# TABLE OF CONTENTS

1 Executive Summary ........................................................................................................ 1
   1.1 Introduction ......................................................................................................................... 1
   1.2 Purpose and Goals ............................................................................................................... 1
   1.3 Analysis Methodology ........................................................................................................ 1
   1.4 Implementation Results ....................................................................................................... 4
   1.5 Lessons Learned ................................................................................................................ 10
   1.6 Conclusion ......................................................................................................................... 11

2 Introduction ................................................................................................................... 12
   2.1 Project Description ............................................................................................................ 12
   2.2 Project Study Area ............................................................................................................. 13
   2.3 Project Team ...................................................................................................................... 15
      2.3.1 System Evaluation ................................................................................................... 15
      2.3.2 Implementation ........................................................................................................ 15
      2.3.3 Benefits Evaluation ................................................................................................. 16
   2.4 Project Goals and Objectives ............................................................................................. 17
      2.4.1 Goal 1: Improve performance of existing system ................................................... 17
      2.4.2 Goal 2: Provide a reliable system ........................................................................... 17
      2.4.3 Goal 3: Provide a user friendly system ................................................................... 17
      2.4.4 Goal 4: System shall be expandable for the rest of the region ......................... 17
      2.4.5 Goal 5: Implement a cost effective traffic signal system ..................................... 18
   2.5 System Description ............................................................................................................ 18
      2.5.1 Time of Day Coordinated Signal System .......................................................... 18
      2.5.2 Adaptive Signal System ...................................................................................... 19
      2.5.3 Sydney Coordinated Adaptive Traffic System (SCATS) Operation ................... 20
   2.6 Evaluation Purpose ............................................................................................................ 22
   2.7 Evaluation Approach ......................................................................................................... 22
   2.8 Previous Evaluation Documents ........................................................................................ 24
   2.9 Structure of Report ............................................................................................................ 24

3 Benefits Analysis ........................................................................................................... 25
   3.1 Methodology ..................................................................................................................... 25
      3.1.1 Travel Time Surveys ............................................................................................... 25
      3.1.2 Intersection Delay Surveys .................................................................................. 27
      3.1.3 Number of Stops Surveys ...................................................................................... 28
      3.1.4 Cycle Failure Surveys ............................................................................................ 28
3.2 Data Evaluation ................................................................................................................. 29
  3.2.1 Goal 1: Improve Performance of the Existing System ........................................ 29
  3.2.2 Goal 2: Provide a Reliable System ........................................................................... 45
  3.2.3 Goal 3: Provide a User Friendly System ................................................................. 50
  3.2.4 Goal 4: System shall be expandable for the rest of region ............................... 53
  3.2.5 Goal 5: Implement a cost effective traffic signal system ................................. 54

4 Was it worth it to install the SCATS Adaptive Signal System? ................................. 59

APPENDICES

Appendix A: Average Travel Time
Appendix B: Average Stop Delay
Appendix C: Average Number of Stops
Appendix D: Average Probe Vehicle Trajectories
Appendix E: Average Travel Time Statistical Analysis
Appendix F: Average Stop Delay Statistical Analysis
Appendix G: Average Number of Stops Statistical Analysis
Appendix H: Average Minor Street Delay
Appendix I: Travel Time Standard Deviation
Appendix J: 95th Percentile Travel Time
Appendix K: Benefit to Cost Calculations
Appendix L: Volume Counts
Appendix M: Previous Evaluation Documents
LIST OF TABLES
Table 1: Summary of Results Based on Project Goals and Objectives ................................. 5
Table 2: Summary of Goal 1 Objectives ............................................................................... 6
Table 3: Summary of Goal 2 Objectives ............................................................................... 7
Table 4: Summary of Goal 3 Objectives ............................................................................... 8
Table 5: Summary of Goal 4 Objectives ............................................................................... 8
Table 6: Summary of Goal 5 Objectives ............................................................................... 9
Table 7: Travel Time Data Collection Time Periods ............................................................. 26
Table 8: Minor Street Delay Data Collection Time Periods ................................................... 27
Table 9: Comparison of Cycle Failures Experienced by the Probe Vehicles during Travel Time
Surveys ...................................................................................................................................... 43
Table 10: Comparison of Denied Vehicles on Minor Street Approaches ................................ 44
Table 11: Gresham Adaptive Signal System Installation Costs .............................................. 54
Table 12: Gresham Adaptive Signal System Installation Benefits .......................................... 55

