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POWELL BLVD. BUS SIGNAL PRIORITY PILOT PROJECT

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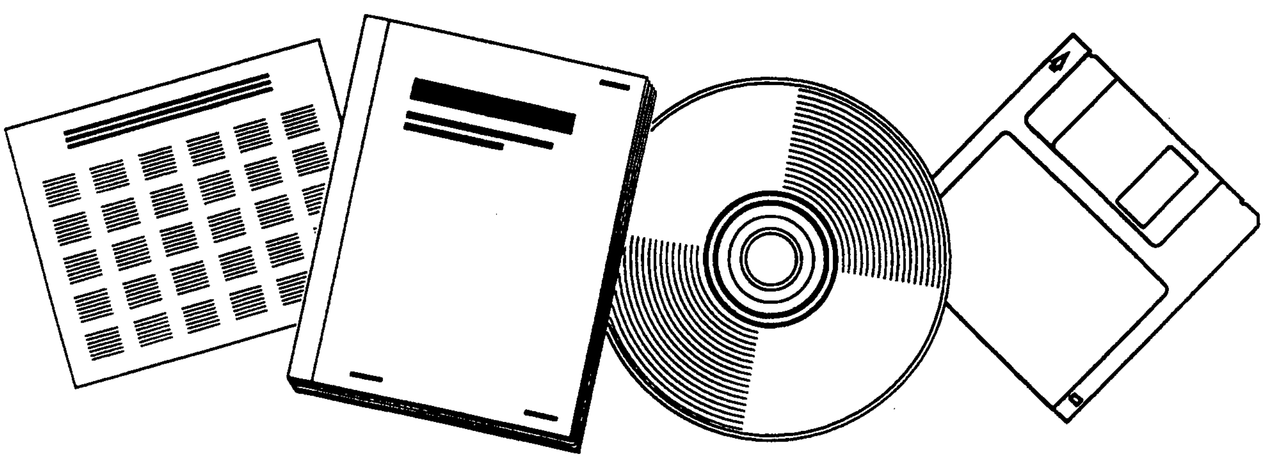

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<tr><td colspan="6">16. Abstract
An incremental approach to the application of APTS technology is being applied to the use of bus pre-emption at a number of signalized intersections in Portland, Oregon. The project has evaluated software and hardware combinations that provide the best solutions for signal pre-emption. Project benefits may include: saving in travel time for bus passengers, and real time monitoring of "bus on time performance". Project products will include the dissemination of information of the incremental approach for the application of APTS technology for small transit agencies, and a toll for the evaluation of intersection performance with bus priority at signalized intersections.</td></tr>
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</table>

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 Need for Priority Treatments in Portland

The new Strategic Plan of the Tri-County Metropolitan Transportation District of Oregon (Tri-Met) calls for improving bus on-time performance and increasing ridership in the future. Critical to achieving these objectives is to reduce bus travel time on arterial streets, and make the bus more competitive with the auto. In response to this need, Tri-Met established a bus signal priority development program. 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.

Given that most of Tri-Met's bus service is in the City of Portland, in 1993, Tri-Met entered into an intergovernmental agreement with the City of Portland to pursue an initial bus signal priority pilot project. This pilot project would evaluate two new bus signal priority technologies on the market (the LoopComm and TOTE systems), as well as identify the traffic impact of bus signal priority on bus travel time and delay, general traffic queuing and delay, and overall intersection person delay. If the pilot project proved successful, Tri-Met and the City would agree to pursue a widespread application of bus signal priority on City streets, using a particular technology at an agreed-upon set of intersections.

1.2 Pilot Project Identification

In 1991, Tri-Met hired JRH Transportation Engineering of Eugene, Oregon to analyze the potential for bus priority at traffic signals in Portland. The study included an analysis of priority techniques, a study of bus detection technologies, and a list of potential test sites. In the study, JRH identified the following three leading bus detection technologies:

- Opticom by 3M Corporation;
- TOTE by the TOTE Division of McCain Traffic Supply; and
- LoopComm by Detector Systems.

Each technology uses a completely different method for bus detection. Opticom uses a strobe light emitter on the bus with special (RF) light detectors installed at the intersection. TOTE uses radio frequency activated tags on the bus with special RF readers installed along the roadside. LoopComm uses a special transmitter on the bus that is "read" through standard vehicle loop detectors imbedded in the pavement.

The initial pilot project was to include a test of detection equipment as well as a test of priority concepts. A two mile segment of Powell Blvd. in southeast Portland between Milwaukie and 50th Avenues was chosen for the pilot project (in particular, the #9

Powell bus line) (see Figure 1). S.E. Powell Blvd. is a major 4-lane arterial carrying 40,000 to 50,000 vehicles per day. The corridor experiences significant traffic congestion today. The #9 Powell route has 10-15 minute service during weekdays. Overall there are 141 bus runs (both directions combined) on weekdays, 104 runs on Saturday, and 63 runs on Sunday.

Only a limited number of buses (75) on the #9 Powell line had to be retrofitted with on-board signal priority equipment. Since a test of Opticom for bus signal priority operation was recently conducted by Kitsap Transit in Bremerton, Washington, and with the relatively high cost to install Opticom emitters on buses ($1,000 per bus), it was decided to not test Opticom on the Powell pilot project. Thus the pilot project focused its evaluation on the TOTE and LoopComm systems.

Four intersections were chosen along Powell where the bus signal priority equipment would be installed. The TOTE system was installed at the S.E. Milwaukie and S.E. 50th Avenue intersections, while the LoopComm system was installed at the S.E. 26th and S.E. 39th Avenue intersections.

1.3 Project Organization

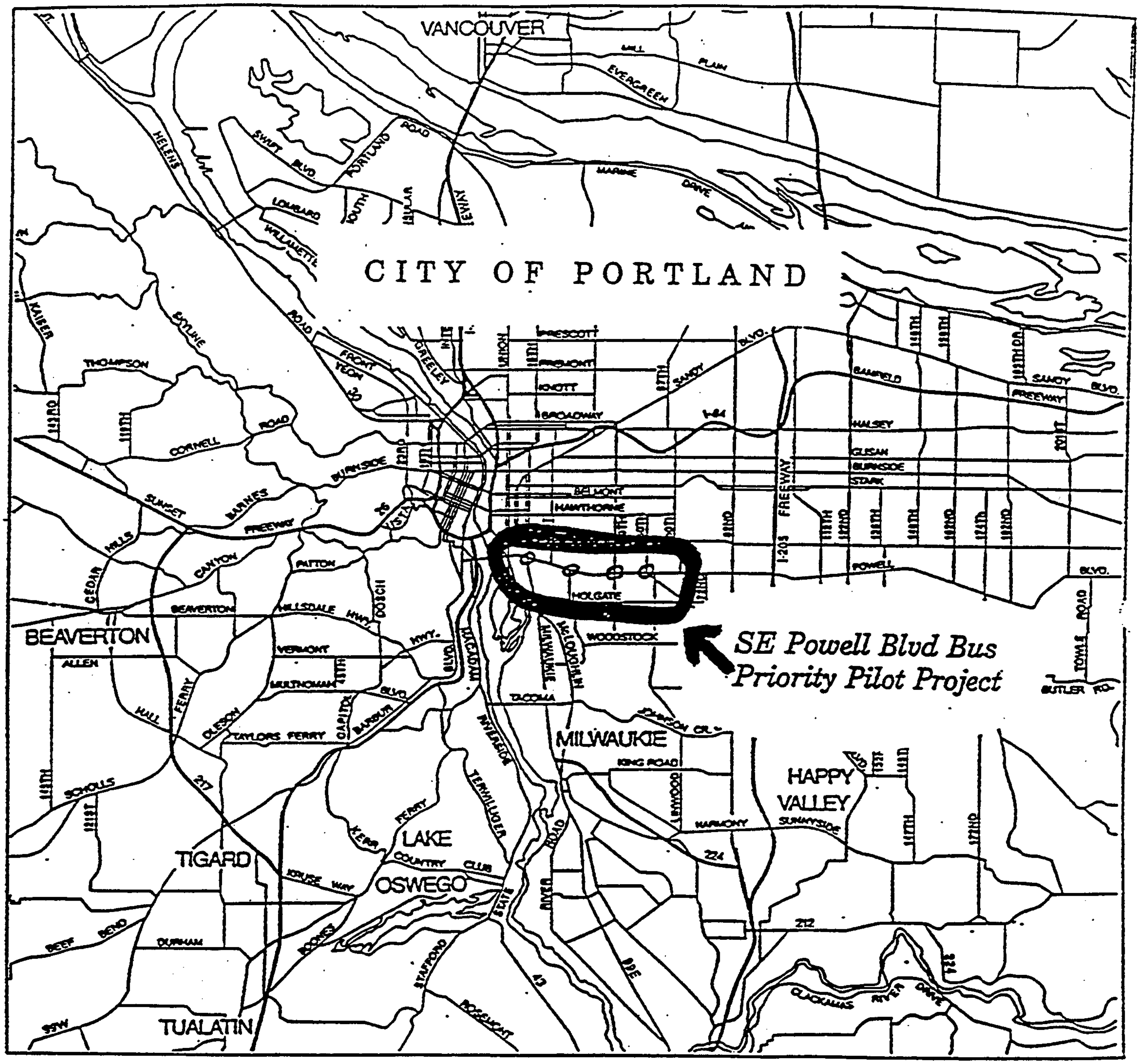
The pilot project was a collaborative effort involving Tri-Met, the City of Portland, and the Oregon State University (OSU) - Transportation Research Institute. The Tri-Met Transit Development Department managed the pilot project, with Alan Danaher, P.E. serving as Project Manager. Tri-Met purchased the signal priority equipment and installed the on-bus detection equipment.

The City of Portland, led by Bill Kloos, P.E., Traffic Signal Engineer in the Bureau of Traffic Management, provided design support to the signal priority equipment suppliers, installed all "street side" priority equipment and made required signal timing modifications to optimize bus operations during the priority equipment test period. Bureau of Maintenance signal technicians actually installed the street side equipment.

OSU, under Professor Kate Hunter-Zaworski's direction, lead the data tabulation and analysis associated with traffic surveys performed during the test period. Gargan Research and Traffic Smithy, two traffic survey firms, were responsible for all field traffic surveys. Gargan measured bus travel times and delays, while Traffic Smithy obtained traffic counts and conducted vehicle delay measurements.

FIGURE 1

PROJECT LOCATION MAP



Bus Priority Test Locations on SE Powell Blvd:

SE Milwaukie	- Tote - "green extension" for WB only; log EB bus entry time
SE 26th	- Detector Systems - EB "queue jump"
SE 39th	- Detector Systems - EB and WB "green extension"
SE 50th	- Tote - EB and WB "green extension"

2.0 ALTERNATE PRIORITY TECHNIQUES/EQUIPMENT TESTED

2.1 Priority Techniques

Tri-Met and the City of Portland decided to test two priority techniques in this pilot project. The techniques being tested were:

green extension/early green return - If the signal phase serving the bus is already "green", then the "green" can be extended passed the normal yield point. If the signal phase is "red", then the "green" will return earlier than normal. For the Powell Blvd. test, the extensions or early returns typically ranged up to 100 seconds per signal cycle. This technique is only applied where the bus has a farside stop.

queue jump - A bus stopped at a "red" light at the stop bar will receive an advance "green" so that it can pull in front of the parallel stopped vehicle queue. This technique is used only at nearside bus stops with right turn only /bus only lanes.

Figure 2 illustrates these two techniques. On Powell Blvd., "green extension" was used at Milwaukie Avenue (westbound only), 39th Avenue (eastbound and westbound), and 50th Avenue (eastbound and westbound). The "queue jump" treatment was only used at eastbound 26th Avenue.

2.2 Priority Equipment

Two different types of signal priority equipment were tested in this pilot project:

1. TOTE by the TOTE Division of McCain Traffic Supply

2. LoopComm by Detector Systems

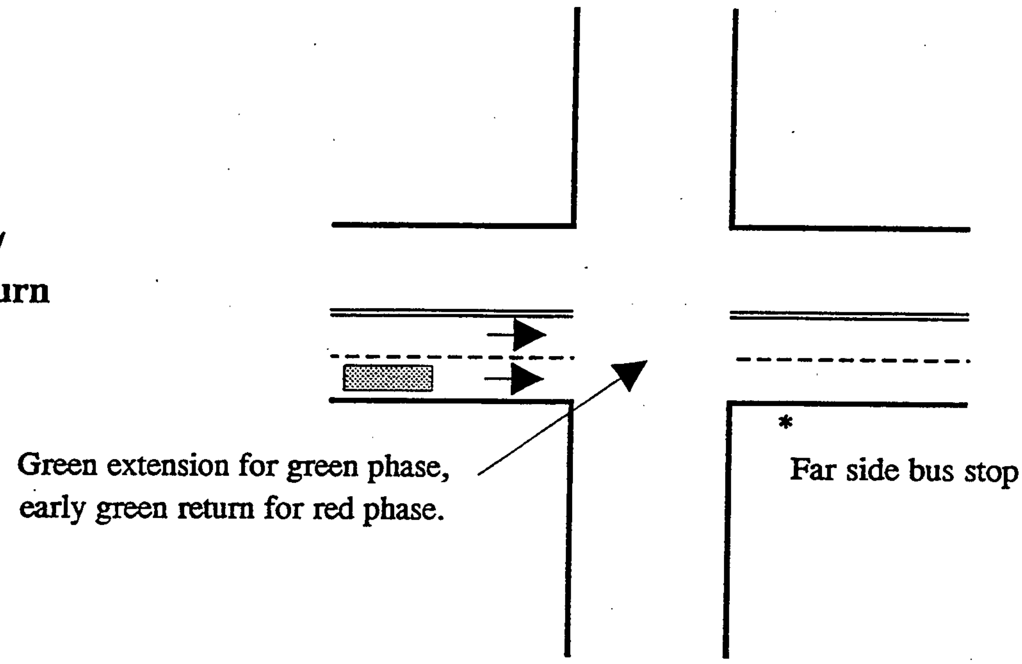
Table 1 compares the characteristics of the two systems.

