# Traffic Signal Priority (TSP)
# and
# Automatic Vehicle Tracking System
# (AVTS)
# For Calgary Transit Buses

(Project #2001-06)

**Calgary Transit**

**Transit Planning**

**2004 July**

## Introduction

The purpose of this report is to document the progress and benefits achieved by Calgary Transit related to the installation of Transit Signal Priority (TSP) and Automatic Vehicle Tracking System (AVTS) technology. Funding assistance for these projects was provided under the Transport Canada Intelligent Transportation Systems (ITS) Deployment and Integration Plan.[1]

## Background

In 1995, the Calgary Transportation Plan (CTP) was approved by Calgary City Council to replace the City's previous transportation plan. The CTP addresses projected transportation needs for Calgary as it expands to a population of 1.25 million and beyond. The overall objective of the CTP is to achieve a balance between community and environmental quality, providing mobility and minimizing costs. Key policies of the CTP are to:

- Encourage increased use of other forms of transportation, particularly public transit. The plan recognizes that improvements to transit service frequency and speed of travel are required to make transit a more attractive mode of travel.
- Minimize new road construction and maximize the use of the existing transportation infrastructure.
- Manage the supply of parking in the downtown
- Manage growth and encourage higher density, mixed use developments with pedestrian and transit friendly design.
- Promote transportation demand management concepts including carpooling, flextime, teleworking and implement carpooling

To enable Calgary Transit to play an increasing role in serving the needs of Calgarians, the CTP recognizes that significant expenditures are required to increase the attractiveness of travel by transit. This includes continuing the expansion of the Light Rail Transit (LRT) system and bus route network, providing more frequent transit service, decreasing transit travel times, providing transit priority, and continuing to provide a reliable service.

During the 1990s Calgary Transit achieved a significant increase in ridership and a growing share of the Calgary travel market, particularly for travel to work. These gains were the result of improved transit service, increased costs associated with driving/parking and positive changes in the economy. It was recognized that to maintain

[1] This report is provided to satisfy the terms of the Contribution Agreement between Her Majesty The Queen In Right of Canada and The City of Calgary dated 14 August, 2002 for Project #2001-06.

this trend and achieve the CTP objectives, additional transit improvements, particularly those aimed at increasing the speed and reliability of transit travel were required. However, recent rapid growth and the lack of sufficient capital funding for transportation improvements has resulted in increasing travel delays related to traffic congestion. Calgary Transit customers have experienced slower bus travel times, reduced service reliability and crowded transit vehicles.

## Calgary Transit ITS Projects

In 2000, Calgary Transit initiated a several projects intended to decrease transit travel time and improved service reliability. These initiatives included:

- A High Occupancy Vehicle (HOV) lane on Centre Street North (see Figure 1).
- Traffic Signal Priority (TSP) measures for buses.
- Replacement of the Automatic Vehicle Tracking System (AVTS) for buses.
- Retiming of downtown traffic signals to reduce LRT delays in the downtown

In 2000, The City of Calgary selected Opticom™[2] as a means of detecting an approaching bus and modifying traffic signal operation (extended green and truncated red). Opticom ™ was already in use by the Calgary Fire Department to obtain full traffic signal preemption along major fire response routes. As a first phase of the Calgary Transit TSP program, seven signalized intersections and sixty Calgary Transit buses were equipped with Opticom™ detectors and emitters (respectively) as part of the Centre Street HOV lane. The HOV lane opened in 2000 September and TSP was introduced on downtown express buses serving North Calgary (see Figure 1).

Also in 2000, Calgary Transit began to replace its Automatic Vehicle Tracking System (AVTS) that had been providing bus passenger counting and schedule adherence tracking since 1985. The previous system became obsolete due to Y2K non-compliance. A new AVTS was purchased from Infodev EDI Inc (Canada)[3] .

A study to identify and resolve LRT delays in the downtown was successfully completed in 2003.

The TSP and AVTS projects have been implemented in phases. The initial phase of each project provided some operating experience so that the effectiveness of the technology could be evaluated. A phase 1 evaluation of the TSP installation indicated that peak period express buses were achieving travel time saving of about 15 percent on Centre Street North in the HOV lane. Phase 1 of the AVTS installation had shown that the equipment was able to collect very accurate (98%) passenger count and schedule adherence data. However, to increase the utility of the AVTS, software

[2] Opticom is a trademark of 3M Inc.
[3] Infodev, Electronic Designers Inc, Sainte-Foy, Quebec

development was required to automate report generation. As well, additional AVTS equipped buses were required to increase data collection capabilities.

