on Multnomah Street between 1st and 16th Avenues was collected using survey personnel riding each bus for each peak period on the "before" and "after" survey days. The travel time and delay survey identified the travel time between the ends of the corridors and an intermediate scheduled "time point" (at 11th Ave, as well as all of the bus delays in the study corridor during each bus run. Delays were associated with traffic signals, dwell times at bus stops, pedestrians crossing the street, and other delay factors. The number of persons on the bus through the 9th, 11th, 13th, and 16th Avenue intersections was also recorded. A total of 58 bus runs were surveyed during the midday and PM peak periods.

In addition to the manual #10 bus travel time and delay runs for the six day "before" and "after" period, a continuous logging of bus arrival times at each intersection with signal priority equipment was conducted by the signal controllers at the 1st, 11th and 16th Avenue intersections. The controller data was logged for the entire weeks of March 14 and March 21.

Signal Controller Splits Data

To identify the extent to which added green time was given to the #10 line buses when the signal priority call was given, an analysis of the change in green time allocation to Multnomah Street was measured. This analysis focused on a single day measurement (Wednesday, March 15) at the 11th Avenue intersection.

Traffic and Vehicle Occupancy Counts

At four of the intersections along Multnomah - 9th, 11th, 13th, and 16th Avenues, peak period turning movement counts were taken during the "before" and "after" survey. This data was used to identify any differences in traffic volume during the two survey periods, as well as to provide control totals in identifying the number of stopped vs. non-stopped vehicles on each intersection approach.

To translate vehicle delay into person delay, sample vehicle occupancy counts were conducted for a 15-minute period along Multnomah Street and 9th Avenue during the midday and PM peak survey periods.

Vehicle Delay Study

For each intersection approach at the four locations surveyed, the number of queued vehicles were measured every 15 seconds during the peak periods surveyed. Every 15 minutes during each period, the number of non-stopped vehicles passing through the intersection on each approach after the queue dissipated were also identified. This information, with the total traffic counts on each approach, lead to a calculation of stopped delay on each approach. At the 16th Avenue intersection, the eastbound left turn queue and number of non-stopped vehicles were segregated from the through/right vehicle queue and non-stopped vehicle measurements.

Other Bus Delay Surveys

For the northbound 11th Avenue and southbound 16th Avenue approaches, the bus delay on these cross street approaches (#70 route on 11th and #8 route on 16th) were estimated during the midday and PM peak periods each of the three days during the "before" and "after" survey. The bus delay for the eastbound #8 route making the left turn in the exclusive left turn lane at 16th Avenue was also measured.

Also for the #8, #63, #70 and #91X bus lines along Multnomah Street between 9th and 16th Avenues, an observer estimated the number of passengers in each bus passing by a particular location. This bus passenger occupancy along with the general traffic delay information was used to identify the change in bus passenger delay associated with non-#10 bus line segments operating along Multnomah with the #10 line signal priority test.

5.2 SURVEY RESULTS

Problems with Actual Surveys

The major problem which surfaced during the surveys was during the "after" survey period, where several buses were not logged in at the signal controllers with a bus signal priority call. As shown on Table 3, only 49% of the buses operating during the one-week "after" period (393 of the 798) were actually logged in at the controllers at all three time points at the 1st, 11th, and 16th Avenue intersections.

There appear to be three reasons why buses were not being logged:

1. Certain bus operators did not heed the instructions for the test and either did not have the bus signal priority emitter turned on during their particular runs through the test corridor, or were improperly using the unit.

2. Certain emitters might not have been functioning properly, not issuing a bus signal priority call. A check of emitter operation at the bus garage after the test revealed that only two emitters had problems - one with a loose wire and one with a wrong ID code.

3. Though not originally intended, ten bus runs on the #10 line during the "after" survey period were operating with other than the 900-series buses, thus not having the Opticom equipment and being unable to issue a signal priority call.

A second problem which plagued the study was the overall increase in traffic volumes for three of the four intersections surveyed during the peak hours of the "after" survey period. The intersections at 9th, 11th, and 13th Avenues had increases in the total entering traffic volume of at least 15% for the entire intersection (see Table 4). The other intersection, 16th Ave., had an increase during the PM period of 7.5% while the midday period was basically unchanged. This major difference in traffic volume between the "before" and "after" periods made comparisons in the travel time and delay data between the "before" and "after" periods difficult.

The final problem the manual survey faced was the relatively small sample size. Of the 25 trips that were surveyed during the midday and pm periods on March 15th, only eleven of those altered the signal timing at 11th Avenue (due either to the operator not using the emitter, or an existing green light). These eleven trips have a large degree of variability, and it is difficult to

TABLE 3
BUS LOGIN DATA SUMMARY
Login successes by direction

Eastbound

Date	Scheduled Buses	Number of missed bus loggings				
		0	**1 (first)**	**1 (other)**	**2**	**3**
03/07/95	42	17	8	4	4	9
03/08/95	42	24	11	0	1	6
03/09/95	42	25	4	0	3	10
03/10/95	42	18	8	0	1	15
03/11/95	10	3	2	0	1	4
03/13/95	42	21	14	1	2	4
03/14/95	42	20	10	1	3	8
03/15/95	42	20	8	2	2	10
03/16/95	42	15	9	1	3	14
03/17/95	42	21	5	0	2	14
03/18/95	10	1	3	0	0	6
TOTAL	398	185	82	9	22	100
PERCENT OF TOTAL		**46.5%**	**20.6%**	**2.3%**	**5.5%**	**25.1%**

Westbound

Date	Scheduled Buses	Number of missed bus loggings				
		0	**1 (first)**	**1 (other)**	**2**	**3**
03/07/95	42	23	3	3	1	12
03/08/95	42	29	1	3	1	8
03/09/95	42	24	2	2	2	12
03/10/95	42	20	0	4	4	14
03/11/95	11	6	1	0	0	4
03/13/95	42	28	3	1	0	10
03/14/95	42	24	4	3	1	10
03/15/95	42	18	6	9	2	7
03/16/95	42	14	2	10	2	14
03/17/95	42	20	3	2	4	13
03/18/95	11	2	0	3	1	5
TOTAL	400	208	25	40	18	109
PERCENT OF TOTAL		**52.0%**	**6.3%**	**10.0%**	**4.5%**	**27.3%**

TABLE 4
CHANGE IN TRAFFIC VOLUMES
(From "Before" to "After" Periods)

Intersection	*Midday Study Period*	*PM Peak Study Period*
9th	17.1%	15.7%
11th	30.4%	19.6%
13th	24.9%	20.5%
16th	-0.1%	7.5%

identify from this limited sample whether the Opticom signal had a strong effect on the overall travel time for the manually surveyed trips.