TOTE System

The TOTE System uses radio frequency-activated (RF) tags on the bus with special RF readers installed along the roadside. TOTE uses standard Amtech RF tags and readers for bus identification. TOTE adds reader interfaces and a master controller to complete their system (see Figure 3). For the pilot project Tri-Met purchased 75 tags, two master controllers, and seven readers with interfaces for $54,000. The tags were mounted on the outside front of the bus just above the reader board.

FIGURE 2
BUS SIGNAL PRIORITY TECHNIQUES

1. Green Extension/ Early Green Return



2. Queue Jump

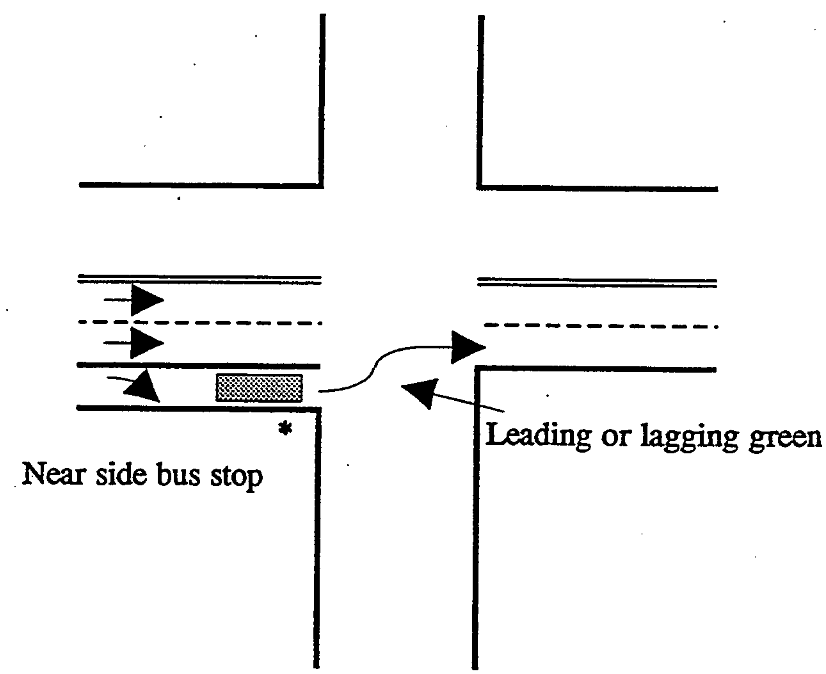


Table 1

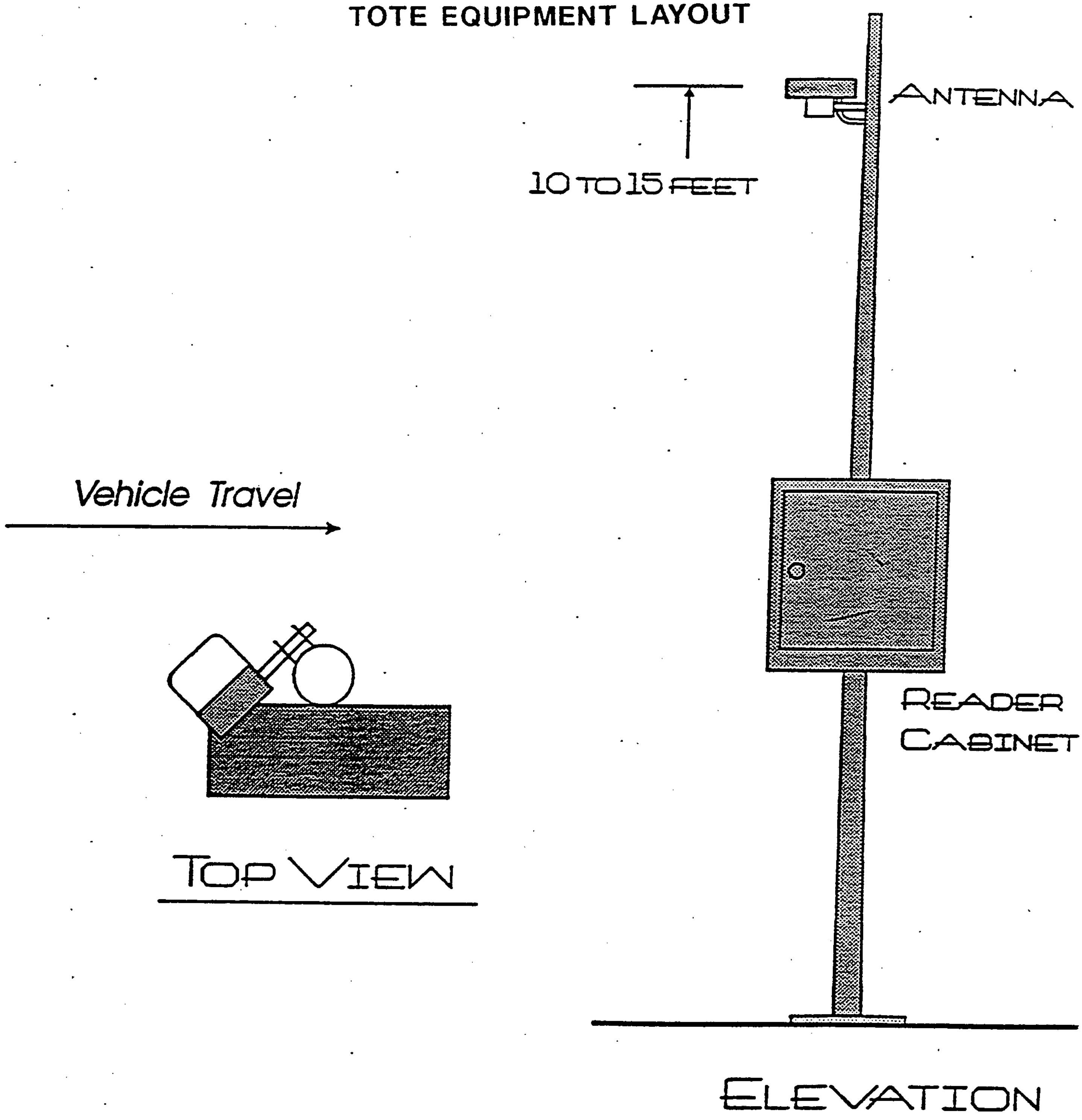
Comparison of TOTE and LoopComm Equipment

	General Description	Vehicle Tag/Transmitter Information			Wayside Cost per Intersection*	Interface with traffic controller	Data Logging Capabilities
		Type	Equipment Cost/Bus	Mounting Method			
TOTE	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".
LoopComm	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.

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

FIGURE 3

TOTE EQUIPMENT LAYOUT



LoopComm System

LoopComm uses a special transmitter on the bus that is "read" through standard inductive loop detectors imbedded in the pavement. The LoopComm Model 630 vehicle detector functions both as a vehicle identification system and a standard vehicle detector. For the "green extension" application, the City of Portland needed to add an external logic package to the traffic controller. This external logic package consisted of timed relays that took the valid output from the Model 630 units and provided the priority call to the controller. For the pilot project, Tri-Met purchased 75 transmitters and five Model 630 detectors for $22,125. The transmitters were mounted on the undercarriage of the bus, approximately two feet behind the front bumper and 2.5 feet above the pavement.

3.0 FIELD INSTALLATION/OPERATION

3.1 Detection Design

Appendix A includes drawings showing the placement of the bus detection at each of the four intersections evaluated in the pilot project. The TOTE system was used to provide bus detection and preempt request at Milwaukie and 50th Avenues. Eastbound and westbound check-in and check-out readers were installed at 50th Avenue. At Milwaukie Avenue, westbound check-in and check-out readers were installed, with only a check-out reader in the eastbound direction since there is a nearside bus stop in this direction at this location. Both intersections had a TOTE controller for processing reader data, providing preempt calls, and logging data.

The LoopComm equipment was used to provide bus detection and preempt request at 26th and 39th Avenues. Eastbound and westbound check-in and check-out receivers were located at 39th. A queue jump treatment was installed at eastbound 26th, which required only one receiver. The LoopComm Model 630 receivers logged and time stamped each bus arrival. These receivers acted as standard detector amplifiers. At 39th Avenue, the City of Portland provided external logic to provide the needed preempt call.

3.2 Signal Priority Operation

The "green extension/early green return" was applied to the Tri-Met #9 bus line using Powell Blvd.. With the heavy traffic volume on Powell Blvd., this street is considered the "main street" for signal timing purposes, and therefore the bus through movement is associated with the main coordinated phases for Powell. The use of this bus priority technique generally added "green" time for the major movement on Powell. All four intersections evaluated are controlled by Model 170 controllers with Wapiti IKS actuated firmware.

"Green Extension" Operation at TOTE Locations

The two TOTE intersections (Milwaukie and 50th Avenues) had an advance RF tag reader about 400 to 800 feet from the intersection. These readers were mounted on existing utility poles within the street right-of-way. As a "tagged" bus passed a reader, the bus identification number programmed onto a particular tag was passed on to the TOTE controller. The TOTE controller activated a six HZ pulsed contact with the Model 170 controller. This six HZ signal called the low priority/bus priority module in the Wapiti firmware. If the signal was already green for the approaching bus, the Wapiti firmware tried to extend the "green" by up to ten seconds beyond the normal yield point if needed. The lost side street time would normally be subtracted from the cross street left turn or the main street left turn. If the signal cycle were "red" for the approaching bus, then the signal controller would attempt to move to the bus-associated phase sooner by forcing off the left turn phases.

The TOTE controller has a "max" timer feature to terminate excessively long bus priority calls should a reader fail. The TOTE controller logged the "in" and "out" times for every bus. The TOTE controller also logged the intersection "end of main street green" for every cycle with preemption.

"Green Extension" Operation at LoopComm Location

At the LoopComm installation at 39th Avenue, advance inductive loops were located in the curb lane about 400 to 800 feet from the intersection. A Detector Systems Model 630 receiver was located in the signal controller cabinet. The Model 630 recognized buses with "legal" transmitters and passed a "call" onto the Model 170 controller. City of Portland staff constructed external logic to receive the Model 630 call and convert it to the six HZ signal noted above under the TOTE description. That six HZ signal was then an input to the Wapiti firmware bus priority routine. The controller operation was the same as for the TOTE installations.

A second inductive loop with a Model 630 receiver was located at the nearside stop bar to "checkout" the bus. The external logic package also has a "max" timer which terminated the six HZ call after a user-selected time had passed to avoid problems associated with a missed checkout.

"Queue Jump" Operation at LoopComm Location

At 26th Avenue, a 20 foot presence loop was cut into the existing eastbound right turn lane where there is a nearside bus stop. This lane is a "right turn only except buses" lane. A Model 630 receiver was installed in the signal controller near the loop. A properly detected bus caused the receiver to give the controller a call for the exclusive "queue jump" phase. If the bus was at the bus stop during a normal eastbound through "red" phase, then the bus received a short advance "green" as displayed on a programmable visibility signal head located on the far right strain pole. This advance "green" occurred at the normal start of the eastbound through "green" phase. The bus then was able to pull in front of the eastbound through traffic.

3.3 Equipment Performance Evaluation

Issues considered for equipment evaluation included:

- Difficulty in establishing reader/detector locations;
- Ease of overall equipment installation;
- Bus reading accuracy of the equipment;
- Equipment reliability;
- Data logging issues; and
- User interface features.

Table 2 is a summary of the equipment performance evaluation for the TOTE and LoopComm technologies which were tested. Discussions of each category follows.

Difficulty in Establishing Reader/Detector Locations

Each technology requires the user to have a fully-developed design before installation. Adjustments in the field are not trivial.

<u>TOTE</u> - The TOTE readers are to be installed on poles adjacent to the street. In the Powell pilot project only existing poles were used for mounting. Using existing poles reduces installation costs, but may constrain the bus detection zone design. The readers can be relocated to other poles only with re-cabling.

<u>LoopComm</u> - The inductive loop locations for LoopComm are sawed in the pavement and therefore, very difficult to adjust in the field. On this project two existing vehicle detectors were used.

Ease of Overall Equipment Installation

In both technologies some sort of communication and power cables are required from the controller to the reader or loop detector location. The TOTE equipment requires antenna orientation as part of installation. TOTE staff provided all required technical staff needed for equipment installation. Since LoopComm is similar to a standard vehicle detector, City of Portland maintenance staff was more familiar with how to do the installation.