## Transport Canada ITS Deployment and Integration Plan

In 2002, Calgary Transit was awarded a $250,000 grant to assist with the Phase 2 expansion of the TSP and AVTS programs during 2002 and 2003. The following is a brief description of these programs and their outcomes.

It is important to recognize that the information gathered for this report represents the first opportunity to examine the performance of the Phase 2 development of these systems. The TSP installation was mostly completed in late 2003, however, dry pavement / non-winter driving conditions, required to conduct a comparative analysis, were not present until late 2004 March. Until recently, the AVTS data could not be easily accessed due to software development difficulties.

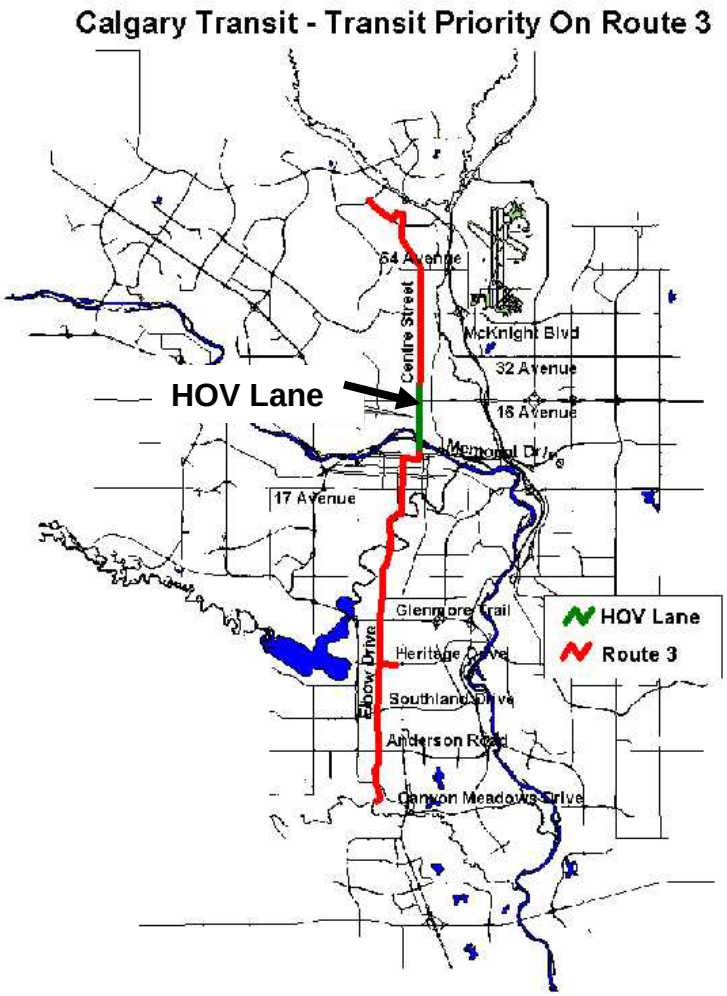
### *1. Traffic Signal Priority*

Figure 1 illustrates the scope of the TSP project and how it functions. Buses equipped with an Opticom™ emitter are detected by an Opticom™ detector mounted next to a traffic signal. When a bus is detected, the traffic signal operation is modified to provide an extended green or a truncated red signal. Depending on the operating phase of the traffic signal, bus priority time can be up to 20 seconds.

The Phase 2 expansion of TSP is intended to provide buses on Route 3 – Sandstone Elbow Drive with fewer delays, decreased travel time and a more reliable operation. Route 3 connects communities in north and south Calgary with the Downtown (see Figure 1). Route 3 is one of the most popular bus routes in Calgary carrying approximately 21,000 weekday passengers. In 2001, a travel study found that Route 3 buses experienced average total delays of approximately 17 minutes during a 160-minute round trip (54 kilometres) due to stops at traffic signals. The study found that during an average round trip, Route 3 buses stopped at 44 percent of the 47 traffic signals outside of the downtown core (there are now 50 traffic signals).