LIST OF FIGURES
Figure 1: Burnside Road Analysis Routes (Routes 1-3) .......................................................... 3
Figure 2: Burnside Road Study Area ....................................................................................... 14
Figure 3: Example of a SCATS System Architecture .............................................................. 22
Figure 4: Cycle Length Comparison (Mothers Day versus Typical Sunday) ......................... 30
Figure 5: Cycle Length Comparison (Thanksgiving versus Typical Thursday) .................... 31
Figure 6: Cycle Length Comparison (Christmas Day versus Typical Tuesday) .................... 32
Figure 7: Screen shot of SCATS Graphical User Interface ..................................................... 33
Figure 8: Average Travel Time Comparison – Burnside Road Route 1 (Weekday/Weekend) ... 34
Figure 9: Average Minor Street Delay Comparison – Burnside Road/Eastman Parkway ....... 36
Figure 10: Average Minor Street Delay Comparison – Burnside Road/Cleveland Avenue ...... 37
Figure 11: Average Minor Street Delay Comparison – Burnside Road/3rd Street ................. 38
Figure 12: Average Minor Street Volume Comparison ......................................................... 39
Figure 13: Average Left Turn Delay Comparison – (Weekday/Weekend) .............................. 40
Figure 14: Average Mainline Delay Comparison – Burnside Road Route 1 (Weekday/Weekend) .................................................................................................................. 41
Figure 15: Average Number of Stops Comparison – Burnside Road Route 1 (Weekday/Weekend) ....................................................................................................................... 42
ACKNOWLEDGEMENTS

This project was completed with the partnership of DKS Associates (System Manager/Evaluator), TransCore (System Integrator), City of Gresham (System Operator/Maintainer) and Portland State University (System Evaluator). Funding for this project was provided by the City of Gresham and the USDOT ITS Integration Program via Portland State University’s ITS Integration Grant (project number VII.L.28.a).

Data collection was performed by Quality Counts and TrafStats while analysis presented in this benefits report was completed with the partnership of DKS Associates and Portland State University’s Intelligent Transportation System Laboratory.

The following individuals are recognized for their efforts with this project:

**City of Gresham**
- Jim Gelhar
- Tony Sepich
- Jay McCoy
- Tony Sepich
- Larry Skinner
- Robert Reeder

**Portland State University**
- Robert Bertini
- Chris Monsere
- Li Huan
- Maisha Mahmud
- Sandeep Puppalo

**DKS Associates**
- Jim Peters
- Steven Boice
- Robert Spierling
- Mike Mauch

**TransCore**
- Neil Gross
- Travis White
- John Haigwood

**Quality Counts**
- Matt Melius

**TrafStats**
- Jerry Womack
- Joshua Womack
1 EXECUTIVE SUMMARY

1.1 Introduction
The City of Gresham, Oregon is committed to improving the operational efficiency of congested arterial roadways within their city. In response to this commitment, the city initiated an evaluation of traffic signal control systems in 2005. This evaluation aimed to determine if another signal system currently in operation, but not used by the city, featured components that could provide improved traveler benefits above and beyond the time of day actuated coordinated signal timing plans currently used on arterial roadways in the city.

Following the evaluation of several signal systems in operation throughout the world, the city determined that the Sydney Coordinated Adaptive Traffic System (SCATS) could improve the operational efficiency along arterial roadways beyond the current time of day coordinated signal timing plans. Based on the recommendation to install the SCATS adaptive signal system, the city proceeded with the implementation phase and activated the SCATS system on Burnside Road between Eastman Parkway and Powell Boulevard in March, 2007. The adaptive signal system was implemented at eleven intersections. This report presents the results of the benefits analysis conducted to assess how the SCATS adaptive system has performed in relation to the previous time of day coordinated timing plans that were in operation along the Burnside Road corridor.

1.2 Purpose and Goals
The purpose of this project was to implement a traffic signal control system that would improve the operational efficiency of a congested corridor during both peak and off-peak periods. The following goals for the project were established by a regional steering committee. These goals were identified during the evaluation of traffic signal control systems and are documented in the respective report1.

- Improve performance of the existing system
- Provide a reliable system
- Provide a user friendly system
- Provide a system that is expandable for the rest of the region
- Implement a cost effective system

1.3 Analysis Methodology
A detailed analysis was conducted to assess the performance of the newly implemented adaptive signal system and determine if the project goals and objectives were achieved. The analysis consisted of collecting traffic data to compare the previous time of day coordinated signal timing plans with traffic adaptive operations. The following detailed

Field surveys were conducted to compare the time of day coordinated signal timing with the new adaptive system:

- Travel time surveys
- Intersection delay surveys
- Cycle failure surveys

These surveys were conducted while the eleven traffic signals along the Burnside Road corridor operated in two different operating modes:

- Time of day actuated-coordination – Using time of day plans implemented and fine tuned in March 2005 (existing condition)
- SCATS adaptive traffic signal control (adaptive condition)

The travel time surveys were conducted on three separate analysis routes to capture the mainline operating conditions and represent vehicles turning on and off the corridor at various points. The three analysis routes are shown in Figure 1. The intersection delay and cycle failure surveys were evaluated at three intersections along the corridor:

- Burnside Road/Eastman Parkway
- Burnside Road/Cleveland Avenue
- Burnside Road/3rd Street

Cycle failures at protected left turn movements were collected from the traffic surveys along analysis routes 2 and 3. In all, cycle failures were evaluated at the following protected left turn movements.