Bus Reading Accuracy of the Equipment

Accuracy of reading bus tags was done by comparing the logged observations with the actual #9 bus line schedule. Neither TOTE nor LoopComm obtained 100% accuracy. Record accuracy during the test period for the two systems is shown below:

TOTE Accuracy

	Reader 1 (WB Check-in at Milwaukie)	Reader 2 (WB Check-out at Milwaukie)	Reader 3 (EB Check-out at Milwaukie)	Reader 4 (WB Check-in at 50th)	Reader 5 (WB Check-out at 50th)	Reader 6 (EB Check-in at 50th)	Reader 7 (EB Check-out at 50th)
Record %	95.5%	98.5%	95.7%	99.0%	98.4%	98.1%	97.8%

Table 2

Equipment Performance Evaluation

	Detection Location Issues	Ease of Installation	Bus Reading Accuracy	Equipment/ System Reliability	Data Logging Issues	User Interface
TOTE	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.
LoopComm	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.

LoopComm Accuracy

	Loop 1 (EB Check-in at 39th)	Loop 2 (EB Check-out at 39th)	Loop 3 (WB Check-in at 39th)	Loop 4 (WB Check-out at 39th)
Record %	98.9%	96.7%	97.7%	88.6%

The exact locations for the specific readers and loops are shown on the drawings in Appendix A.

TOTE readers showed better overall accuracy. The average logging percentage in the last month of the testing period was 97.6%.

LoopComm accuracy for loops 1-3 was as good as the TOTE accuracy. Loops 1-3 are 6' x 6' loops. Loop 4 is a 6'x 17' loop for westbound exiting vehicles at 39th Avenue. The loop 4 performance was poor initially until Detector Systems provided a "Hi Gain" version of the Model 630 receiver. The loop 5 data (eastbound 26th queue jump detector) is not shown since not all buses stopped at this location, therefore making an accuracy reading impossible. However, this 6'x 20' loop did need a "Hi Gain" unit to properly read the transmitters.

Some TOTE reading errors occurred at the westbound readers at Milwaukie. At that location a truck travelling the curb lane could effectively "screen" a bus travelling in the middle lane from being seen by the reader. This unusual circumstance pointed out the need to carefully review each site before reader installation. The Amtech tags need to be in "line of sight" with the Amtech reader to be read.

Equipment Reliability

Numerous reliability problems were experienced with the TOTE equipment. These problems ranged from water in the antennas to non-functioning readers to poor master controller software. Frequently communication was lost between the readers and the master controller. During initial operation, a reader station often recognized an allowable bus, but the master controller did not respond. The TOTE staff made numerous field trips to fix communication problems. During the equipment testing period, nearly 20% of the logged data was unable to be retrieved from the TOTE master controllers. Also one of the Amtech readers failed during the test period.

The LoopComm equipment worked reliably during the test period.

Data Logging Issues

Both systems log the times when bus tags are read. The desire was to have a product that could store at least one month of bus data. The #9 bus line on Powell Blvd. has approximately 440 buses per week per direction (2,000 per month per direction).

The LoopComm Model 630 receiver specifies a capacity to store 10,000 entries. This capacity was more than sufficient to store the desired level of data for this project.

The TOTE system specification stated that the master controller should store up to 7,000 entries. In actuality this amount of data was never able to be stored. The most data that was successfully retrieved was three days of data. When the master controller was allowed to log data for longer than three days, often the entire data log was lost and sometimes the master controller stopped communicating with the individual reader stations.

User Interface Features

Both the TOTE and LoopComm systems use a IBM compatible personal computer (PC) with custom software as the user interface for programming the systems and retrieving logged data. Both systems create log files that are easily imported into spreadsheet programs.

The LoopComm software is easy to use. The interface is very intuitive and City of Portland staff mastered its operation without even reading the instruction manual. One issue with LoopComm is the time setting of the Model 630 unit. The Model 630's time is immediately set to the PC's time when the two are connected. The user needs to verify that his PC is properly set before connecting to the Model 630.

The TOTE interface was also fairly simple to operate. However, City of Portland staff had several instances where they were unable to communicate to the master controller with their PC. The exact reasons for these problems were never known. The City also had some concerns with the lack of hand-shaking protocol between the master and the PC.

From the standpoint of collecting data, the TOTE system is easier than LoopComm since the TOTE master stores the data for four antenna stations, while each LoopComm detector needs to be read individually.

4.0 TRAFFIC SURVEYS

4.1 Scope and Methodology

Extensive field traffic data collection was undertaken to evaluate the effectiveness of the bus priority techniques being tested in this project. The data collected allowed a determination of:

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

2. the effect on delay to other vehicles on Powell Blvd. and to side street traffic; and

3. the change in total person delay at the four 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 traffic surveys each week were conducted on Tuesday through Thursday (March 8-10, 1994 for the "before" survey, and, March 29-31 for the "after" survey) during the AM peak period (7-9 AM), midday peak period (11:30 AM - 1:30 PM), and PM peak period (4-6 PM). Over 40 traffic survey personnel were involved in the data collection effort.

Traffic and Vehicle Occupancy Counts

At the Milwaukie, 26th, 39th, and 50th Avenue intersections along Powell, 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 provide control totals in identifying number of stopped vs. non-stopped vehicles on each intersection approach.

To translate vehicle delay into person delay, sample vehicle occupancy counts were conducted at two locations along Powell Blvd. at both ends of the study corridor.

Vehicle Delay Study

For each intersection approach at the four locations, 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 Powell/39th intersection, the left turn queue and number of on-stopped vehicles was segregated from the through/right vehicle queue and non-stopped vehicle measurements.

Bus Travel Time and Delay Study

Bus travel time and delay data for the #9 Powell line 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 different intersections where signal priority equipment was installed, 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. A total of 68 bus runs were surveyed during the AM, midday, and PM peak periods.

In addition to the manual Powell bus travel time and delay runs for the six day "before" and "after" period, a continuous logging of bus arrival and departure times at each intersection with signal priority equipment was conducted by the signal controller. The controller data was logged for the entire week of March 7 and March 28, 1994.

In addition to the bus travel time and delay survey on Powell, the delay to buses on the four cross streets intersecting Powell where bus signal priority was instituted was measured. The bus lines surveyed on these streets (with associated bus runs during AM, midday and PM peak periods) include:

1. #70 line southbound on Milwaukie Avenue (26 runs), and #19 line northbound on Milwaukie (28 runs);

2. #10 line on 26th Avenue (northbound and southbound) (50 runs);

3. #75 line on 39th Avenue (northbound and southbound) (58 runs); and

4. #5 line on 50th Avenue/Foster Road (northbound and southbound) (72 runs).

This bus delay information was collected separate from the general traffic queue/number of non-stopped vehicles data collection on the cross street approaches.

4.2 Survey Results

Problems with Actual Surveys

When the surveys were conducted in the field, three major problems surfaced which could have resulted in some inconsistencies in how the manual "before" and "after" bus travel time and delay, vehicle queue and percent non-stopped vehicle measurements were performed. First, there were some survey personnel who arrived late or not at all at their particular survey station during a particular time period, and thus there was some missing data in the original survey. All missing data was obtained through later surveys on the same weekday, but the traffic conditions on these days were somewhat different from the original survey day, thus possibly skewing the data to some degree.

The second problem was a delay in the "after" surveys such that they were not conducted until three weeks after the "before" surveys. This is because of a Portland Bureau of Maintenance resurfacing project which inadvertently cut the loop detection on southbound 39th Avenue at Powell, thus disrupting the signal timing at this location. The delay in the "after" surveys resulted in a fairly high turnover of survey personnel for the vehicle queue/non-stopped vehicle measurements, such that in many cases the same person had not recorded both the "before" and "after" data for a particular approach, which could have led to some differences in how queues and non-stopped vehicles were measured.

The third problem was the presence of an accident on the Ross Island bridge in the AM peak period on two of the three days during the "after" survey period. This resulted in greater than normal traffic delays in the west portion of the study corridor during these periods. Given this condition, the AM peak survey data for these days was not included in the total "after" survey data that was compared with the "before" data. This resulted in different sample sizes for the AM peak "before" and "after" periods which probably skewed the data comparison for the AM peak period.

Statistical Validity

In general, there was sufficient data obtained from the general traffic surveys to provide inferences on the impact of signal priority systems on vehicle traffic flow. The exception was the AM peak period during the "after" survey (with only day of data). The bus passenger loading data was specific to individual buses and thus provided an accurate portrayal of bus person delay at intersections. The vehicle occupancy rates were derived from only a limited time duration at spot locations, and therefore were used as a trend to project intersection person delay as a function of vehicle delay and calibrated vehicle occupancy rates.

The bus check-in and check-out times obtained from the signal controllers was post-processed to account for missing data. Once again sufficient data was collected (with the exception of the AM peak "after" period) to project trends in bus travel time on route segments.

Overall Traffic Volumes

Traffic counts were obtained on Powell Blvd. and the side streets during the traffic survey period to be used in the vehicle delay calculations as well as to identify if there were any changes in traffic volumes which might skew the vehicle queue measurements and delay calculations. Table 3 summarizes traffic counts obtained on Powell in the vicinity of Milwaukie and 50th Avenues during the survey periods. The counts show

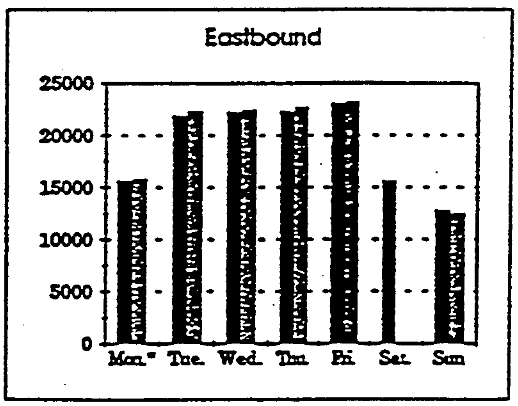
TABLE 3

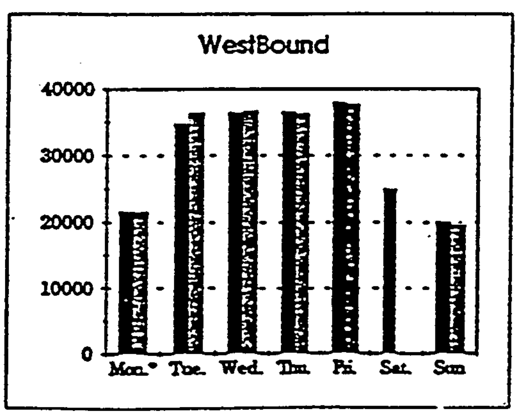
TRAFFIC COUNTS ON ROSS ISLAND BRIDGE DURING TEST PERIOD

The comparison of traffic volumes in before and after weeks of bus priority study.

	Eastbound Before (3/7-3/13)	Eastbound After (3/28-4/3)	After - Before	%	Westbound Before (3/7-3/13)	Westbound After (3/28-4/3)	After - Before	%
Mon.*	15676	15825	149	0.95%	21637	21526	-111	-0.51%
Tue.	21913	22276	363	1.66%	34804	36408	1604	4.61%
Wed.	22237	22441	204	0.92%	36482	36684	202	0.55%
Thu.	22318	22671	353	1.58%	36610	36315	-295	-0.81%
Fri.	23043	23204	161	0.70%	38081	37719	-362	-0.95%
Sat.	15616				25029			
Sun	12838	12478	-360	-2.80%	20130	19565	-565	-2.81%
Weekday Total	105187	106417	1230	1.17%	167614	168652	1038	0.62%

* Monday's data was from 10:45am to 24:00am.





little variation in weekday traffic volume for the "before" and "after" periods.

Bus Travel Time Savings

Figure 4 summarizes the weekday and weekend "before" and "after" Powell bus travel time survey between Milwaukie and 50th Avenues, based on the signal controller data. The controller data was used for the analysis as opposed to the manual bus travel time survey due to the before-mentioned inconsistencies in the manual survey procedures. The controller travel time comparison for the weekday condition revealed that, for the entire study corridor, average bus travel times with the signal priority were reduced in the peak traffic direction during the peak period. In the westbound direction during the AM peak period, bus travel time was reduced by about 5% (32 seconds). In the eastbound direction during the PM peak period, bus travel time was reduced by about 8% (45 seconds). During other traffic direction/time period conditions, bus travel time slightly increased with the signal priority.

During the weekend, there was no definite pattern in the change in bus travel time in the corridor with the signal priority. Bus travel time during the weekend was generally lower than the weekday, due to the lower traffic volumes and fewer bus passenger boardings/alightings.