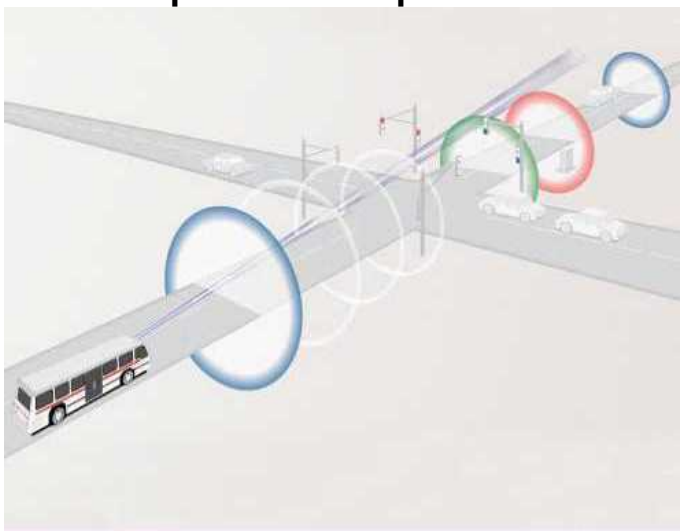
Since in 2002, Calgary Roads, Traffic Signals Division have installed Opticom™ detectors at 31 traffic signals on Centre Street N. and Elbow Drive. Most of the Phase 2 installations were completed in late 2003 with the final work being completed in April 2004. A total of 38 traffic signals (including 7 from Phase 1) now provide bus priority for Route 3 and the north Calgary express bus routes. The remaining 12 signals along Route 3 have not been equipped since they are either part of the downtown traffic signal plan or there is pending major construction at these intersections.

**Figure 1**




Route 3
54 km
round trip
connecting
north and
south
Calgary
with the
downtown

## Opticom TM Operation



The bus sends an infrared signal to the traffic signal as it approaches. The traffic signal responds by extending the green or shortening the red. The signal returns to normal operation after the bus passes through the intersection.

To support this initiative, Calgary Transit has been installing Opticom™ emitters on all new buses added to the fleet since 2002. A total of 150 of Calgary Transit's 750 buses are now equipped with Opticom™.

## *1.1 TSP Project Findings*

Travel time studies on Route 3 were conducted prior to and following the implementation of TSP. The before and after studies were conducted by staff who recorded the number and duration of stops at traffic signals. The result of these studies is shown in Table 1.

**Table 1**

**Route 3 Opticom TM Analysis**

**Comparison of Before and After Travel Data**

| | Signal Stops | | | Signal Delays (seconds) | | |
|---|---|---|---|---|---|---|
| | **North Section** | **South Section** | **Total** | **North Section** | **South Section** | **Total** |
| **Before** | | | | | | |
| **Northbound** | 8 | 8 | 15 | 175 | 192 | 367 |
| **Southbound** | 7 | 8 | 16 | 165 | 211 | 375 |
| **Total Before** | **15** | **16** | **31** | **340** | **402** | **742** |
| **After** | | | | | | |
| **Northbound** | 6 | 6 | 12 | 163 | 189 | 352 |
| **Southbound** | 3 | 6 | 9 | 91 | 177 | 269 |
| **Total After** | **9** | **12** | **21** | **254** | **367** | **621** |
| **Changes** | | | | | | |
| **Northbound** | -2 | -2 | -4 | -12 | -2 | -14 |
| **Southbound** | -4 | -2 | -6 | -73 | -33 | -107 |
| **Total** | **-6** | **-4** | **-10** | **-85** | **-36** | **-121** |
| | | | | | | |
| **Percent Change** | **-38%** | **-25%** | **-32%** | **-25%** | **-9%** | **-16%** |

Before Studies done in 2001 May
After Studies done in 2004 Mar/Apr/May

These data indicate that the number of stops due to traffic signals has been reduced by 32% while the time spent stopped at traffic signals has been reduced by 16% or about two minutes per round trip. The data also indicates that the improvements were more significant within the north section of the route. As well, the reduction of traffic related signal stops and total time stopped was greater in the southbound direction. This suggests that fine-tuning of the traffic signals or the Opticom™ detection may yield further improvements.

**Schedule Adherence Benefits**

In addition to fewer and shorter delays, the installation of Opticom™ on Route 3 has provided improvements in service reliability. Schedule adherence data collected using AVTS equipped buses is summarized in Table 2[4]. These data show that AVTS buses equipped with TSP had a 9% higher level of schedule adherence than AVTS buses without TSP. Further evidence of the value of TSP is that Calgary Transit Operators (drivers) now lodge complaints if they don't receive a TSP equipped bus for their work on Route 3. The Operators are more confident of being able to keep their bus on schedule if they have TSP. This may explain the fact that there is less likelihood of an Operator of a TSP equipped bus leaving early from a time point (see Table 2).