Bus Travel Time and Delay

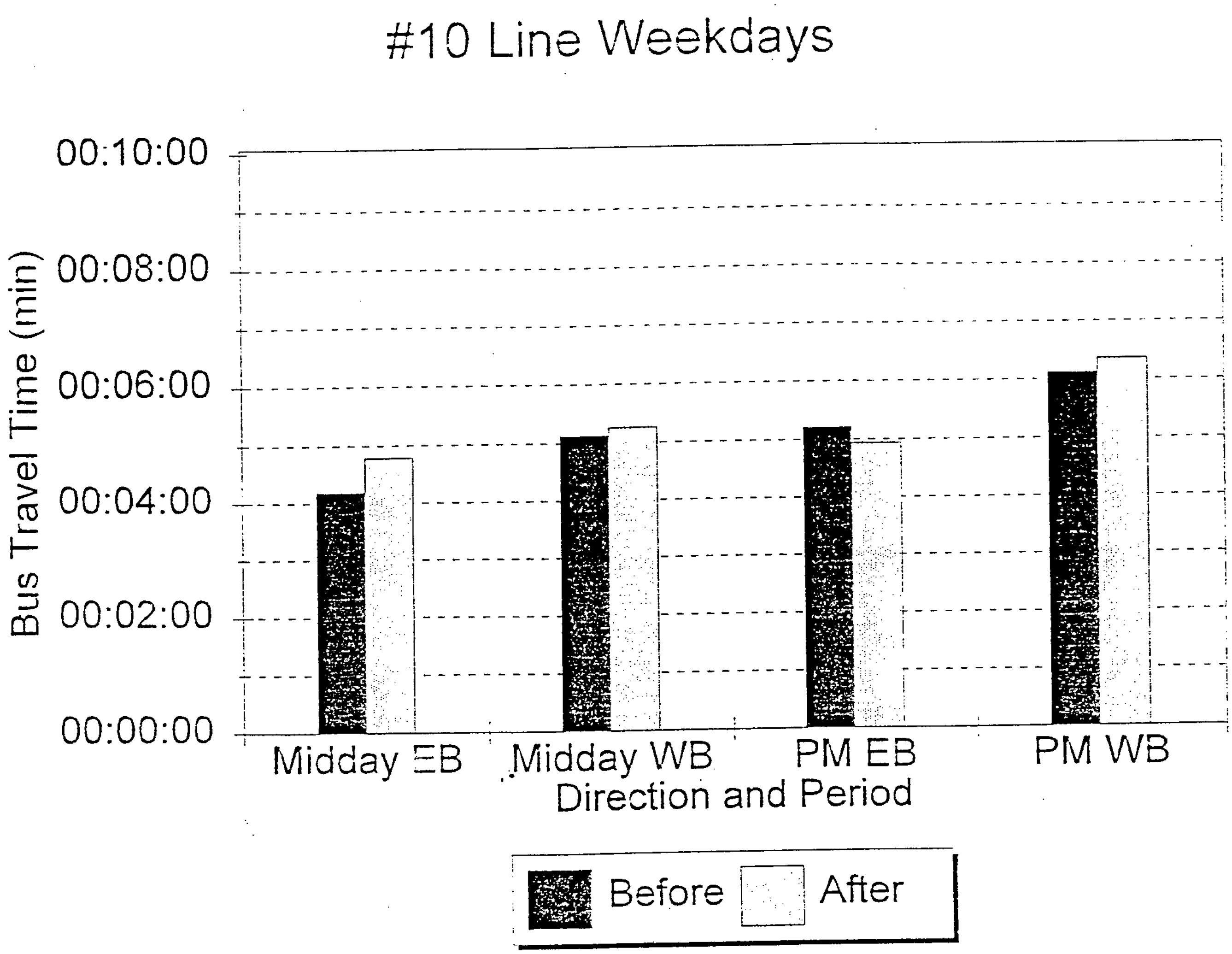
Table 5 summarizes the results of the #10 bus login data as it relates to the change in bus travel time with the signal priority during the weekday.

TABLE 5
BUS TRAVEL TIME
Bus Login Data - (Before and After Periods)

Direction	*Time Period*	*Travel Time (Before)*	*Travel Time (After)*	*Percentage Change*
Eastbound	Midday	4:16	4:08	-4.7%
Eastbound	PM Peak	4:47	4:47	0%
Westbound	Midday	4:52	4:36	-5.6%
Westbound	PM Peak	6:18	5:52	-7.1%

The login data indicated reduction in bus travel time with the signal priority for three of the four bus travel direction/ time period scenarios analyzed, with travel time savings ranging from 4.7 to 7.1%. This data comparison is tempered by the fact that only 49% of the buses were logging during both the "before" and "after" survey periods. The analysis of the manual "before" and "after" bus travel time survey data (with a higher bus sample) revealed a different comparison. The manual survey (Figure 2) showed a reduction in bus travel time only in the peak direction (eastbound) during the PM peak period, which was a similar result in the Powell Blvd. test in 1994.

FIGURE 2
BUS TRAVEL TIME
MANUAL SURVEY SUMMARY



Extent of Bus Signal Priority (Analysis of Controller Splits Data)

Table 6 summarizes the analysis of the change in green time allocation to Multnomah at 11th Avenue with the bus signal priority for March 15. Throughout the entire 18 hour period, which contained 826 signal cycles, only about 7% (35) of the cycles were altered by an Opticom bus signal priority call. The change in green time throughout this day including only extended periods of green totaled 185 seconds. This resulted in an average green time extension of 5.29 seconds for Multnomah. Twenty of the 35 extensions in the green time were followed by a cycle which featured a reduction of the green time that averaged 5.52 seconds.

Vehicle Queues

Figures C-1 and C-2 in Appendix C summarize the average vehicle queues for Multnomah Street traffic and side street traffic during the two weekday survey periods.

There was little difference in overall vehicle queuing during the midday and PM peak period, on both Multnomah and the side streets. This is because of the fairly high peaking of traffic during the noon hour, and Multnomah PM peak period traffic not being as high as this is not a major commuter route. Along Multnomah, vehicle queues were higher with the bus signal priority during both the midday and PM peak periods. On the side streets to Multnomah at 9th, 11th, 13th and 16th Avenues, there was an inconsistent pattern in the change in vehicle queuing. During the midday peak period, five of the eight side street approaches exhibited an increase in vehicle queuing. In the PM peak period, only three of the eight approaches exhibited increased queuing.

Vehicle Delay

Figures C-3 through C-6 in Appendix C summarize the average weekday general traffic stopped delay data for Multnomah Street traffic and side street traffic during the two weekday survey periods. In general, there was a direct correlation between vehicle queuing and delay, as would be expected. A reduction in vehicle delay for Multnomah through traffic was only achieved at 16th Avenue, in both directions during both the midday and PM peak periods. The eastbound left turn delay at this intersection increased during the midday peak period (as might be expected as green time was taken from this movement for the bus signal priority), but during the PM peak period a reduction in left turn delay was experienced (contrary to the midday operation).

On the side streets, there was no consistent pattern on the change in vehicle delay with the bus signal priority. At 9th and 16th Avenues, there was a reduction in vehicle delay with the signal priority, while an increase in vehicle delay was experienced on the 11th and 13th Avenue approaches.