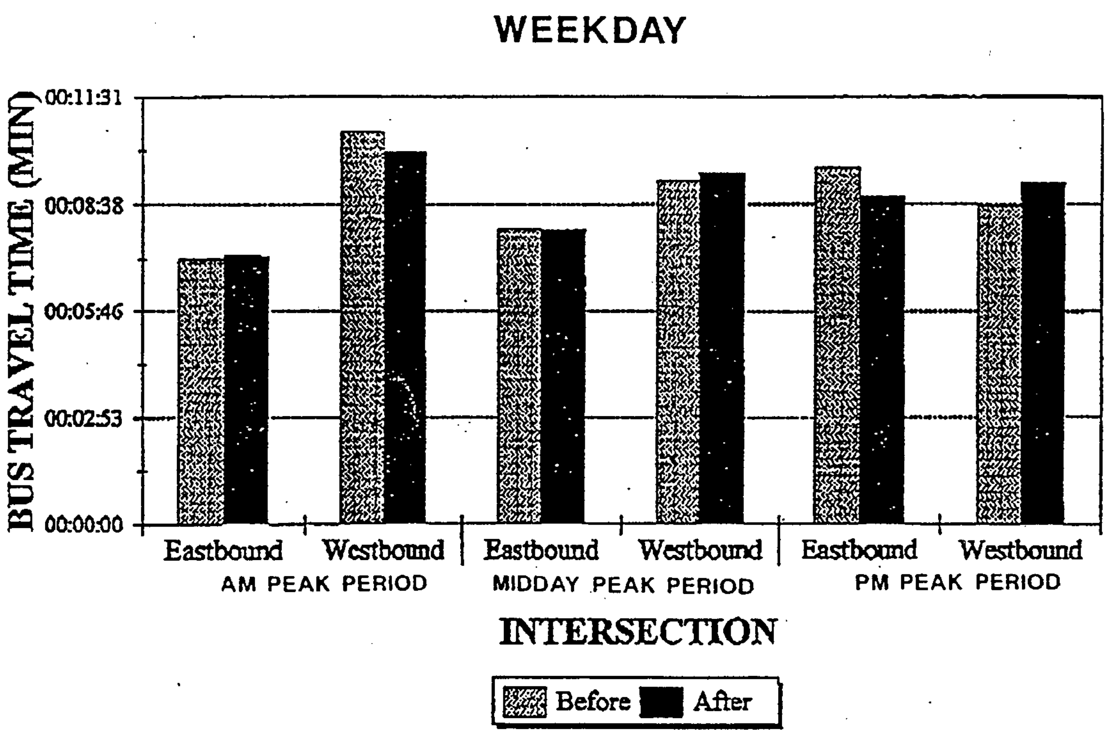
Vehicle Queues

Figures 5 and 6 summarize the average vehicle queues for Powell through traffic and side street traffic during the three weekday survey periods.

The greatest queuing "before" and "after" the bus signal priority equipment was turned on was during the AM and PM peak periods, on both Powell and the side streets. Queuing on Powell in general was higher than on the side streets during all peak periods. In general, vehicle queuing stayed the same or slightly increased with the bus signal priority in the Powell through lanes. The exceptions were westbound Powell at 39th during the AM peak period, and eastbound Powell at 39th during the PM peak period, where reductions in vehicle queues with the bus signal priority occurred. A substantial increase in vehicle queues occurred on westbound Powell of Milwaukie, possibly explained by congestion on the Ross Island bridge downstream of this intersection.

Queues on the side street approaches in general were lower than the Powell through traffic queues during the AM and PM peak periods, and comparable during the midday peak period. The bus signal priority resulted in increased side street queuing in most cases, most noticeably on northbound Milwaukie Avenue during the AM peak period, and on southbound 39th Avenue during the PM peak period.

FIGURE 4
BUS TRAVEL TIME PROFILE - POWELL LINE



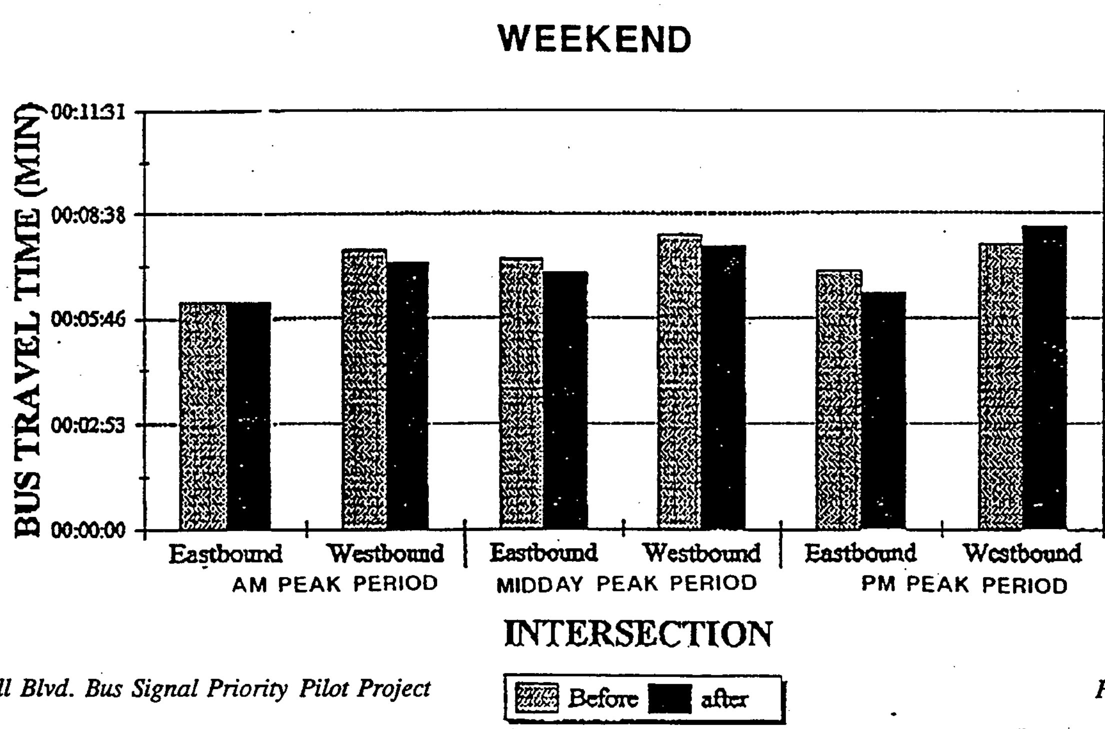
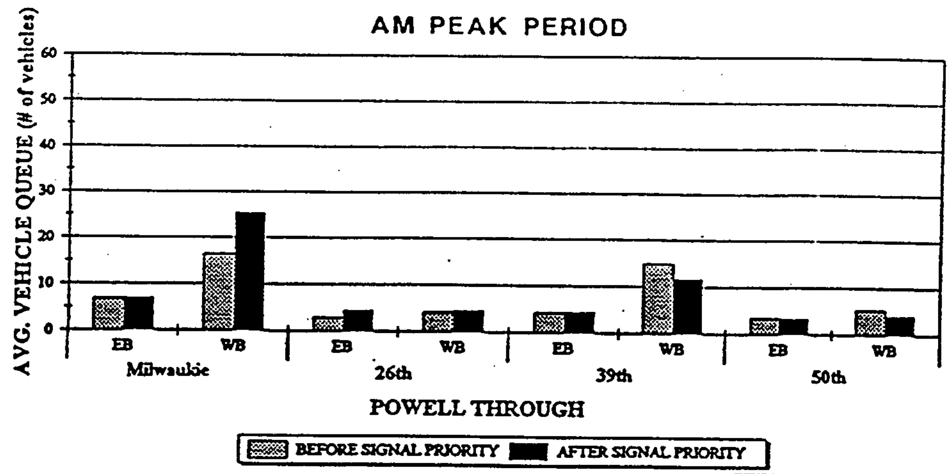
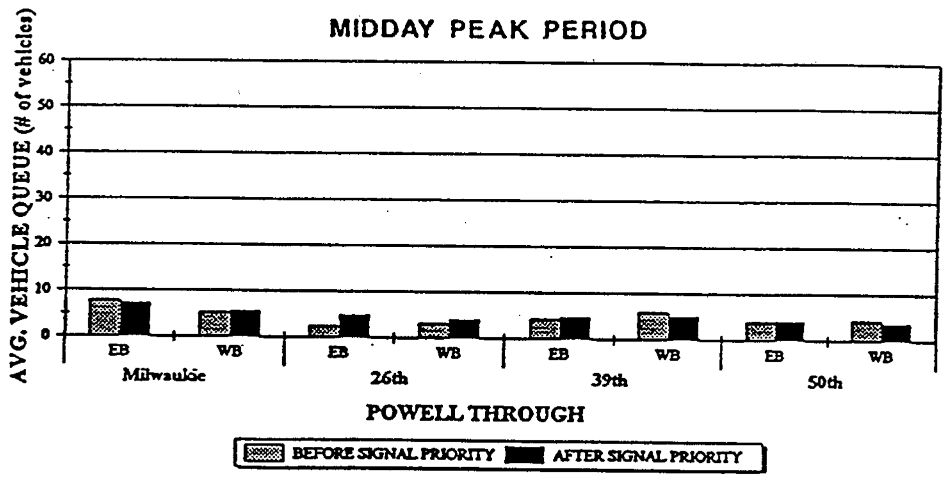


FIGURE 5
AVERAGE VEHICLE QUEUE FOR
POWELL THROUGH LANES - WEEKDAY PEAK PERIODS





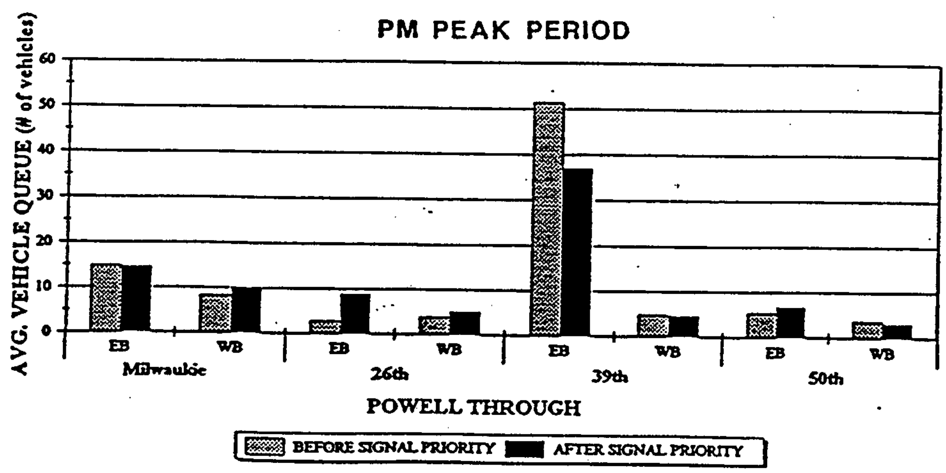
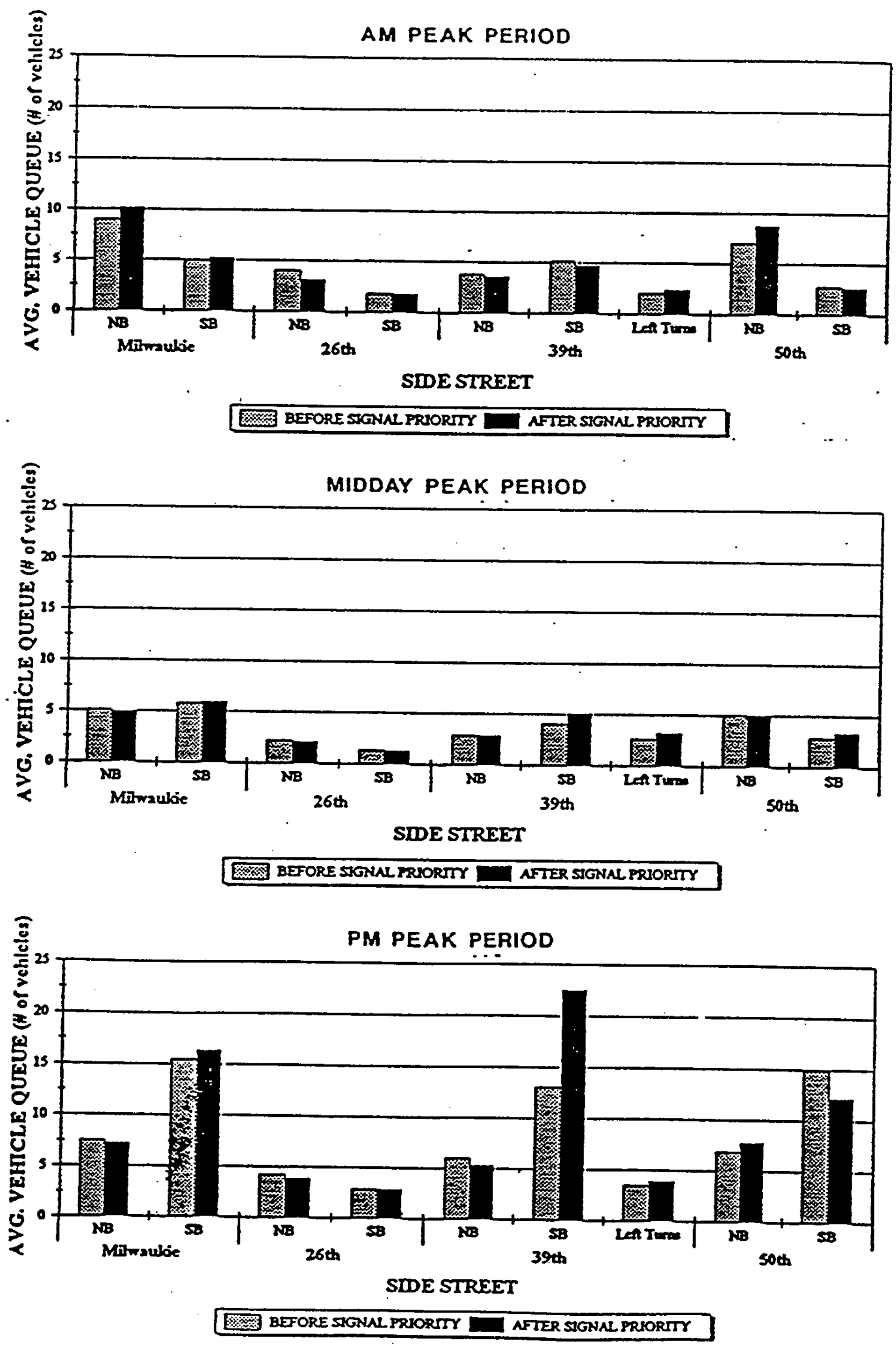


FIGURE 6
AVERAGE VEHICLE QUEUE FOR SIDE STREET APPROACHES - PEAK PERIODS



Vehicle Delay

Figures 7 through 10 summarize the average weekday general traffic stopped delay data for all approaches to the four intersections where the signal priority equipment was located. Figure 11 summarizes the average bus delay on the side street approaches. In general, there was a direct correlation between vehicle queuing and delay, as would be expected.