**Table 2**
**Route 3 Schedule Adherence**

| | Leave Early | Leave Late | On Time |
|---|---|---|---|
| **TSP Buses** | 10% | 10% | **80%** |
| **Non TSP Buses** | 18% | 12% | **71%** |

Based on 2,678 records.

As noted previously, these data have not been analyzed by Calgary Transit scheduling staff to determine if improvements can be made to Route 3 service. Currently, Calgary Transit drivers use the travel time saved to extend layovers at time points and transfer locations. In the future, reduced delays at traffic signals will certainly hedge increasing delays due to traffic congestion on these roads.

**Mechanical Benefits**

Reduced stopping and starting of buses at traffic signals also contributes to the reduction of vehicle maintenance costs (increased life of brakes and vehicle driveline components). No data is available to assess the value of this benefit.

[4] Some AVTS buses are also equipped with TSP

**Environmental Benefits**

TSP also contributes environmental benefits from lower fuel consumption and greenhouse gas emissions as a result of the reduction of times that a bus must accelerate from a stop. Engine / bus performance data[5] indicate that an average reduction of 10 stops and starts at traffic signals on Route 3 will produce a net diesel fuel saving of approximately one percent per round trip. Based on typical fuel consumption, this equates a reduction of approximately 0.2 litres of fuel and emission savings of 0.59 kg of $CO^2$ per trip.

On an annual basis Route 3 buses make approximately 38,000 round trips. Therefore, the fuel saving is estimated at about 7,600 litres and a reduction of $CO^2$ emissions of approximately 22,000 kg on an annual basis. At current fuel prices the value of the fuel saved is approximately $4,600 per year. This saving will offset some of the costs associated with Opticom™ installation.

## *2. Automatic Vehicle Tracking System*

The purpose of the AVTS is to enable the efficient collection of data to monitor bus route performance – passenger boardings and schedule adherence. These data can be used to identify opportunities for service changes that will result in a more responsive and reliable service.

Prior to the replacement of the previous AVTS, Calgary Transit had considerable experience in using passenger count and vehicle tracking data as a tool to plan and schedule bus service. In the past, this type of data had been collected manually, but, given the size of the transit system and the amount of data required, manual collection and tabulation of this type of information would be prohibitively expensive and the information would not be timely.

A number of passenger counting and bus tracking products were evaluated. A system developed by Infodev[6] was judged as being best able to meet the needs of Calgary Transit. Software development was required to integrate the data collected by the AVTS with Calgary Transit Calgary Transit scheduling and customer information systems. This integration was required to minimize the manual intervention required to match the data collected with bus assignments / schedules. It should be noted that Calgary Transit did not pursue the purchase of a system that would provide ‘real time’ information due to the cost and complexity involved with implementing such a system. To be effective, a real time system would require equipping the entire bus fleet and adding staff to monitor the information.

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[5] Data is from Detroit Diesel Engine Control fuel consumption data for a 12 metre low floor bus accelerating from a stop to a speed of 40 km/hr net of the fuel consumed by a bus travelling at constant speed of 40 km/hr over the same distance.

[6] [6] Infodev, Electronic Designers Inc, Sainte-Foy, Quebec

As note previously, Phase 1 of the AVTS project involved equipping 16 buses with passenger counting and tracking equipment. This system uses GPS to track bus movements and infrared technology to count transit passengers getting on and off the bus. A microprocessor on the bus stores data regarding the location and time of bus stops, schedule adherence and passenger 'ons' and 'offs'. The data is then downloaded to a central computer when the bus returns to the garage (see Figure 2). Additional information about this system is available at www.infodev.ca.

Phase 2 of the AVTS program was intended to increase the number of AVTS equipped buses from 16 to 36. The expanded AVTS fleet would enable AVTS buses to be rotated through most of Calgary Transit's 175 bus routes on a regular basis. As well, Infodev was engaged to develop more comprehensive software reporting required to automate the summary and retrieval of the large amount of data collected each day.

Delays were experienced in the completion of the customized data analysis software. Over a three-year period, Calgary Transit and Infodev spent considerable time working on software development. This was a difficult task since it required the meshing of records from several software packages used by Calgary Transit to create schedules, map transit routes and provide customer information.