TABLE 6
SIGNAL CONTROLLER GREEN TIME ADJUSTMENT DUE TO PRIORITY

Int Number: 2133 Location: NE 11th & Multnomah

Cycle	Time	Actual Green Time		Additional Mult Green Time
		Mult	11th	
87	6:40:15	41	21	6
111	7:08:16	36	27	1
112	7:09:26	34	27	-1
114	7:11:46	39	27	4
115	7:12:56	31	27	-4
125	7:24:36	44	27	9
126	7:25:47	25	26	-10
153	7:57:16	41	27	6
154	7:58:26	29	27	-6
171	8:18:16	41	21	6
188	8:38:07	36	27	1
189	8:39:16	34	27	-1
213	9:07:17	40	27	5
214	9:08:26	30	27	-5
235	9:32:56	40	22	5
258	9:59:47	39	27	4
259	0:00:56	31	27	-4
265	0:07:57	41	21	6
289	0:35:56	44	27	9
290	0:37:07	26	27	-9
320	1:12:06	35	28	0
339	1:34:16	41	21	6
366	2:05:46	40	22	5
386	2:29:06	48	27	13
387	2:30:16	22	27	-13
443	3:35:36	41	21	6
464	4:00:06	40	22	5
488	4:28:07	37	27	2
489	4:29:16	33	27	-2
511	4:54:56	38	27	3
512	4:56:06	32	27	-3
528	5:14:47	36	27	1
534	5:21:46	44	27	9
535	5:22:56	26	27	-9
537	5:25:17	41	22	6
546	5:35:46	42	27	7
547	5:36:57	28	27	-7
565	5:57:56	41	27	6
566	5:59:06	29	27	-6
588	6:24:47	40	21	5
595	6:32:56	40	22	5
609	6:49:16	41	21	6
643	7:28:56	40	21	5
645	7:31:16	38	27	3
646	7:32:26	32	27	-3
674	8:05:06	43	27	8
675	8:06:16	27	27	-8
685	8:17:56	36	27	1
686	8:19:06	34	27	-1
699	8:34:16	43	27	8
700	8:35:26	28	27	-7
704	8:40:07	39	27	4
705	8:41:16	32	27	-3
718	8:56:26	38	27	3
719	8:57:36	32	27	-3
803	0:35:36	41	21	6
825	1:01:16	35	26	0
826	1:02:26	35	26	0

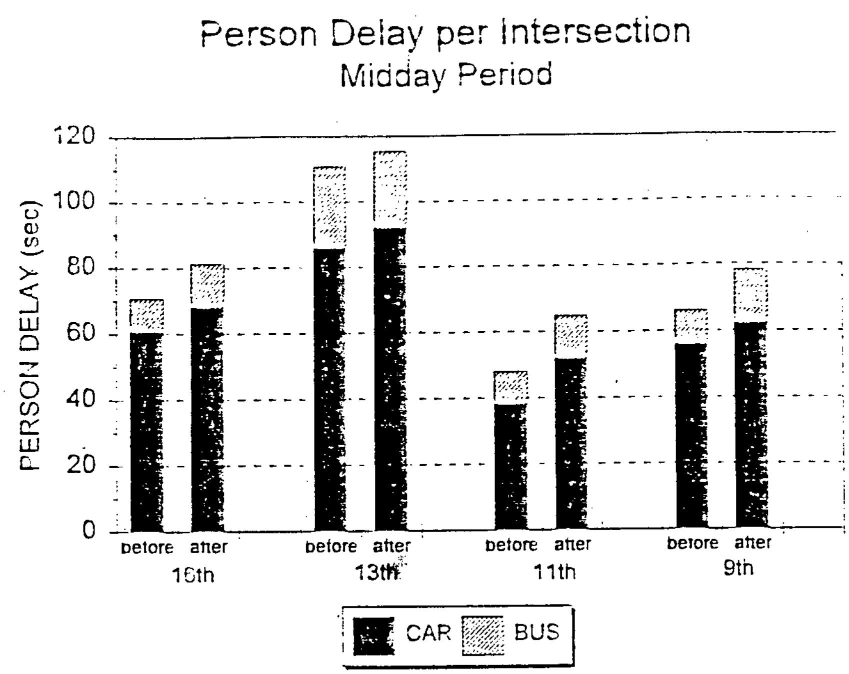
Person Delay

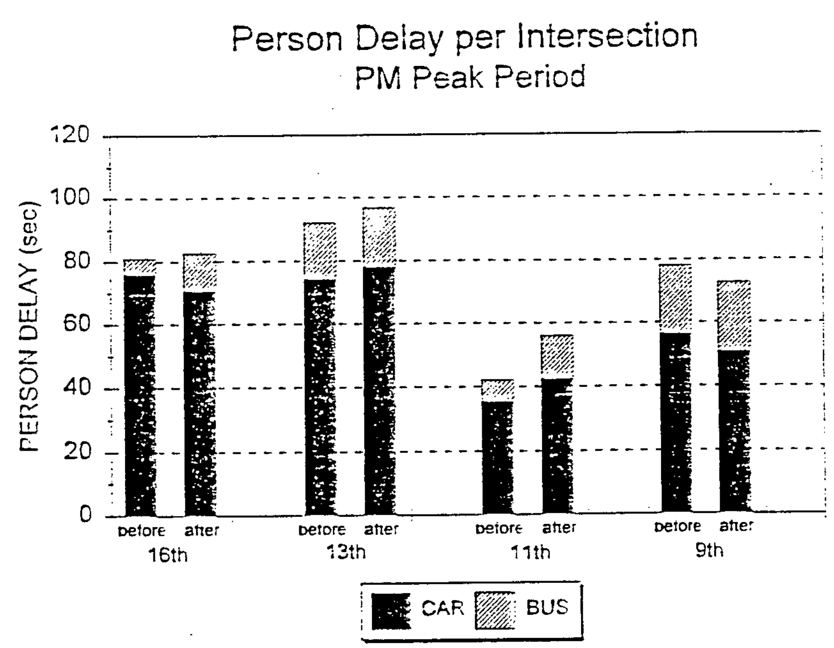
Figure 3 translates the total bus and auto vehicle at each intersection into person delay with and without bus signal priority, for the weekday midday and PM peak periods. The bus person delay presented represents the average person delay on all of the bus routes entering each intersection. This figure reveals intersection person delay only being reduced at the 9th Avenue intersection, during the PM peak period. The other intersection conditions exhibited an increase in person delay.

Statistical Validity

The statistical analysis is centered on testing the hypothesis that there is a decrease in bus travel time in the study corridor. Using the basic statistical techniques of hypothesis testing at the 5% level a one sided test would be performed. The data from this presents a number of problems for statistical analysis, and these problems are discussed extensively in the report. The main issues center around the small sample size due to the login failures on the part of the participating operators. The bus travel time of the login data indicated a 6% decrease in travel time for the westbound direction and a 3% decrease in travel time in the eastbound direction, but it would be very difficult to say whether this was statistically significant given that only 52% of the operators logged in the westbound direction and 46% in the eastbound direction.

FIGURE 3
INTERSECTION PERSON DELAY





Section 6

Operator Survey

OPERATOR SURVEY

As an added feature of the Multnomah Street Bus Signal Priority Study, bus operators participating in the test were surveyed to obtain their insight on the performance of the Opticom equipment, and their particular driving habits during the test period. The intent of the survey was to assess if operator behavior during the test might have influenced the traffic survey results and overall bus travel time savings.

6.1 OPERATOR PROFILE

Twenty five bus operators were assigned to the #10 line during the "before" and "after" survey period. In general, the same operator ran a particular bus run through the test area throughout the survey period, although some "extra board" operators did fill in occasionally. By the time of the operator survey in April, only 6 operators were still assigned to this line. The other 19 operators moved to new lines.

6.2 OPERATOR SURVEY RESULTS

A two-part operator survey was conducted approximately two weeks after the end of the test period. First, for five of the six operators still assigned to the #10 line, a personal interview was held at the Powell bus garage to obtain their thoughts on the signal priority test, using the operator survey form in Appendix D. Second, the other 19 bus operators no longer assigned to the line were sent a different survey form, with responses requested in writing, and 12 of these operators responded to the survey.