At Milwaukie Avenue, general traffic stopped delay was higher during the AM peak period with the bus signal priority. General traffic stopped delay was highest during the PM period, with the highest delays on northbound Milwaukie. Vehicle delay on eastbound Powell was reduced during the midday and PM peak periods with the bus signal priority, while there was a decrease in vehicle delay along westbound Powell during the midday peak period. Vehicle delay on the two Milwaukie approaches stayed about the same with and without signal priority, with the exception of northbound Milwaukie during the AM peak period, which experienced a sizable increase in delay during the AM peak period. There was no consistent pattern in the change in average bus delay with signal priority, with bus delays decreasing in the northbound direction during the midday and PM peak periods, and increasing in this during the AM peak period and for all periods in the southbound direction.

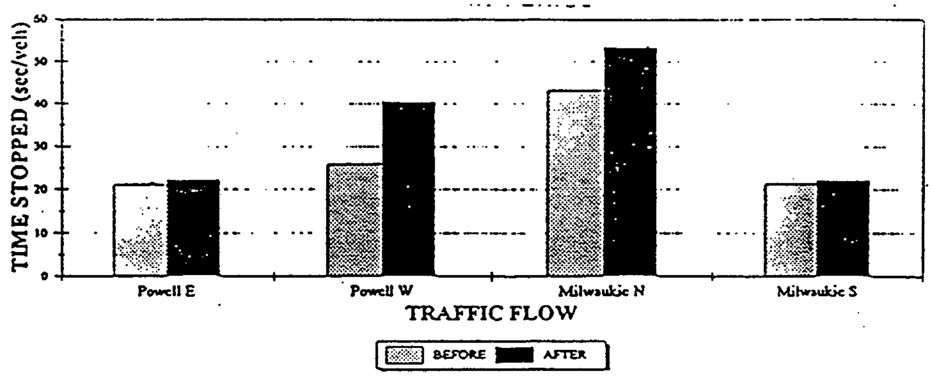
At 26th Avenue, an increase in vehicle delay in the Powell through lanes was experienced with the bus signal priority because of the green phase for the eastbound queue jump signal took away green time from Powell through traffic. Vehicle delays on 26th Avenue were much higher than on Powell, and were in general slightly lower with the signal priority (as green time for the queue jump was taken from the Powell through lanes). Average bus delay in general was lower with the bus signal priority for both directions on 26th Avenue during the three survey periods.

At 39th Avenue, the bus signal priority slightly increased left turn delay on both Powell and 39th. Delays for left turn traffic were much higher than for through traffic, as would be expected. Powell through traffic delay only decreased with the bus signal priority during the PM peak period. Through traffic delay on northbound 39th was consistently lower with signal priority across all time periods surveyed, while delays to southbound 39th traffic were lower only during the AM peak period. Average bus delay in general was lower on both 39th Avenue approaches with bus signal priority.

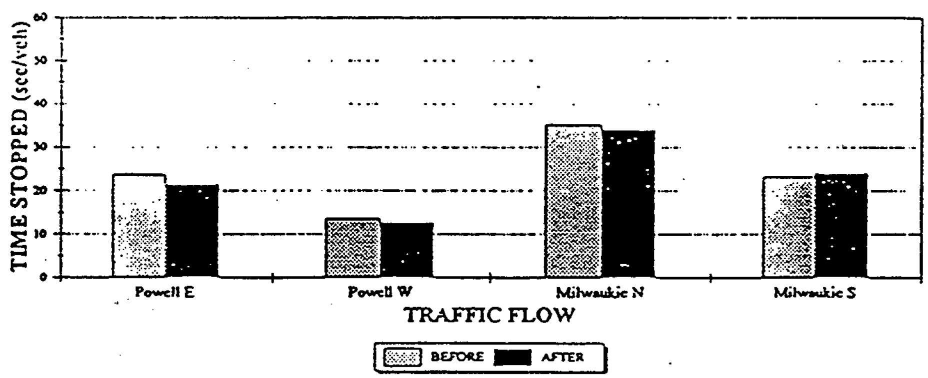
At 50th Avenue, the bus signal priority decreased through traffic delay on Powell, while generally increasing traffic delay on 50th. The exception was the PM peak period where southbound 50th traffic delay was substantially lower with the signal priority. Vehicle delays on 50th in general were much higher than on Powell. There was no consistent pattern in the change in average bus delay with bus signal priority.

FIGURE 7
AVERAGE STOPPED DELAY
POWELL AND MILWAUKIE - WEEKDAY PEAK PERIODS

AM PEAK PERIOD



MIDDAY PEAK PERIOD



PM PEAK PERIOD

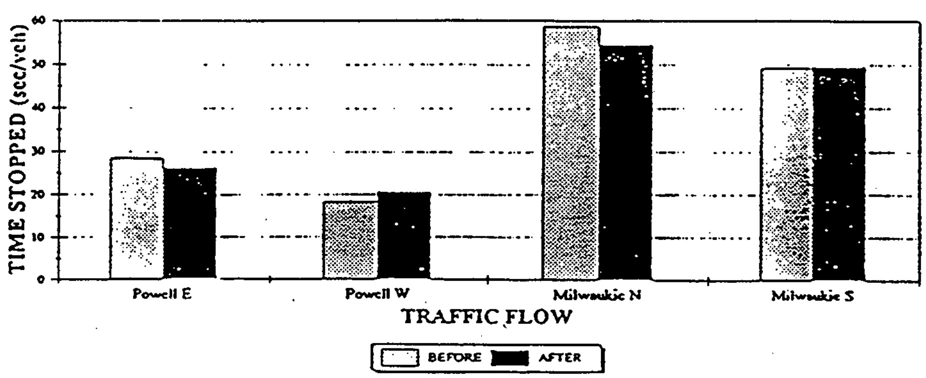
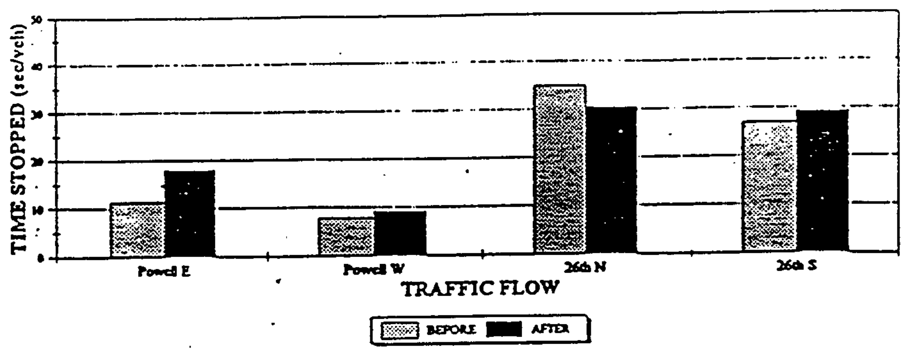
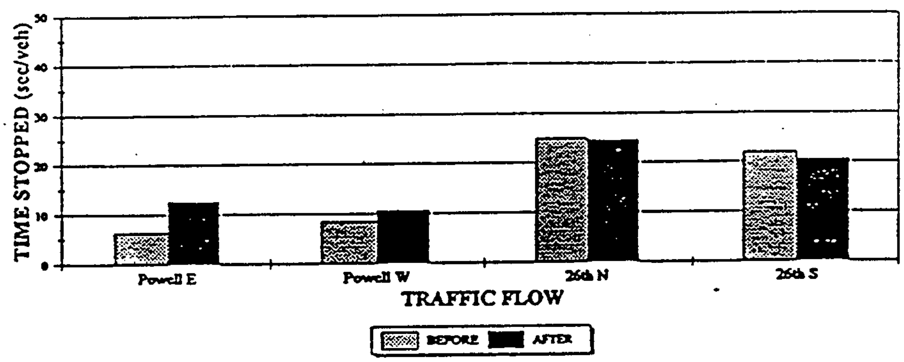


FIGURE 8
AVERAGE STOPPED DELAY
POWELL AND 26TH - WEEKDAY PEAK PERIODS

AM PEAK PERIOD



MIDDAY PEAK PERIOD



PM PEAK PERIOD

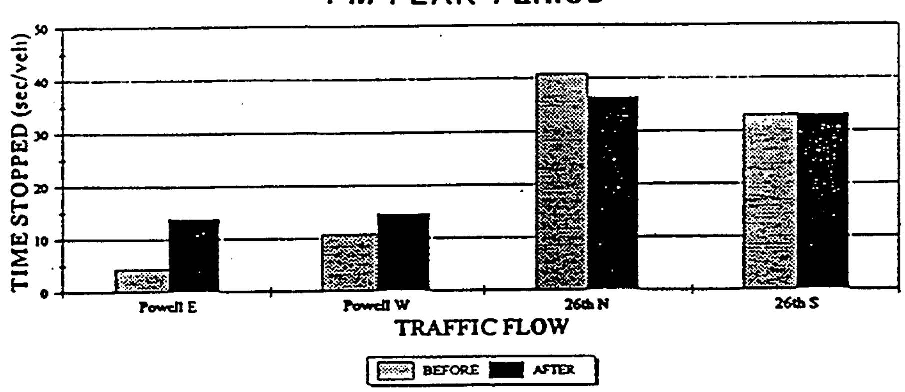
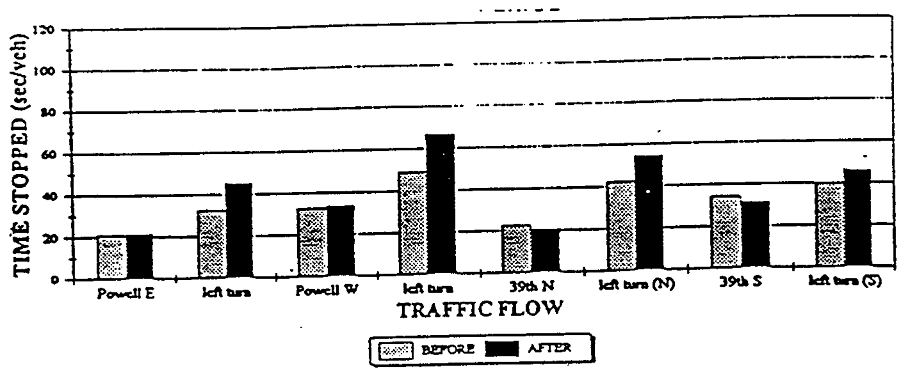
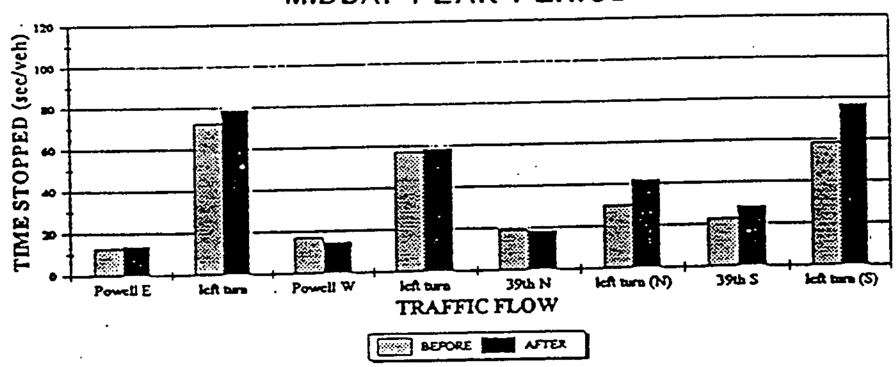