In mid 2003, due to a capital funding shortage and software development difficulties, the scope of the AVTS project was reduced and only 8 additional buses were equipped. In early 2004, the software difficulties were resolved.

## Figure 2

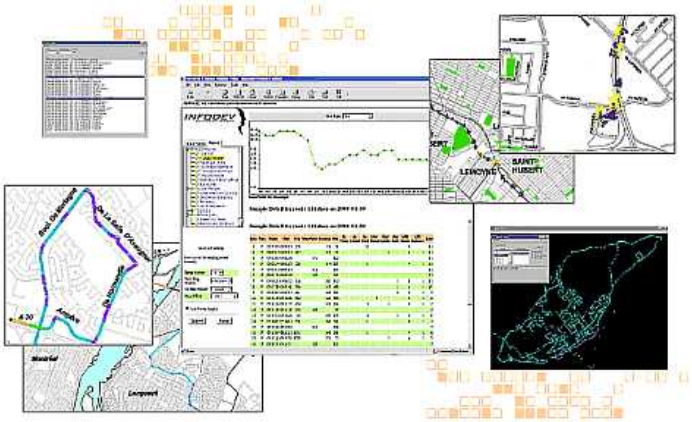
## AVTS
## Vehicle Tracking and Passenger Counting System Operation


Passenger ons and offs are recorded at each stop.

GPS determines the location bus at stops or scheduling time points.

A microprocessor on the bus stores passenger and locational data.

Data downloaded from the bus is used to create a variety of reports.



Phase 2 of the AVTS project is now complete with 24 buses equipped with AVTS. System software is now able to create a variety of reports. This information is summarized below and examples of some of the system reports are provided in Appendix 1.

- Stop By Stop – ons and offs at each bus stop help planners to determine customer requirements at a stop such as the need for a shelter or an information display. This data can also be used when planning service changes that may require skip-stop operation.

- Passenger Load Profile - indicates the number of passengers on the bus as it moves along the route. This data is used by schedulers to determine where bus overloads can be addressed by inserting additional service.

- Schedule Adherence – A comparison between actual and schedule bus arrival and leave times. This data provides an assessment of service reliability and helps to determine common areas where Operators experience difficulty in maintaining the schedule. A comparison of schedule adherence and passenger activity can determine if passengers boardings are the source of delays.

- Dwell Time – This report provides a summary of the time a bus is stopped at various locations along a route. This data is useful in analyzing 'lay over' time that could be used to extend a route or adjust schedules.

- Travel Time Between Time Points (no example provided) – provides data on the actual time required to travel from point to point on a route during different time periods (peak, off peak, weekends, etc). This will assist in creating schedules that better match changing traffic congestion and passenger demand conditions.

These data can also used in conjunction with the City of Calgary's Geographic Information System to create maps that depict passenger load and schedule adherence profiles.

## Conclusion

The implementation of these ITS projects has involved the installation and learning of new systems and technologies. In the case of AVTS, integration with the output from other suppliers' products required additional time and effort. The Phase 2 installation of both projects is now complete. Fine-tuning and modification is still required to achieve optimal results. The data presented in this report indicate promising benefits.

TSP enables Calgary Transit to offer improved service to Route 3 customers with fewer stops and improved schedule reliability. As well, TSP contributes to lower vehicle operating costs and reduced emissions.

Calgary Transit, the Calgary Fire Department and Calgary Roads plan to continue adding TSP capabilities at traffic signals along other major bus corridors and fire response routes. All Opticom™ installations provide dual priority, i.e. full preemption for fire trucks and priority for buses. Calgary Transit is equipping all new buses with TSP and will soon be able to dispatch TSP equipped buses on other major routes including new Bus Rapid Transit (BRT) service that will commence in 2004 September.

Calgary Transit planners and schedulers have begun to work with the AVTS data and reports. While no service adjustments can yet be attributed to the data provided by this system, it is recognized that the AVTS provides a significant benefit in terms of the ability to collect and analyze route performance data. The AVTS enables the data to be collected transparently and in sufficient volume to permit meaningful analysis. The cost of collecting and tabulating this volume of data manually would be prohibitive.

Table 3 provides a summary of the projected and actual costs for these two projects.