The personal interview questions were intended to better understand the human factor issues involved, and get feedback from the drivers about their overall experience with the equipment. The interviews returned mixed results. There were two drivers that seemed positive about the study and had few problems with the equipment. The remaining operators seemed less impressed with the survey and had some interesting responses. The most interesting response came from question #3 of the interview that asked the drivers about the decision making process of approaching a near side stop. Four of the five drivers admitted they sometimes forgot to turn it on and off during their progress through the corridor. One driver even admitted to turning it on and leaving it on for the entire corridor. The interview also posed questions about the setup and operation of the toggle switch. The written questionnaire responses were similar to the responses from the interview. Most of the operators found the switch easy to use and answered that they had trouble remembering to use the switch for various reasons, including the location of the switch. Question #5 of the written survey is of some interest. About half of the operators attributed the problems with the system not registering at all three check points to operator error.

Section 7

Conclusions

CONCLUSIONS

7.1 EQUIPMENT PERFORMANCE EVALUATION

The overall equipment performance for this study was somewhat inconclusive. The bus login data indicated that only about 50% of the buses were logged at all three check points on each run. The primary reason for this low level of recording is not believed to be equipment performance, but rather bus operator error in properly activating the emitter. Also a few non 900-series buses without the Opticom emitters were used as a substitute for out-of-service 900-series buses.

Only one emitter was found to be truly defective. This unit was identified prior to installation and returned to the manufacturer for repair. After the study, Tri-Met maintenance staff discovered one emitter had a loose ground wire, which is an installation issue and not an equipment problem. Another emitter was found to have an incorrect bus identification code. These latter issues pointed to the need for maintenance staff to have an operating Opticom discriminator at the bus maintenance facility to allow easy verification of emitter operation.

Regarding the intersection equipment, no problems were encountered. Staff did require an initial familiarization period to understand the equipment operation. Three issues noted during the test include:

- The laptop computer software used to setup the discriminators was not user friendly. The laptop has to be connected to an actual discriminator in order to view the database.
- The discriminators were only able to log 100 events, which was barely more than one-day's worth of data.
- The discriminators only emit with valid ID codes. The discriminators logging feature would be more useful if it also logged non-valid ID codes.

3M's Opticom product line has been in service for several years and has an excellent repair history. The new 500-series equipment is anticipated to have a similar repair history. Overall, the equipment itself performed very well, but the operation of the equipment was confusing to the drivers and therefore not adequately tested.

7.2 OPERATOR PERFORMANCE EVALUATION

As discussed above, the reaction from the operators was not entirely consistent. It seemed through a survey of the operators during the testing period that there was a serious human factors issue among the drivers. The operators were not consistent in the activation of the system and this issue translated into a large problem in the login data collected and the analysis.

There are several factors that caused the operators to forget about and fail to use the Opticom switch. This corridor places a great demand on a bus operator without a signal priority system in place. The on-street parking, moderate traffic volumes, and number of pedestrians (especially in the Lloyd District) are all factors which place a high demand on the operator throughout this corridor. The extremely short distance between side streets along Multnomah Avenue also contribute to the lack of login data tabulated. It also seemed that operators did not activate the system when they had a green light ahead of them, due to the number of missed login times at the different stops. Possibly the operators thought that the only time they needed to trigger the switch was if they needed to, even though they were trained otherwise.

In the analysis of the login data, some trends were found that illustrate the issues discussed above. One example, in particular, are buses scheduled to move through the corridor at 3 P.M. experienced a higher percent of missed login times. This particular time is when nearby Benson High School is dismissed for the day. The increase in passenger loading during that period placed added demands on the operator, which diverted some of their attention from the Opticom system. In addition, the operator may have forgotten to use the switch if the light was already green and passengers had already boarded the bus.

The eastbound login data indicated that bus operators had trouble remembering to activate the system at the start point for the study (1st Ave). Signs were posted to remind the operator on both ends of the corridor. Even with this signage, the start point for the eastbound route was missed 20% of the time during the study (Table 3). The percentages are scattered throughout the study and indicate no particular failure of the sensing device on any one day. The operators could have missed the signs due to a sight distance problem at the start of the eastbound route. The I-5 overpass might have blocked the driver's view of the signage indicating the corridor's beginning point. The operator is also faced with a large number of passengers boarding at the Coliseum Transit Center. This burden could explain some of the missed login times as well.

The overall success rate for bus login at the start, end, and checkpoints along the study corridor was disappointingly around 50% for both directions. Initially, in preparing for this pilot project, it was hoped that a higher percentage of buses would be logged and matched for "before" and "after" comparison. However, after investigating and realizing the demands on the operators in this corridor, it can be understood how the operator difficulties led to this low login rate.

These problems with operators and equipment could stem mostly from the corridor itself. This particular corridor poses several problems for the operator to face. The idea of giving the operators time to practice during the before study is a great idea, however it appears that the operators found difficulty in remembering to use the system for several reasons. A possible solution to ease the operator burden is to have the emitter energized all of the time which would only require the operator to hold a spring-loaded "off" toggle switch when needed at a near side stop.

7.3 TRAFFIC IMPACTS OF SIGNAL PRIORITY

As noted before in section 5.2, the traffic surveys provided somewhat disappointing results. An explanation for some of the increase in bus travel time for certain time periods with the signal priority was due to the overall increase in traffic volumes during the after period as shown in Table 4. The increase of at least 15% in total traffic volume during the peak hours existed at every intersection in both directions except at 16th Avenue.

The overall change in the signal timing was small. The cycle length was 70 seconds at the 11th & Multnomah intersection and an average change of 5.3 seconds makes minimal difference in the operation of the intersection for the entire day. For March 15th, the signal was extended on 61% of the runs that activated the equipment.

7.4 NEXT STEPS

The results of this study are very site specific. There are a large number of components that are required in order to develop a bus travel time savings in an Opticom corridor. This system requires considerable preparation and a strong basic understanding of the equipment by the bus operator. It would seem that the operators during this study failed to meet the expectations the study had laid out. This failure changed the data and results considerably.

The possibilities for bus travel time savings along this corridor are limited, but with the overall increase in total traffic volume during the study, some bus travel time savings were realized. The question of whether it was statistically valid clouds this analysis. The control variables and conditions changed considerably during the before and after studies, however under before and after conditions that contain equal volumes, the results may be considerably different. The travel time of the buses decreased slightly for the after periods in both directions as shown in Table 5. Overall there seems to be a positive benefit from the use of the Opticom system from this data.

There is potential for bus travel time savings with signal priority, and has been proven to some extent in the Powell Boulevard and Multnomah Street studies. The environment for the Opticom equipment along Multnomah placed another demand on the operators and evidently it was too much for them to handle. This study has clearly shown that any signal priority system must be transparent to the vehicle operator. Transit vehicle operators have increasingly complex jobs and it may be too much to expect a transit vehicle operator to consistently activate an additional piece of equipment. Thus, future studies may be steered towards equipment or operating conditions (i.e. only far side stops) that do not require operator intervention.

Future studies should also be focused more on longer, more congested routes which are more operator friendly to this system. Longer routes with far side stops and high signal delay would probably show a greater benefit with the use of signal priority technology. One route which may be investigated is the #4 Division which travels out to Gresham, since Gresham has a number of Opticom signals already installed and the signals are fairly far apart. The #4 also is a good route because of its length, since bus priority systems have tested well for other transit agencies on routes of considerable length. Bus priority is capable of significant savings if allowed to operate in the right corridor. Whether Opticom is the best technology is difficult to conclude from this study.

Appendix A

Summary List of Findings

APPENDIX A
SUMMARY LIST OF FINDINGS

This Appendix includes a summary list of findings from this study.

Equipment Performance

- Currently unsure about the overall performance of the equipment. It is assumed that most of the equipment was installed correctly. It is difficult to say whether or not all of the emitters were working based on the poor login data.