FIGURE 9
AVERAGE STOPPED DELAY
POWELL AND 39TH - WEEKDAY PEAK PERIODS

AM PEAK PERIOD



MIDDAY PEAK PERIOD



PM PEAK PERIOD

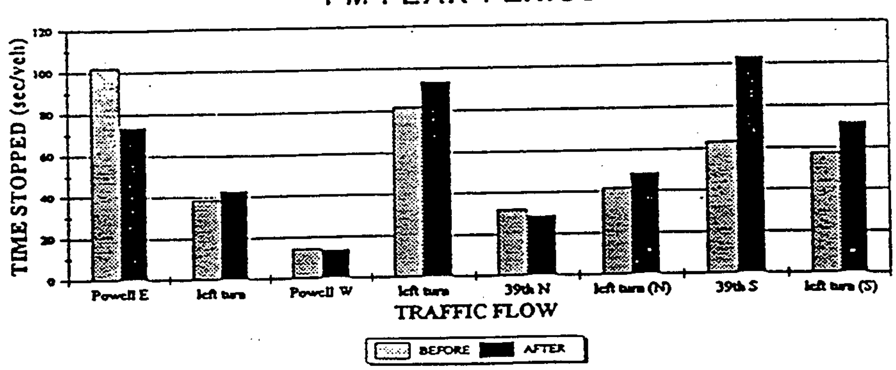
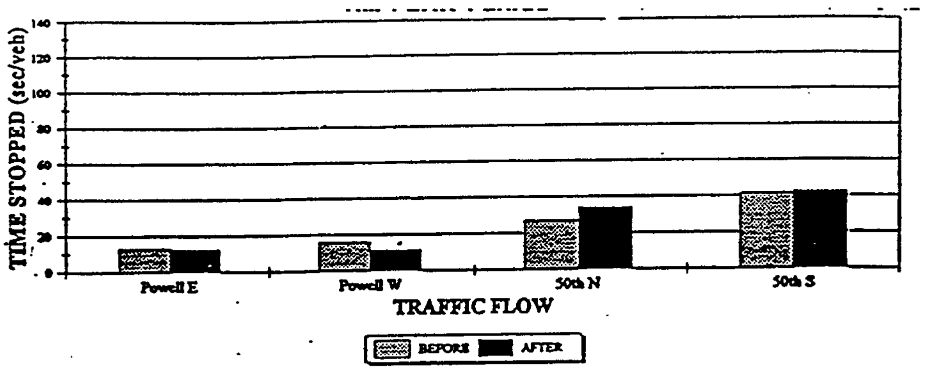
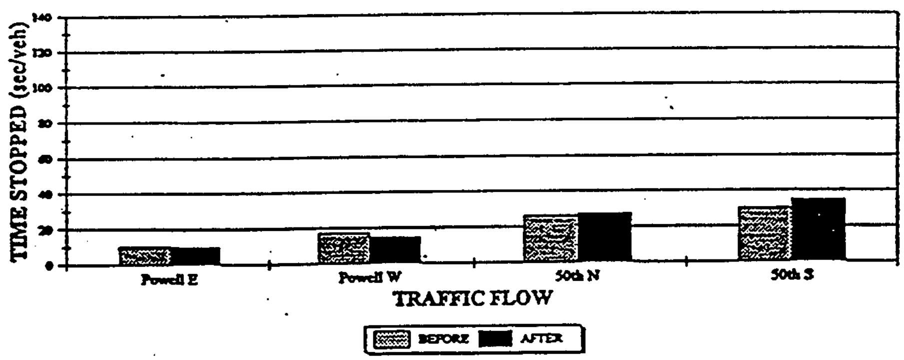


FIGURE 10
AVERAGE STOPPED DELAY
POWELL AND 50TH - WEEKDAY PEAK PERIODS

AM PEAK PERIOD



MIDDAY PEAK PERIOD



PM PEAK PERIOD

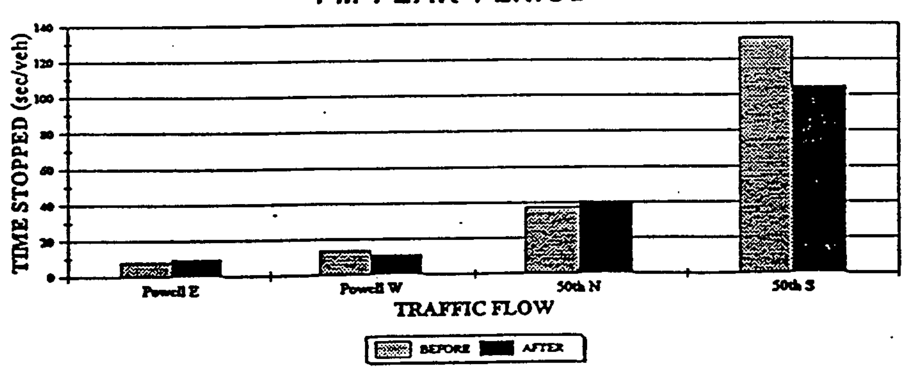
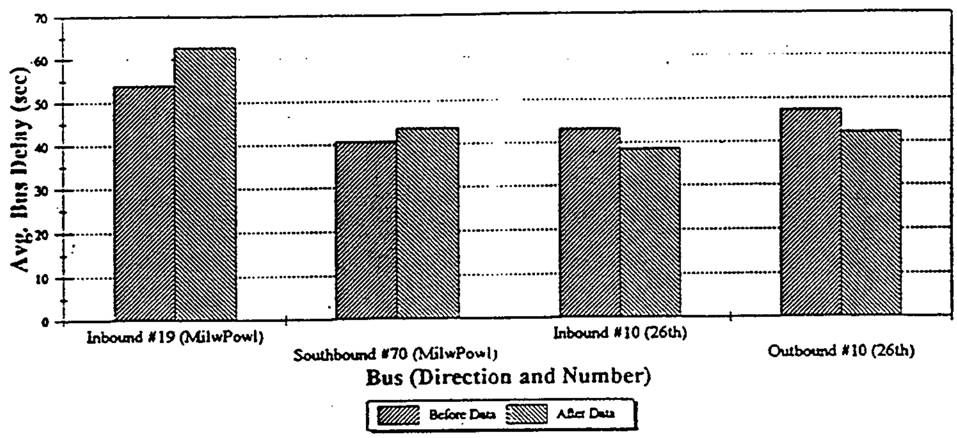
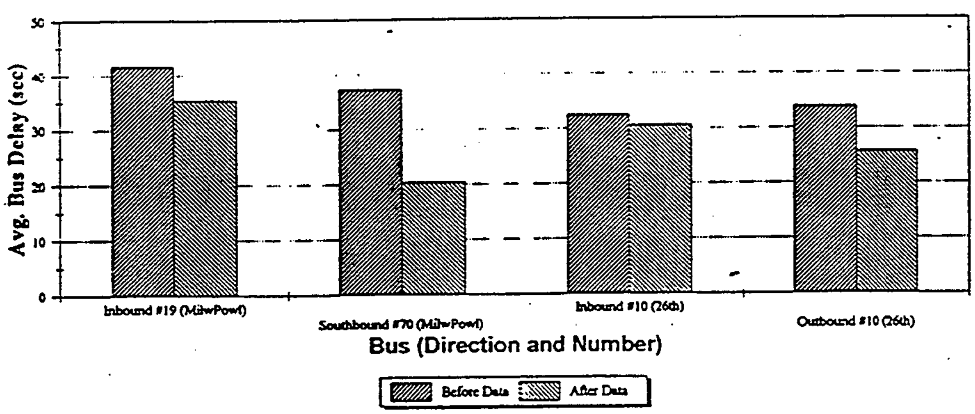


FIGURE 11
AVERAGE BUS DELAY
FOR SIDE STREET APPROACHES - WEEKDAY PEAK PERIODS

Average Bus Delay for Side Street
Approaches - AM Peak Period



Average Bus Delay for Side Street
Approaches -Midday Peak Period



Average Bus Delay for Side Street
Approaches - PM Peak Period

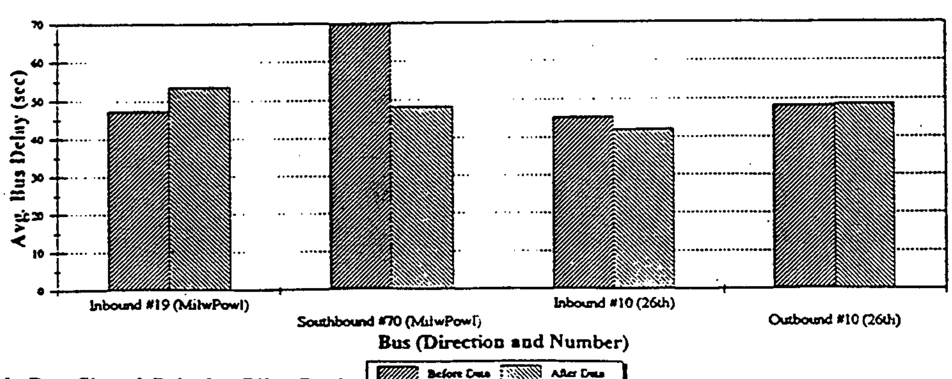
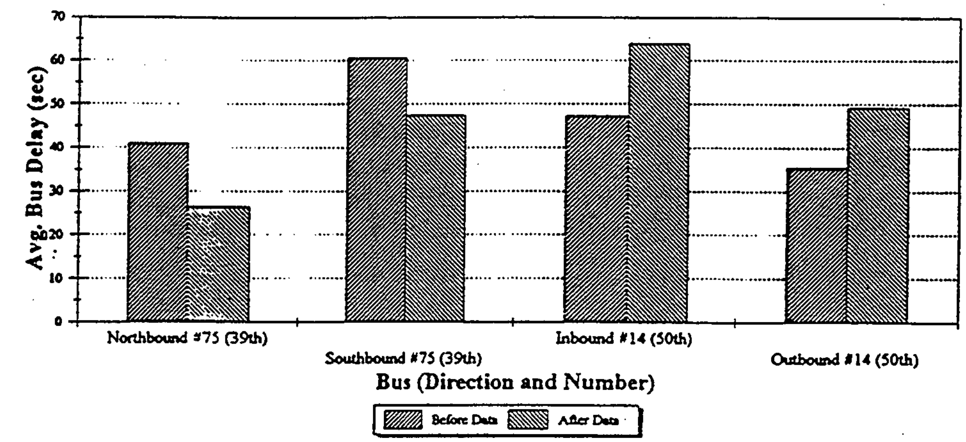
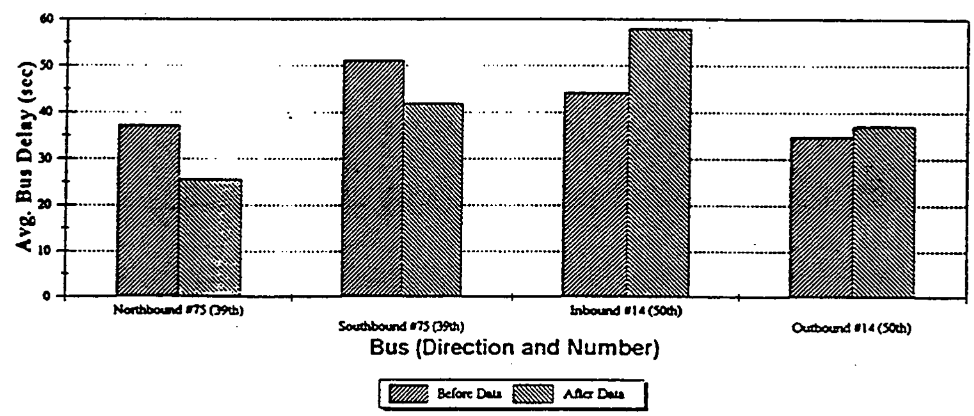


FIGURE 11 (CONT'D)
AVERAGE BUS DELAY
FOR SIDE STREET APPROACHES - WEEKDAY PEAK PERIODS

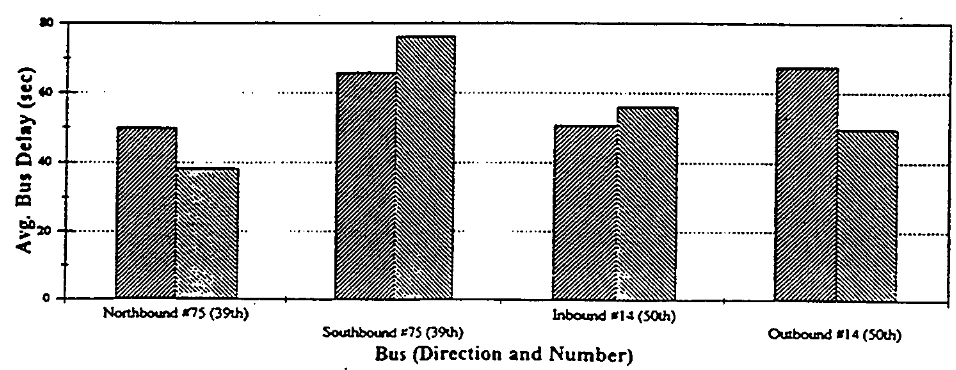
Average Bus Delay for Side Street Approaches - AM Peak Period