**Table 3**

| TSP and AVTS Project Schedule and Actual Costs - 2002 / 2004<br>Phase 2 | | | |
|---|---|---|---|
| | **Task** | **Projected Cost** | **Actual Cost** |
| **Proposed** | | | |
| **TSP** | Equip approximately 10 Centre Street Intersections with new traffic signal controllers where required, plus install Opticom transit signal priority detectors and signal controller interface.<br><br>Equip approximately 20 intersections on Elbow Drive, 4 and 5 Streets SW with new traffic signal controllers (where required), plus install Opticom transit signal priority detectors and traffic signal controller interface. | $400,000 | |
| **Actual** | | | |
| | Equip 31 intersections on Centre Street, Elbow Drive, 4 and 5 Streets SW with TSP detectors and traffic signal controller interface | | $420,696 |
| **Proposed** | | | |
| **AVTS** | Equip 20 transit buses with automatic GPS vehicle locator equipment | $100,000 | |
| **Actual** | | | |
| **AVTS** | Equip 8 buses with AVTS<br>(project reduced in scope due to initial software difficulties and other funding requirements) | | $52,825 |
| | **2002 to 2004 Costs** | **$500,000** | **$473,521** |

# Appendix 1

# Sample of AVTS Reports

## Stop By Stop Report

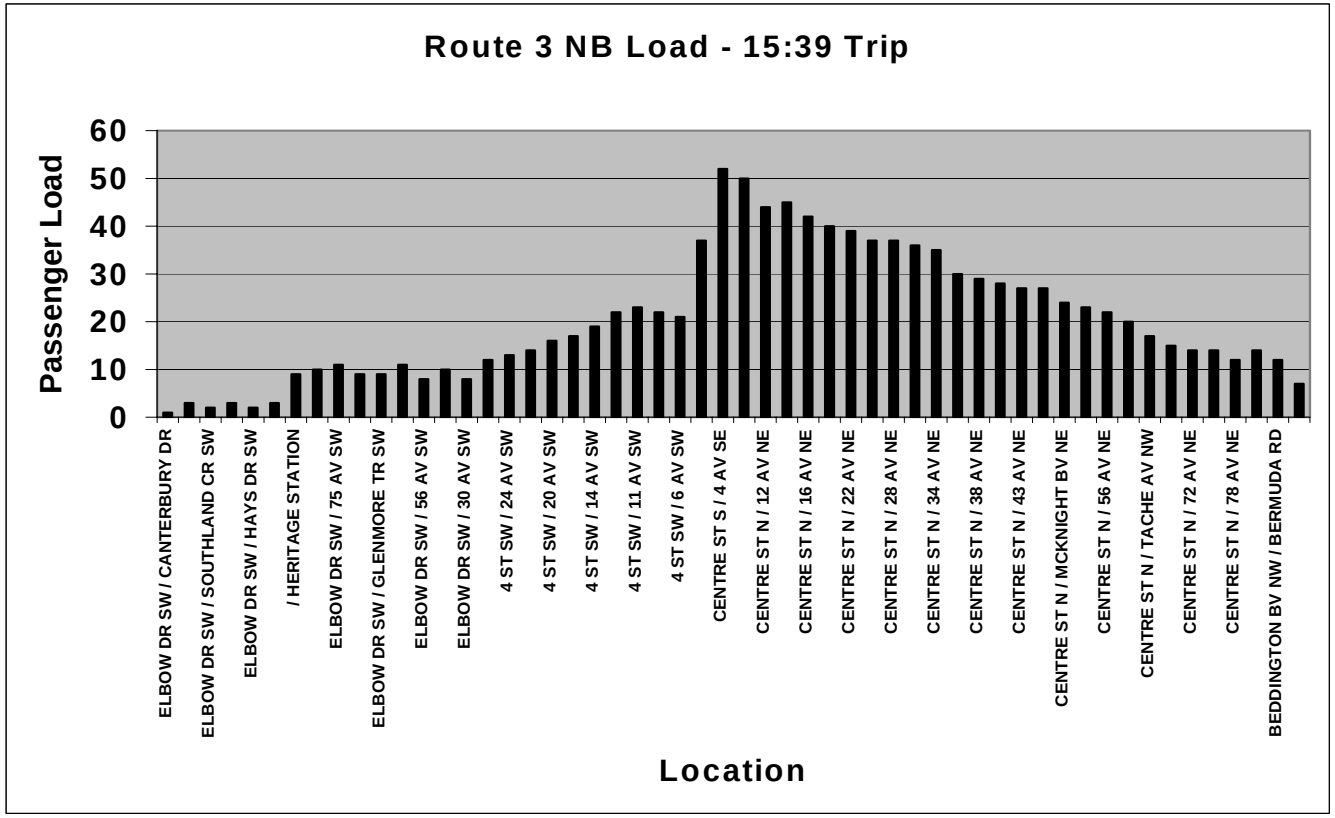
This report provides a summary of all data collected by the bus. Reports on subsequent pages illustrate some uses of this data.