Operator Survey

- The instructions were clear to all of the drivers surveyed.
- The position of the switch was found to be acceptable to the drivers surveyed to the most part, few had suggestions for changing the position of the switch.
- The operators had a difficult time remembering to activate the system, particularly at the starting point (1st Avenue) of the eastbound trip.
- The overall use of the Opticom system by the drivers was poor. The drivers were instructed to activate the switch and some of the driver's did not follow these directions. Some of the drivers answered that fellow drivers would not follow the directions.
- Several drivers commented that having on-board supervisors with them for the study, reminding them to use the Opticom would have helped them remember.

Impact on Traffic

- The total traffic volume went up at 9th, 11th, & 13th by at least 15% in each period.
- There were no strong relationships to be presented in the traffic counts.
- The side street traffic delay was decreased in several cases for the midday and peak period studies.

Login Data

- The bus travel time of the login data experienced some time savings:

  Westbound weekday: 6% decrease in travel time

  Eastbound weekday: 3% decrease in travel time

  even with the increase in total traffic volume over the study.
- The poor login percentages (46.5% EB, 52% WB) could be improved upon with improved signage and greater emphasis in training the drivers before the study occurs.
- A corridor which is longer and has more space in between the signals would allow the driver time to think more about activating the system.

Manual Bus Surveys

- The overall results from the manual bus surveys are poor. The sample sizes for the midday period in particular are very small (approximately 12 buses) and a large degree of variability exists in that data. The PM peak period data shows travel time savings of 5.4% in the eastbound direction and an increase of 3.8% westbound. This is only about fifteen seconds either way of the total travel time, savings is difficult to achieve on such a short corridor!

Improvements

- Select a corridor with potential (#4 Division Route) that is long enough to show significant savings, and easy enough for the operators to use the equipment on.
- Provide some sort of incentive for this "elite" group of bus drivers based on incentive, set goals to motivate the drivers, etc.
- Eliminate use of Extra Board buses; for backup set up extra bus with Opticom equipment.
- Survey the total traffic volume for the entire 18 hour period each day so you can analyze the change in total traffic volume versus the change in login travel time.

Problems and Conclusions

This study had two problems that impaired the potential of the Opticom signals.

- The buses encountered more traffic during the after study. This increase of total traffic volume relates to an increased travel time for the buses. This relationship is not straightforward and it is difficult to estimate what sort of an increase in travel time should be expected. Considering this, the change in travel times were minimal even with the increase in traffic.
- The operators overall performance was unsatisfactory for this study. This application required certain attention from the drivers and this demand was not handled well by a large portion of the drivers. Only 50% of the buses were tagged at all three points in the login data.

The study indicates several promising pieces of data.

- The equipment either malfunctioned or was installed improperly for only two of the buses it was tested on.
- Over the entire corridor, the change in travel time for the buses was less than the overall change in delay for the vehicles on the through streets. This relates to the fact that the total traffic volume was higher for the after study.
- At 11th & Multnomah, (3/15/95) the buses were granted priority on 35 of the estimated 59 runs that activated their system. The average green extension time of 5.29 seconds is not excessive for this intersection.
- The bus travel times decreased during the after period with the increased traffic volumes. The decrease was insignificant under conditions which are expected to be identical, but can be considered significant for the conditions experienced.

Appendix B

Bus Travel Time & Delay Survey Data Summary

TABLE B-1
PRE-TEST COMPARISON OF POTENTIAL PRIORITY ROUTES

Summary of Lloyd District Bus Travel Time and Delays			
Bus/Direction/Period	Corridor Travel Time	Opticom Signal Delay (secs)	Percentage of Travel Time
#9 Eastbound AM	0:03:23	34.04	16.77%
#9 Eastbound PM	0:04:23	44.37	16.87%
#9 Westbound AM	0:03:58	28.16	11.83%
#9 Westbound PM	0:04:56	61.80	20.88%
#10 Eastbound AM	0:04:48	86.57	30.06%
#10 Eastbound PM	0:05:57	84.43	23.65%
#10 Westbound AM	0:04:33	48.46	17.75%
#10 Westbound PM	0:05:15	79.66	25.29%
#70 Inbound (NW) AM	0:05:01	94.85	31.51%
#70 Inbound (NW) PM	0:05:49	108.26	31.02%
#70 Outbound AM	0:05:02	97.49	32.28%
#70 Outbound PM	0:06:50	99.26	24.21%

Appendix C

Intersection Vehicle/Person Delay Survey Data Summary

TABLE C-1a
TRAFFIC VOLUME DATA - MANUAL SURVEY DATA

9th Avenue

	Change in Traffic Volume	Change in Bus Travel Time	Change in Vehicle Delay	Change in Vehicle Queue		Change in Traffic Volume	Change in Bus Travel Time	Change in Vehicle Delay	Change in Vehicle Queue
9th Midday EB Mult	15.8%	14.3%	24.7%	45.1%	**9th PM** EB Mult	4.7%	-5.4%	34.7%	41.9%
WB Mult	13.7%	2.9%	113.4%	132.7%	WB Mult	24.3%	3.8%	63.9%	104.5%
NB 9th	37.4%		-18.2%	11.0%	NB 9th	28.1%		-26 8%	-5.8%
SB 9th	9.8%		-6.3%	1.7%	SB 9th	10.0%		-10.3%	-4.2%
Total Traffic Volume	17.1%				Total Traffic Volume	15.7%			

11th Avenue

	Change in Traffic Volume	Change in Bus Travel Time	Change in Vehicle Delay	Change in Vehicle Queue		Change in Traffic Volume	Change in Bus Travel Time	Change in Vehicle Delay	Change in Vehicle Queue
11th Midday EB Mult	30.9%	14.3%	40.6%	77.6%	**11th PM** EB Mult	4.8%	-5.4%	41.6%	47.6%
WB Mult	4.7%	2.9%	12.2%	-29.2%	WB Mult	32.6%	3.8%	-3.5%	27.3%
NB 11th	90.3%		11.3%	95.8%	NB 11th	21.4%		44.7%	46.6%
SB 11th	71.5%		0.0%	0.0%	SB 11th	27.4%		0.0%	0.0%
Total Traffic Volume	30.4%				Total Traffic Volume	19.6%			