Average Bus Delay for Side Street Approaches -Midday Peak Period



Average Bus Delay for Side Street Approaches - PM Peak Period

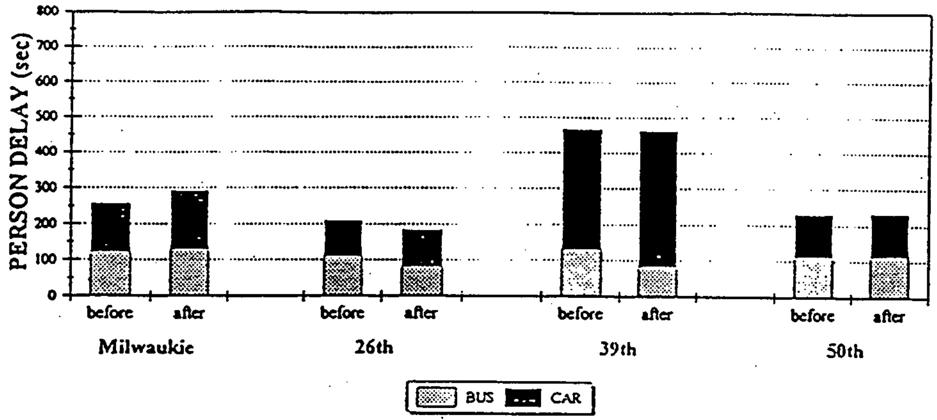


Person Delay

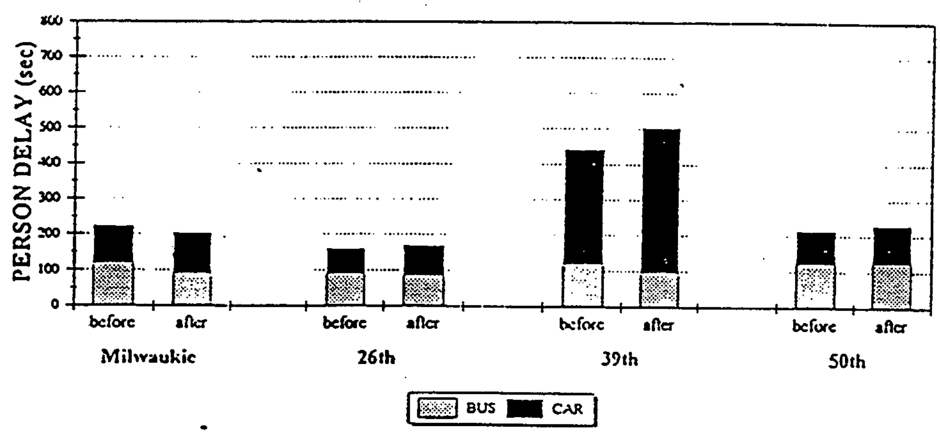
Figure 12 translates the total bus and auto vehicle delay at each intersection into person delay with and without bus signal priority, for the weekday AM, midday, and PM peak periods. The bus person delay presented represents the average person delay on both the #9 Powell line and side street bus routes at each intersection. This figure reveals a general decrease in bus person delay during the most peak periods with the signal priority, which was focused on #9 Powell line. Auto delays generally stayed the same or slightly increased with the bus signal priority.

FIGURE 12
INTERSECTION PERSON DELAY COMPARISON
WEEKDAY PEAK PERIODS

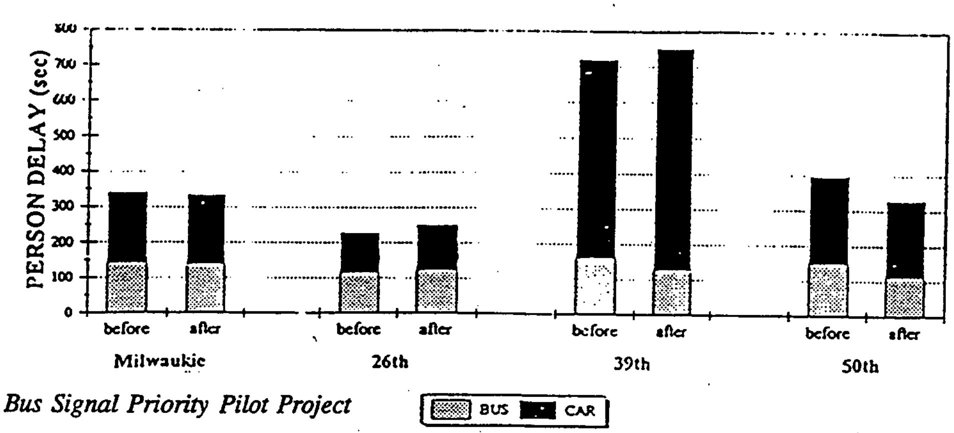
AM PEAK PERIOD



MIDDAY PEAK PERIOD



PM PEAK PERIOD



5.0 CONCLUSIONS

5.1 Equipment Performance

TOTE

Overall the results were somewhat mixed. The TOTE procurement and installation as part of the pilot project became to a large extent an equipment development project. As with any development project, problems occurred. One of the biggest problems was that no written equipment specifications were prepared. Without firm specifications, there were some misunderstandings about equipment design and expectations.

TOTE is a more complex design with several components (readers, reader interfaces, and master). This complexity can lead to additional operations and maintenance problems.

TOTE needs to provide a more reliable user interface. The lost data and difficulty in communicating between the master and the PC are fatal flaws. The interface should allow users' to verify existing master settings.

TOTE has assured Tri-Met and the City of Portland that they will rectify the problems discovered on this project. Assuming that occurs, then this could be a viable system to be considered for further installations in the Portland region.

LoopComm

The LoopComm Model 630 detectors worked simply and reliably. City of Portland maintenance staff found the units straight forward and well built. With the "Hi Gain" units, the overall performance was also improved.

One problem with LoopComm is that this equipment does not provide a total system for providing priority. An individual Model 630 detector is installed at each loop and the end user needs to provide the necessary external logic package to provide the priority call.

Other Systems

Tri-Met and the City of Portland intend to still review the applicability of Opticom as a method for calling bus priority. From a City standpoint, Opticom has an advantage in that the field equipment installed for emergency priority can perform the bus transit priority detection. However, from a Tri-Met perspective, the cost per bus is considerably higher than either TOTE or LoopComm.

5.2 Traffic Impacts of Signal Priority

The "before" and "after" traffic surveys provided data which was inconclusive as to the impacts of bus signal priority on traffic conditions. Due to the turnover in survey personnel and the need to resurvey in many locations due to missing data in the original survey, it is difficult to present a final judgement on the signal priority impacts. Two conclusions are presented for consideration, however:

1. Bus travel time on the #9 Powell line was reduced slightly in the peak direction of travel during peak periods with the bus signal priority.

2. Bus passenger delay on the #9 Powell line slightly decreased with the bus signal priority.

It is probable that the less than optimal signal timing associated with the queue jump signal at 26th Avenue could have resulted in a higher traffic delay on Powell than if the timing were optimized. It should be realized though, that the test corridor on Powell was only two miles in length, and thus the total bus travel time savings from signal priority realized might not be expected to be significant in these circumstances.

From a traffic survey perspective, it is important that more consistency in survey personnel and possible streamlined survey procedures will be required to obtain a more reliable "before" and "after" data comparison to identify the impacts of bus signal priority. This could include some automation of the vehicle delay estimation process.

5.3 Next Steps

Tri-Met is in the process of developing the fiscal year 1995 bus signal priority program with the City of Portland and other jurisdictions. It is important to properly interpret the results of this initial Powell pilot project, and with knowledge of other planning efforts which impact prospective bus signal priority development, proceed to identify a logical course of action for further priority system testing and development.

It is obvious that further pilot project work will be required before final conclusions of the impact of bus signal priority on traffic operations can be drawn. Another pilot project would no doubt enable Tri-Met and the City of Portland to test some improved survey techniques which would hopefully lead to a more reliable comparison of the data.

From the technology testing perspective, there is a desire by both the City of Portland and Tri-Met to test the performance of the latest Opticom system for bus signal priority. The City is planning to have Opticom installed at several added signalized intersections in the next five years, and there are also several Opticom installations at signals in the suburban area. Given this substantial "streetside" investment in vehicle detection equipment, it is appropriate to evaluate the latest in Opticom on-bus emitter technology to assess if this system might be applied in the future. Tri-Met recently leased 75 Opticom bus emitters from the 3M Company to conduct an Opticom bus signal priority test in the City of Portland (probably in the Lloyd District) in FY95. Tri-Met could also be testing upgraded TOTE equipment on Powell Blvd in FY95.

Tri-Met is planning to delay selecting a final bus signal priority technology until an automatic vehicle location (AVL) system for Tri-Met's bus fleet is developed (within the next two years) as part of a broader project to upgrade the agency's bus dispatch system. Until then, Tri-Met will pursue a few queue jump signal installations, probably using the LoopComm system tested on the Powell project. Overall, the LoopComm system had a superior performance to the TOTE system, and added equipment will be procured to be installed at other intersections where buses already with pucks are operating (900 bus series routes).

APPENDIX A

FIELD INSTALLATIONS BY INTERSECTION

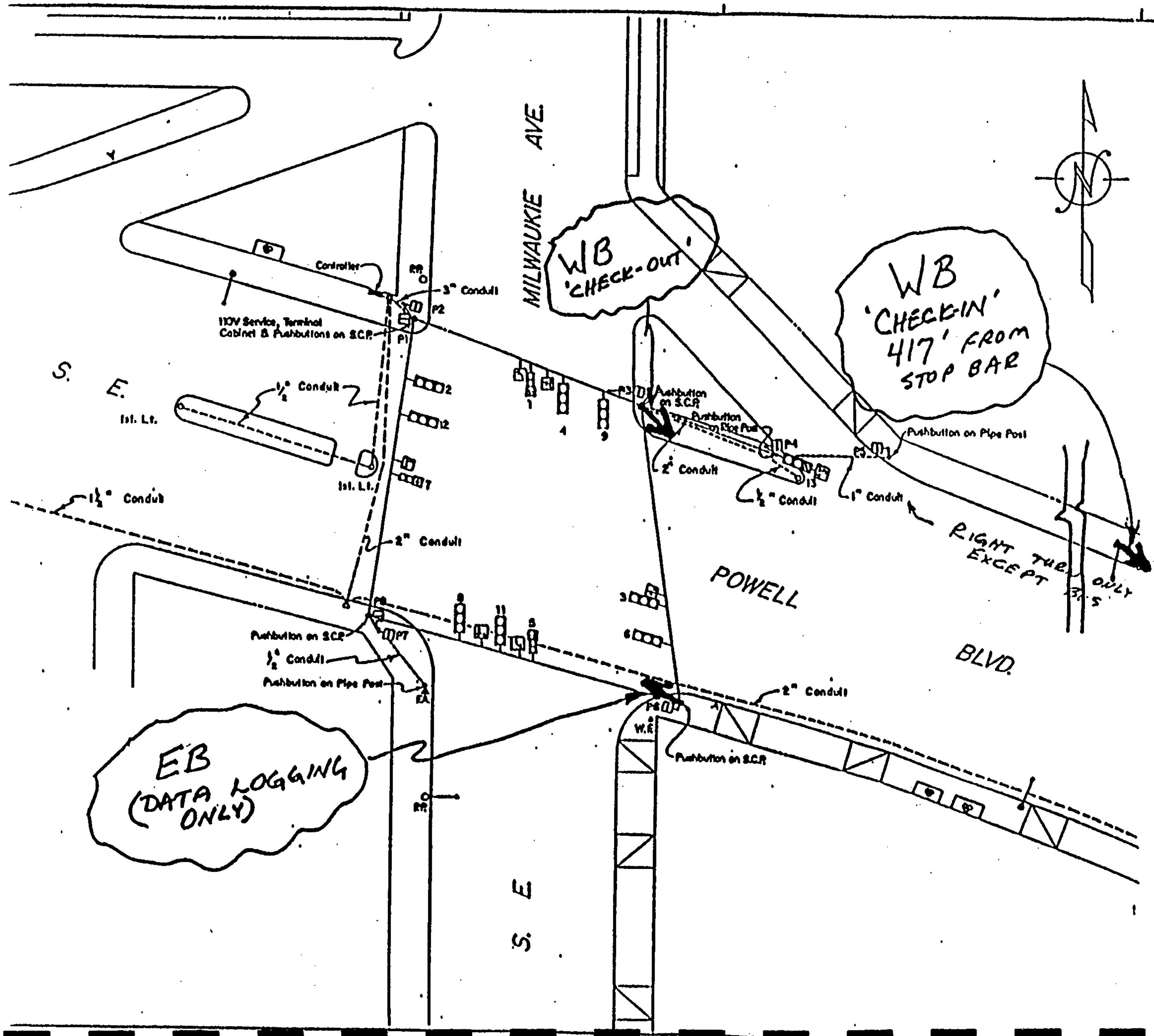


FIGURE A-1

Powell Blvd Bus Priority Pilot Project

SE POWELL BLVD & MILWAUKIE

Tote Equipment Location
(WB priority only)

READER STATION LOCATIONS:

1. Eastbound (data logging only)
   a. "data logging point" - reader on far side strain pole (reader 3)
2. Westbound
   a. "check-in" - reader on street light / strain pole 417' from stopbar (reader 1)
   b. "check-out" - reader on near side strain pole (reader 2)

OTHER NOTES:

1. Tote controller located insided existing Type 332 traffic signal controller cabinet.
2. EB reader is for data logging only.