### Route 3 Key 6

| Bus # | Rte | Date | Day | Stop | Dwell Type | Actual Time | Schedule Time | Dwell Time | Odom | Arr Load | Ons | Offs | Leave Load | Node # | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7801 | 3-I-6 | 04/08/2004 | Thu | 49 | H | 5:55:22 | 5:55:00 | 0:22 | 0 | 0 | 6 | 0 | 6 | 10B053 | 4 ST SW / 23 AV SW |
| 7801 | 3-I-6 | 04/08/2004 | Thu | 53 | H | 5:57:54 | 5:58:00 | 0:19 | 0.96 | 6 | 3 | 2 | 7 | 09B010 | ELBOW DR SW / 30 AV SW |
| 7801 | 3-I-6 | 04/08/2004 | Thu | 63 | P | 6:01:31 | 6:01:00 | 0:17 | 2.94 | 7 | 10 | 1 | 16 | 04B015 | ELBOW DR SW / 49 AV SW |
| 7801 | 3-I-6 | 04/08/2004 | Thu | 69 | P | 6:05:51 | 6:04:00 | 0:13 | 4.74 | 16 | 2 | 8 | 10 | 28A032 | ELBOW DR SW / GLENMORE TR SW |
| 7801 | 3-I-6 | 04/08/2004 | Thu | 71 | P | 6:06:44 | 6:06:00 | 0:09 | 5.08 | 10 | 1 | 8 | 3 | 28A026 | ELBOW DR SW / 70 AV SW |
| 7801 | 3-I-6 | 04/08/2004 | Thu | 76 | H | 6:09:01 | 6:09:00 | 0:39 | 6.24 | 3 | 0 | 0 | 3 | 21A016 | HERITAGE DR SW / ELBOW DR SW |
| 7801 | 3-I-6 | 04/08/2004 | Thu | 78 | P | 6:13:19 | 6:11:00 | 2:54 | 6.85 | 3 | 1 | 3 | 1 | 21A044 | / HERITAGE STATION |
| 7801 | 3-I-6 | 04/08/2004 | Thu | 83 | P | 6:17:11 | 6:17:00 | 0:08 | 8.29 | 1 | 0 | 1 | 0 | 21A008 | ELBOW DR SW / 89 AV SW |
| 7801 | 3-I-6 | 04/08/2004 | Thu | 94 | P | 6:23:18 | 6:23:00 | 0:14 | 11.13 | 0 | 3 | 0 | 3 | 09A023 | ELBOW DR SW / CANTERBURY DR |
| 7801 | 3-I-6 | 04/08/2004 | Thu | 96 | H | 6:25:11 | 6:25:00 | 0:58 | 11.55 | 3 | 7 | 0 | 10 | 09A025 | ELBOW DR SW / CANATA CL SW |
| 7801 | 3-I-6 | 04/08/2004 | Thu | 100 | P | 6:31:12 | 6:30:00 | 0:16 | 12.99 | 10 | 0 | 10 | 0 | 04A035 | ELBOW DR LOOP |
| 7801 | 3-I-6 | 04/08/2004 | Thu | 102 | H | 6:32:42 | 6:32:00 | 0:17 | 13.49 | 0 | 8 | 0 | 8 | 09A059 | ELBOW DR / CANYON MEADOWS DR |

## Passenger Load Profile

This graph displays the passenger load on a Route 3 bus as it proceeds along its route.