TABLE C-1b
TRAFFIC VOLUME DATA- MANUAL SURVEY DATA

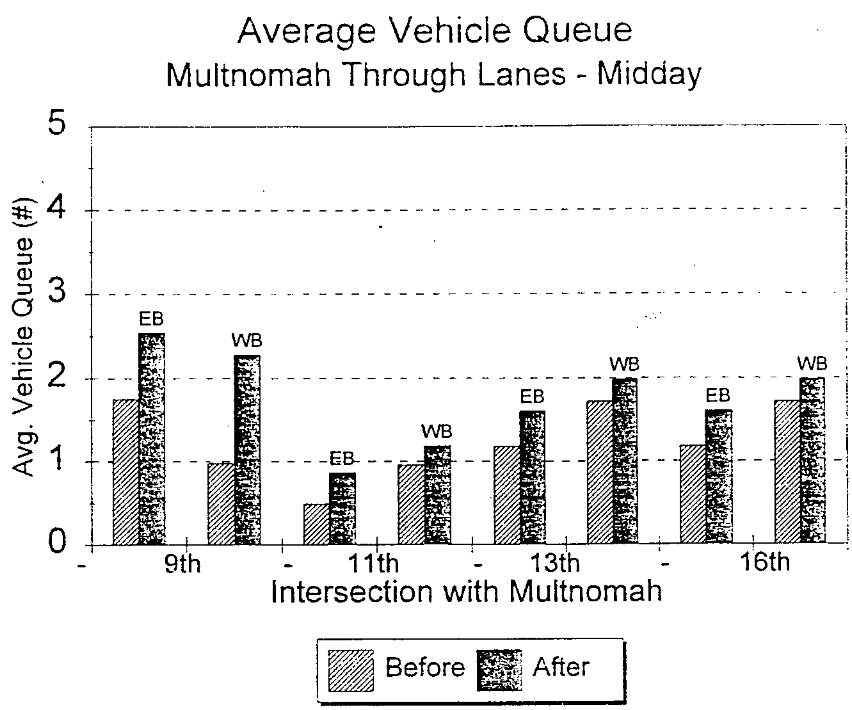
13th Avenue

	Change in Traffic Volume	Change in Bus Travel Time	Change in Vehicle Delay	Change in Vehicle Queue		Change in Traffic Volume	Change in Bus Travel Time	Change in Vehicle Delay	Change in Vehicle Queue
13th Midday EB Mult	13.4%	14.3%	21.8%	36.4%	**13th PM** EB Mult	6.0%	-5.4%	31.3%	37.7%
WB Mult	8.7%	2.9%	4.5%	15.1%	WB Mult	12.6%	3.8%	6.8%	20.4%
NB 13th	7.6%		-8.8%	-1.9%	NB 13th	35.1%		10.5%	44.0%
SB 13th	23.7%		2.5%	33.3%	SB 13th	3.2%		-10.3%	-20.0%
Total Traffic Volume	24.9%				Total Traffic Volume	20.5%			

16th Avenue

	Change in Traffic Volume	Change in Bus Travel Time	Change in Vehicle Delay	Change in Vehicle Queue		Change in Traffic Volume	Change in Bus Travel Time	Change in Vehicle Delay	Change in Vehicle Queue
16th Midday EB Mult	4.9%	14.3%	29.2%	14.3%	**16th PM** EB Mult	7.5%	-5.4%	8.4%	16.3%
left turn	-15.9%	2.9%	25.2%	35.9%	left turn	13.7%	3.8%	-26.8%	2.0%
WB Mult	-1.0%		-3.7%	-27.4%	WB Mult	9.4%		-6.0%	2.8%
NB 16th	-9.1%		-44.1%	-1.4%	NB 16th	2.5%		-9.4%	-6.5%
SB 16th	8.0%		-27.8%	1.1%	SB 16th	9.6%		-25.2%	8.3%
Total Traffic Volume	-0.1%				Total Traffic Volume	7.5%			

FIGURE C-1
AVERAGE VEHICLE QUEUE - MULTNOMAH THROUGH LANES



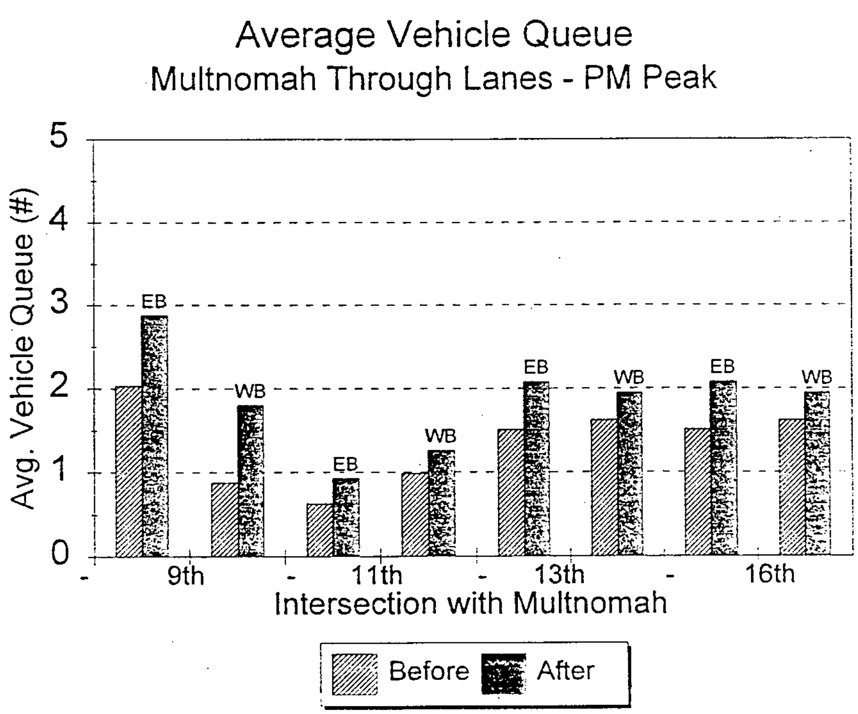
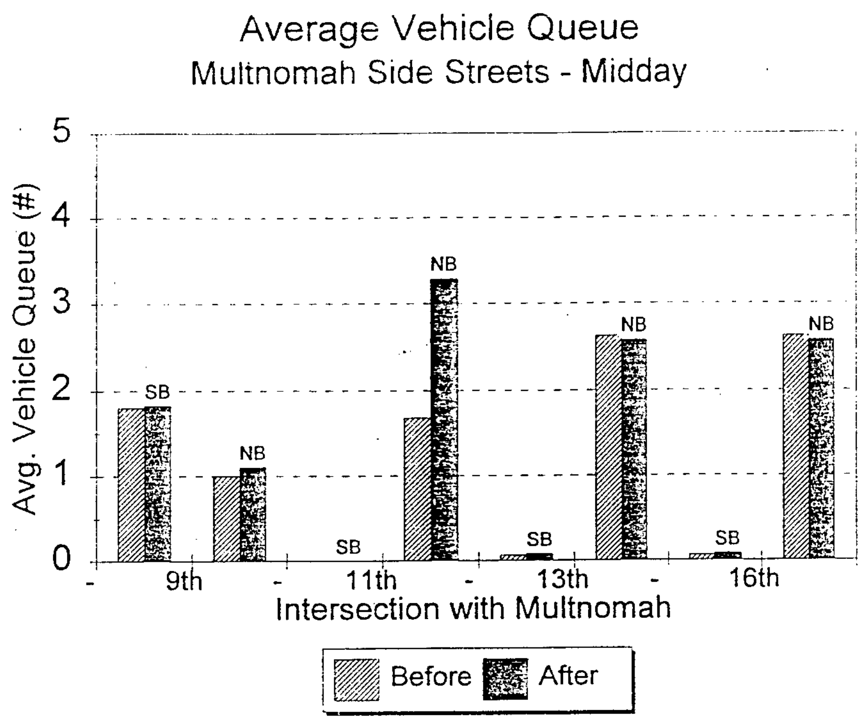