Revised November 30, 1993

PL-4-065

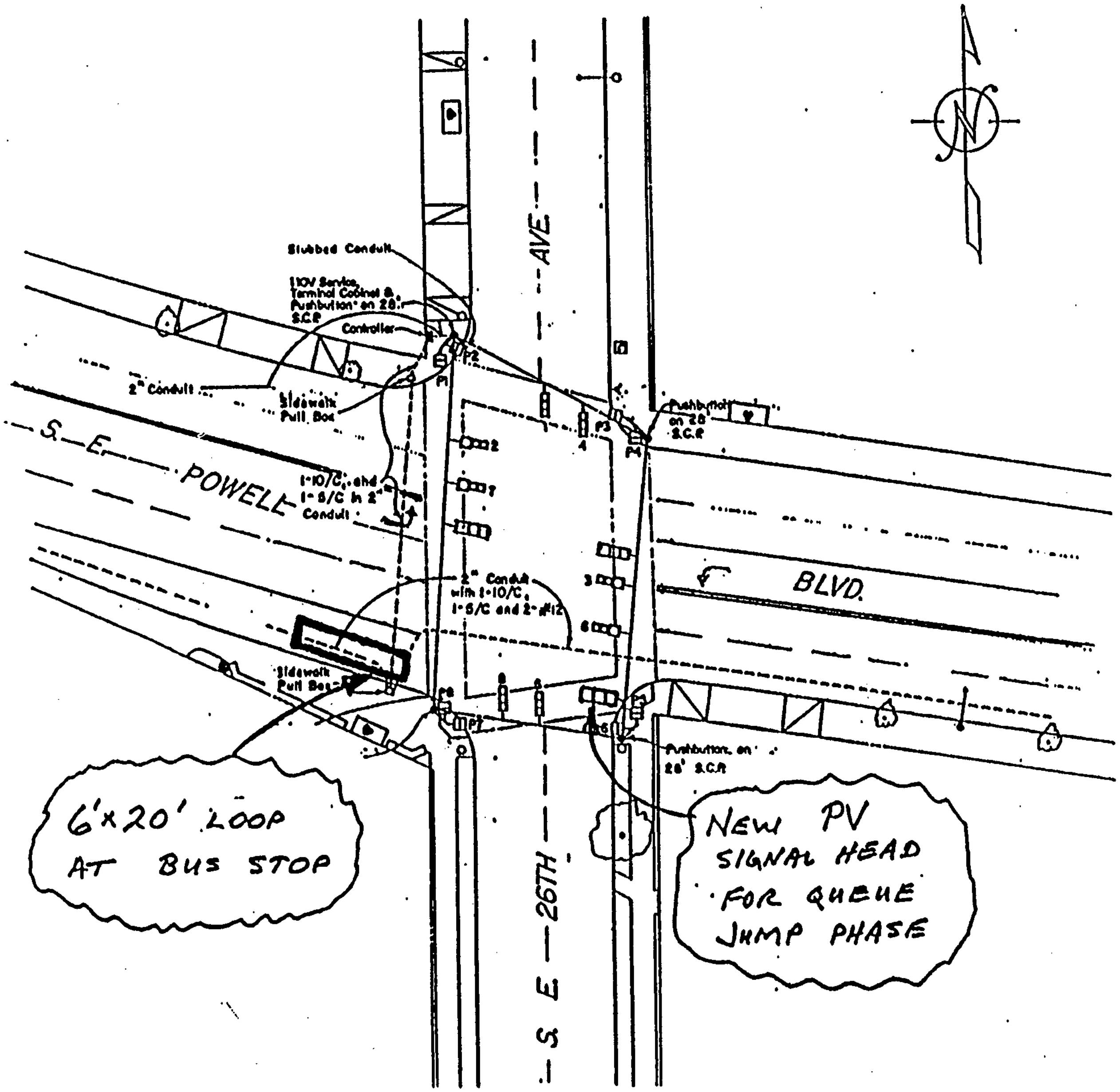


FIGURE A-2

Powell Blvd Bus Priority Pilot Project

SE POWELL BLVD & 26TH

Detector Systems Equipment Location
(EB queue jump only)

1. New 6'x20' long loop in existing EB right turn only lane at bus stop.

2. New programmed visibility signal head on EB span for EB right turn only / bus lane. (Overlap A = phase 7 + phase 2).

Revised November 30, 1993

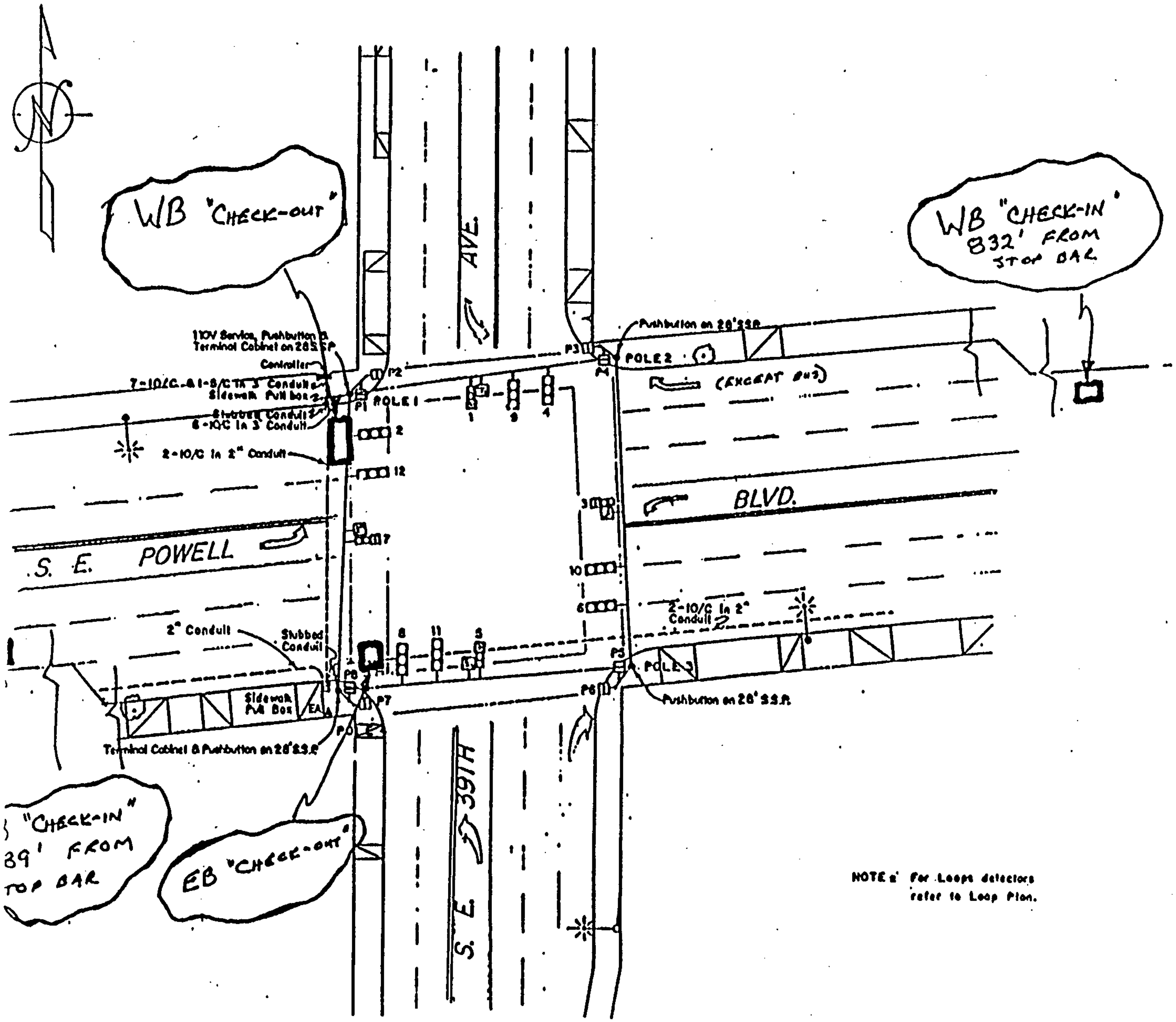


FIGURE A-3

Powell Blvd Bus Priority Pilot Project

SE POWELL BLVD & 39TH

Detector Systems Equipment Location (EB & WB Priority)

LOOP DETECTOR LOCATIONS:

1. Eastbound
   a. "check-in" - 6'x6' in curb lane 589' from stopbar (loop 1)
   b. "check-out" - 6'x6' in right lane on the near side of the intersection (loop 2)
2. Westbound
   a. "check-in" - 6'x6' in curb lane 832' from stopbar (loop 3)
   b. "check-out" - 6'x17' in right two lanes on the far side of the intersection (loop 4)

OTHER NOTES:

1. Requires 4 LoopComm 630 detectors.
2. Includes external logic package in Type 170 controller to provide 6 HZ input to EV input. Also includes programmable MAX timer.

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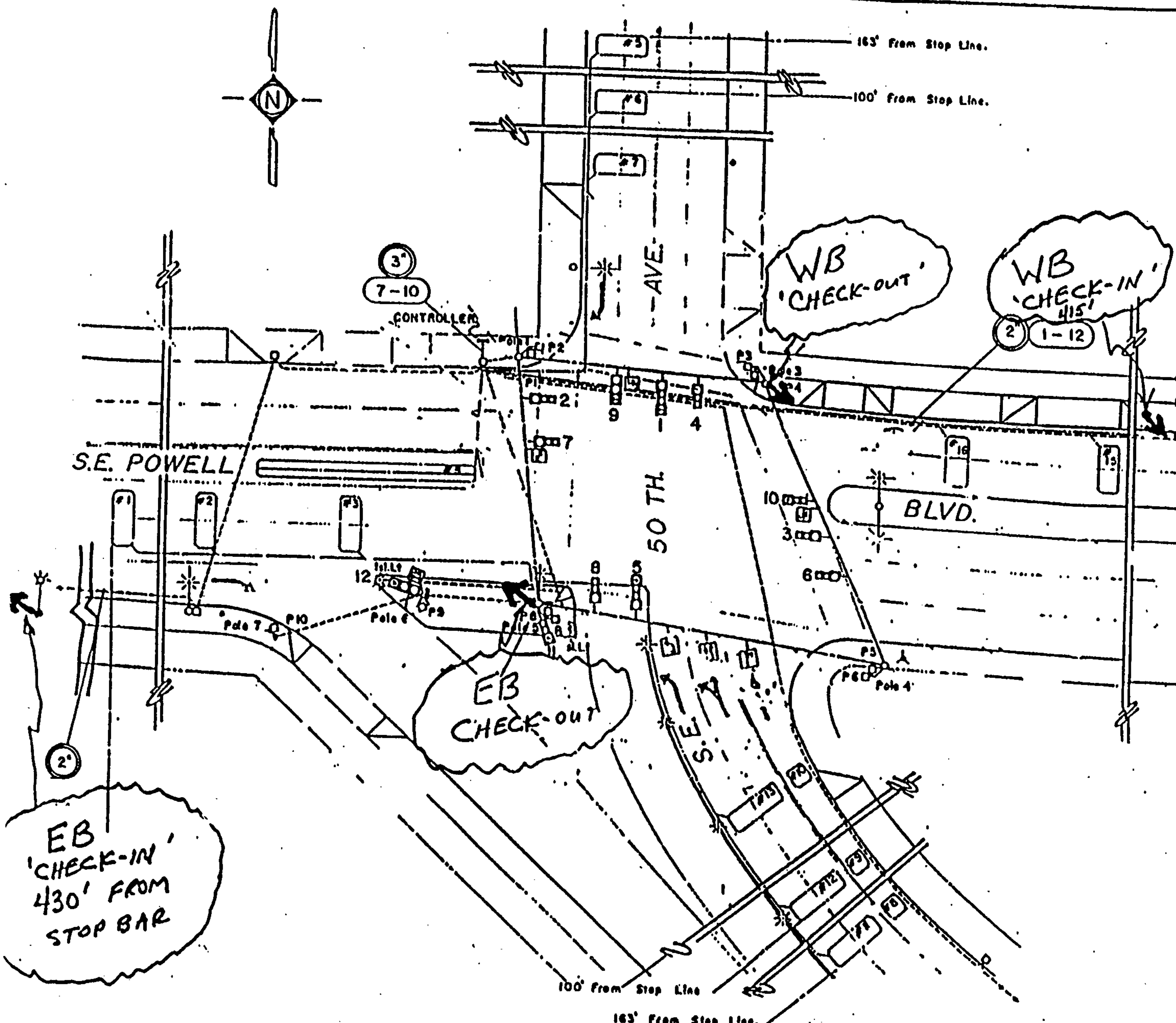

FIGURE A-4

Powell Blvd Bus Priority Pilot Project

SE POWELL BLVD & 50TH

Tote Equipment Location
(EB & WB Priority)

READER STATION LOCATIONS:

1. Eastbound
   a. "check-in" - reader on street light pole 430' from stopbar (reader 6)
   b. "check-out" reader on near side strain pole (reader 7)
2. Westbound
   a. "check-in" - reader on utility pole 415' from stopbar (reader 4)
   b. "check-out" reader on near side strain pole (reader 5)

OTHER NOTES:

1. Tote controller located insided existing Type 332 traffic signal controller cabinet.

Revised November 20, 1993

PL-4-07

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National Technical Information Service
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