## Schedule Adherence

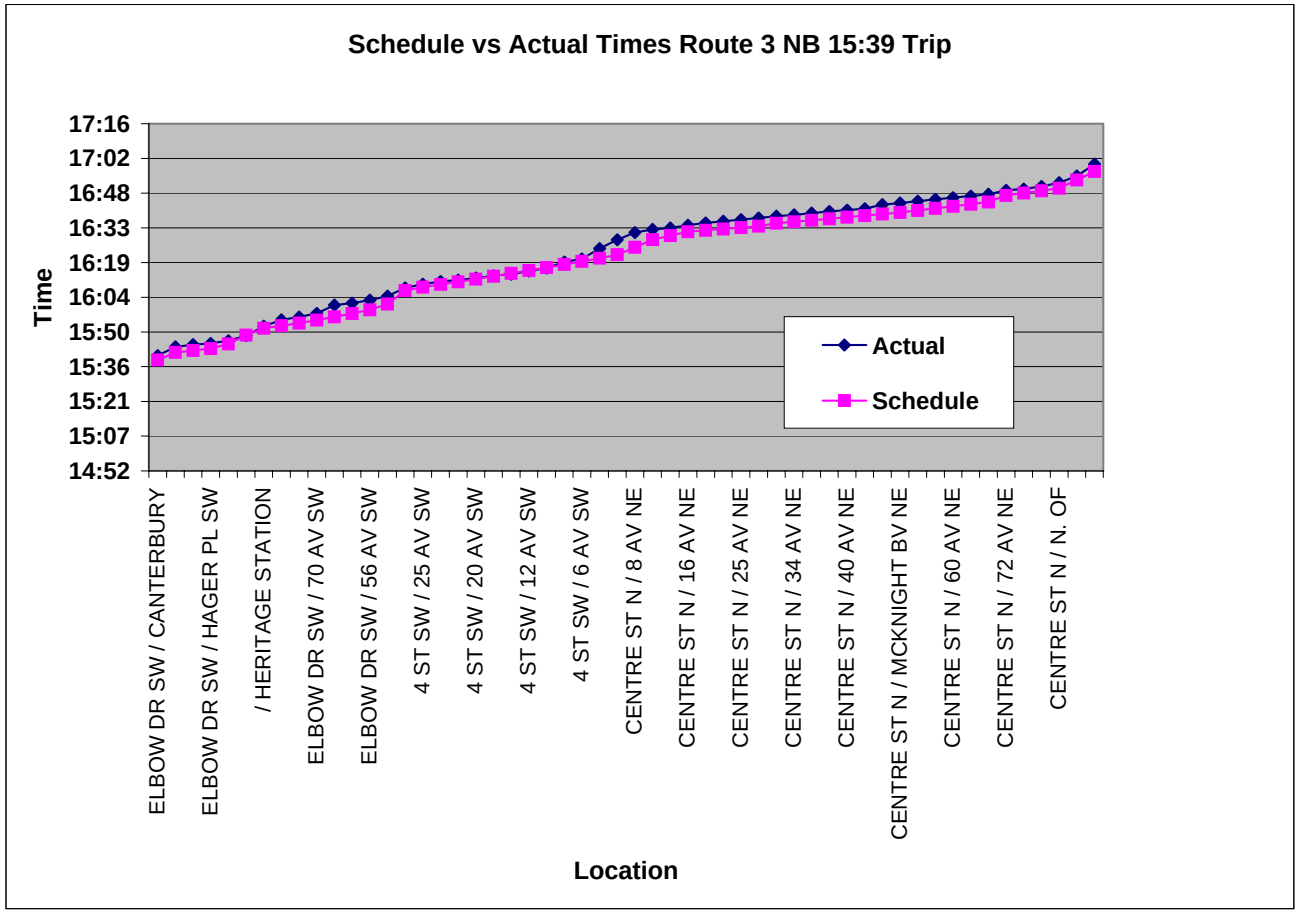
The following report provides a summary of all AVTS buses assigned to Route 3 during the week of April 12, 2004

**Schedule Adherence Summary**

| Route 3 | April 8 to 23, 2004 | | |
|---|---|---|---|
| **Category** | **Definition** | **Records** | **Percent** |
| Leave Early | > 60 second to 120 second early | 30 | 2% |
| Leave Very Early | > 120 second early | 40 | 2% |
| Leave Late | > 180 second to 300 second late | 91 | 5% |
| Leave Very Late | > 300 second late | 6 | 0.3% |
| | **On Time Records:** | 1644 | 91% |
| | **Total Records:** | 1811 | 100% |

## Schedule Adherence Profile

This graph displays a comparison between the scheduled and actual leave times from Route 3 time points.
The graph shows that the bus is **late** if 'Actual' times appear above the 'Schedule' times. The bus is **early** if 'Actual' times are below 'Schedule' times.



## Dwell Time

This graph shows the time that a bus on a Route 3 trip spent ‘dwelling’ or stopped at locations along a trip.