FIGURE C-2
AVERAGE VEHICLE QUEUE - MULTNOMAH SIDE STREETS



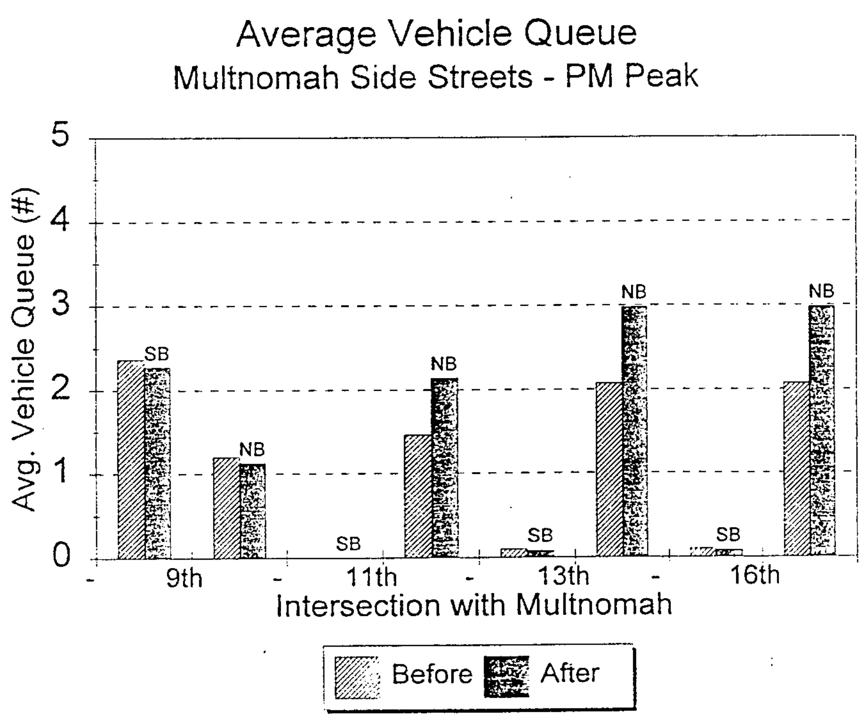
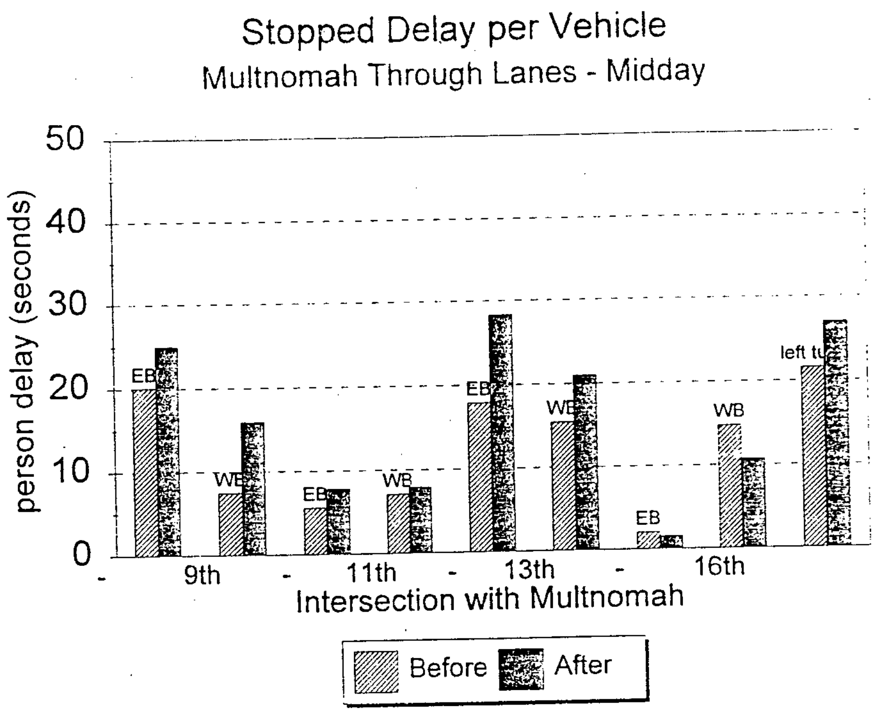


FIGURE C-3
STOPPED VEHICLE DELAY - MULTNOMAH THROUGH LANES



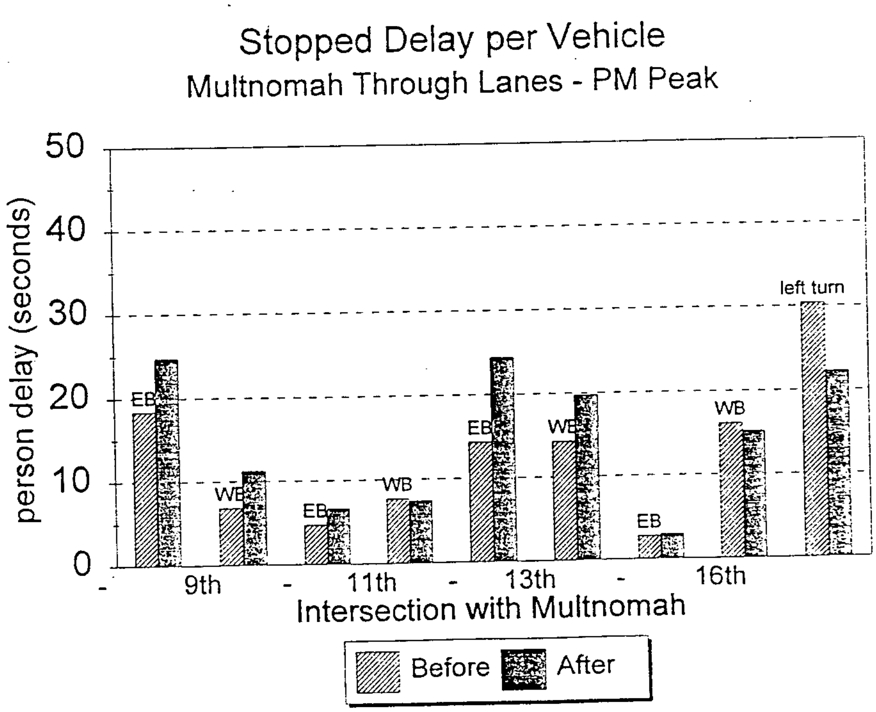
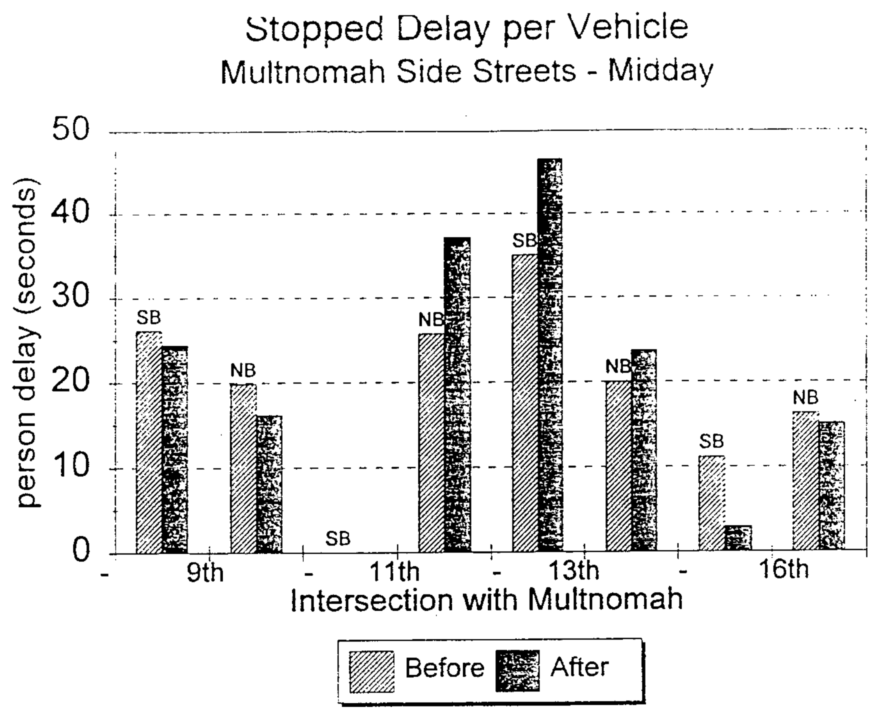
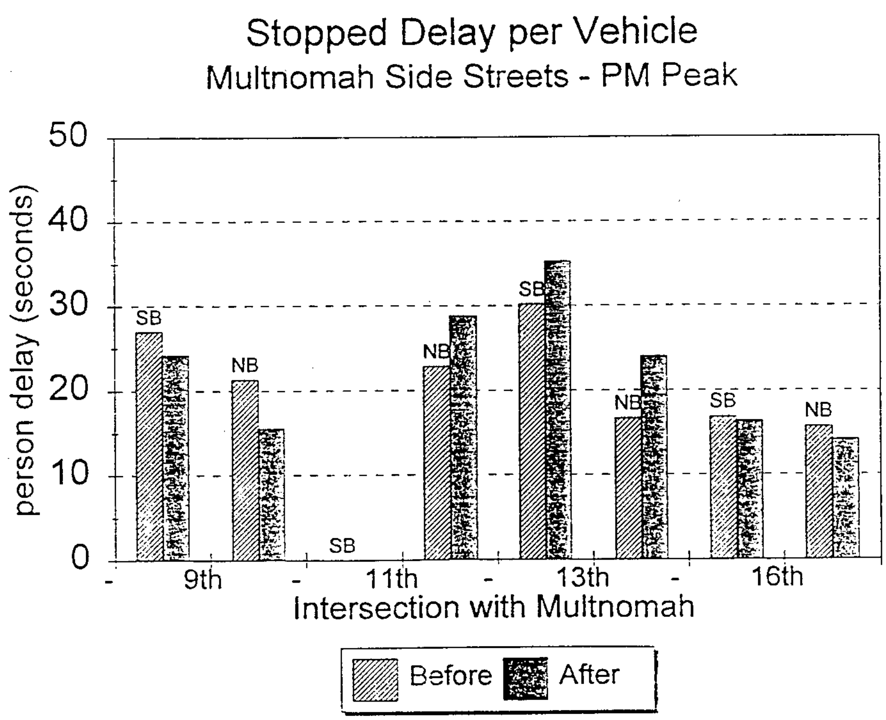


FIGURE C-4
STOPPED VEHICLE DELAY - MULTNOMAH SIDE STREETS





Appendix D

Operator Survey

NE Multnomah Street Bus Signal Priority Project -
Interview Questions & Answers - Line #10 Tri-Met Operators

The following survey was conducted for five of the original 25 drivers who continue to drive the line. The summary of the responses follow underneath the questions in the bold type.

Note: First assure operators that their responses will be held in strict confidence. We just want their honest impression on what happened during the test and how difficult the equipment was to use.

1. Did you personally notice a difference in the travel time / operation of the signals on NE Multnomah during the "after" test? (March 13 to 31)

1. Two of the five drivers experienced no difference during two periods. Two of the remaining three drivers reported time savings of about three minutes during the after test, and the final respondent reported not a lot of savings inbound, and a considerable amount outbound.

2. Did you find the Opticom toggle switch difficult to use? Does operating the button interfere with your duties as an operator? Did you ever notice that you accidentally left the button "on" or "off" at the wrong time? Would some sort of "time out" feature been useful?

2. The responses for this question was mixed. Two of the drivers said they had trouble using the indicator because of the location, and that they would forget to turn off the switch. One operator stated he would turn on the switch and leave it on. The others said that it was not difficult to use.

3. The Opticom test required that you make a decision approaching a near side stop on whether to leave the Opticom on, or turn in off in anticipation of a stop. Was this difficult to do?

3. Four of the drivers admitted that they would forget or just wouldn't turn it on and off during at times during the study. The other driver agreed that the "exception" concept would be better

4. Would some sort of special traffic signal confirmation indication been useful to indicate that you had priority as you approached an intersection?

4. Three of the four drivers answered "yes" to this question, one responded no.

5. Suggestions on how the operating instructions could have be improved?

5. One driver asked for on-board supervisors, one didn't understand some of the instructions during the training. The other said the instructions were very clear and overdone.

6. Several of the buses did not register at all three check points (1st, 11th, & 16th). Any ideas on why?

6. Two drivers said they had no idea why the system would not register. One said that nearside stops lead to forgetting to turn the switch back on. The final respondent thought that some operators will never use the system.

7. Other comments that you think might help use evaluate the equipment?

7. Of the two answers, one mentioned the use of reverse logic "only turn the system on if you have to stop", and the second suggested having an automatic device not requiring operator intervention.

This particular survey echoed the responses from the written one that is attached with this summary. The responses are somewhat disappointing, it would seem that the drivers have a poor attitude towards the study. The reason I say this is that about half of the driver's hint that some of their fellow drivers would not turn the switch on. Half of the written surveys attributed the problems with the buses registering at the checkpoints to driver error. Most of the drivers found that the location of the switch was well easily accessible and the operation of the device did not interfere with their duties. However, the drivers also reported trouble with remembering to use the system especially turning the system off and on. One driver in particular did not understand the directions and left the switch on throughout the corridor.

TRI-MET #10 LINE OPERATOR SURVEY RESULTS

MULTNOMAH STREET BUS SIGNAL PRIORITY STUDY

The following is a summary of the bus operator surveys from the Multnomah Street bus priority study. This particular survey was answered by nine drivers and the results are written in bold.

1. Were the bus signal priority operating instructions clear?
   Yes 100% No 0%

   Ideas on how the operating instructions could have been improved?

   The answers for this particular question varied from just a little clearer to don't be redundant. The majority of the responses were mostly positive.

2. Was the location of the signal priority activation switch on the lower left side of the dashboard easily accessible?
   Yes 89% No 11%

   Did operating the switch interfere with your duties as an operator? **Yes 0% No 100%**

   Is there a better location for the switch, in your opinion?
   Yes 22% **No** 78% Where? Answers ranged from on the right side to on the side panel.

   Did you ever notice that you accidentally left the switch "on" or "off" at the wrong time? **Yes 89% No 11%**

3. Did you notice an improvement in bus travel time when the switch was activated?
   Yes 78% **No** 22% Which direction? **Outbound (1), Inbound (1) Both (6)**

4. The Opticom test required that you make a decision approaching a near side stop on whether to leave the signal priority on, or turn off in anticipation of a stop. Was this difficult to do?
   Yes 33% **No** 45% **Sometimes** 11% **Other** 11%
   A few of the respondents stated they had forgot or the other

category in this case "left it on". It is hard to say whether the drivers who answered "Sometimes" forgot once or twice, and likewise for the drivers that answered "yes".

5. Several of the buses did not register at all three check points (1st, 11th, and 16th). Any ideas on why? About half of the drivers attributed the problems with driver error. Some of the drivers stated that other drivers might not turn their switch on. The other half thought that possibly the system was faulty in various ways.

6. Would some sort of special traffic signal confirmation indication been useful to indicate that you had priority approaching a particular intersection? Yes 71% No 29%
Only seven of the nine respondents answered this question.

Add any further thoughts you have on the operation of the signal priority equipment, and the benefits the signal priority had on bus travel time.
The response for this question varied a great deal. One driver did not notice a difference, while another thought that it was a "handy" system to save time. The only other respondent believed that the far side stops do just as much to save time.

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