- Burnside Road/Main Avenue – Southbound left turn (Analysis Route two eastbound)
- Burnside Road/Division Street – Eastbound left turn (Analysis Route two eastbound)
- Burnside Road/Hogan Drive – Southbound left turn (Analysis Route three eastbound)
- Burnside Road/Powell Valley Road – Eastbound left turn (Analysis Route three eastbound)
Figure 1
STUDY ROUTES
(BURNSIDE CORRIDOR)

LEGEND
- Project Intersection
- Study Route & Number
  (Linetypes Vary for Clarification)
1.4 Implementation Results

Did installing the SCATS adaptive system meet the project objectives? Was it worth it to install the SCATS adaptive system? These are the questions that the analysis was designed to address. The implementation results are provided below and are organized by the project goals and supporting objectives. Table 1 summarizes whether each goal and objective was met (indicated by a checkmark) while Tables 2-6 document objective results for goals 1-5.
Table 1: Summary of Results Based on Project Goals and Objectives

<table>
<thead>
<tr>
<th>Objective</th>
<th>Objective Met?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goal 1 Improve Performance of Existing System</strong></td>
<td>✓</td>
</tr>
<tr>
<td>Timing plans (splits, cycles, offsets) adjust based on input from detectors on the street monitoring traffic conditions</td>
<td>✓</td>
</tr>
<tr>
<td>Reduce travel time by 10 percent or more over normal time of day coordinated plans</td>
<td>✓</td>
</tr>
<tr>
<td>Maintain or reduce side street delay</td>
<td>✓</td>
</tr>
<tr>
<td>Decrease overall corridor delay (side street, left turn and mainline combined) by 5 percent or more</td>
<td>✓</td>
</tr>
<tr>
<td>Decrease overall system stops by 5 percent or more</td>
<td>✓</td>
</tr>
<tr>
<td>Reduce the number of cycle failures for protected left turns and side streets</td>
<td>✓</td>
</tr>
<tr>
<td>Maintain or reduce the number of complaints from the public about signal operations</td>
<td>✓</td>
</tr>
<tr>
<td>Improve travel time reliability</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Goal 2 Provide a Reliable System</strong></td>
<td>✓</td>
</tr>
<tr>
<td>Implement a system that has been installed and operating in at least three other locations</td>
<td>✓</td>
</tr>
<tr>
<td>Implement a system that has been installed and operating for at least one year</td>
<td>✓</td>
</tr>
<tr>
<td>Implement a system with positive user feedback regarding vendor support</td>
<td>✓</td>
</tr>
<tr>
<td>Implement a system that requires a low cost ($15,000 or less) annual maintenance contract</td>
<td>✓</td>
</tr>
<tr>
<td>Implement a system that city and county staff feel comfortable using within an acceptable period of time</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Goal 3 Provide a User Friendly System</strong></td>
<td>✓</td>
</tr>
<tr>
<td>Implement a system that can be operated with existing staff levels (two traffic engineers and three signal technicians)</td>
<td>✓</td>
</tr>
<tr>
<td>Implement a system on a corridor that could apply to other similar corridors in the region</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Goal 4 System shall be Expandable for the rest of the Region</strong></td>
<td>✓</td>
</tr>
<tr>
<td>Implement a system that is expandable to other jurisdictions in the Portland metropolitan area</td>
<td>✓</td>
</tr>
<tr>
<td>Implement a system that provides the benefits described in Goal #1 within the project budget</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Goal 5 Implement a Cost Effective System</strong></td>
<td>✓</td>
</tr>
<tr>
<td>Implement a system (detectors and communications) that can be maintained by the existing staff levels</td>
<td>✓</td>
</tr>
<tr>
<td>Deploy a system that maximizes the use of existing infrastructure (detectors, controllers, cabinets and software)</td>
<td>✓</td>
</tr>
<tr>
<td>Implement a system that can share information with the existing TranSuite (formerly Series 2000) traffic signal system or at a minimum does not restrict the future ability to share information with the existing TranSuite</td>
<td>✓</td>
</tr>
</tbody>
</table>
Table 2: Summary of Goal 1 Objectives

<table>
<thead>
<tr>
<th>Goal 1: Improve Performance of the Existing System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective 1: Timing plans (splits, cycles, offsets) adjust based on input from detectors on the street monitoring traffic conditions</strong></td>
</tr>
<tr>
<td>Archived data provides evidence that the system adapts to changing volumes by adjusting its cycle length, split times, and offsets along the Burnside Road corridor. These changes are made based on actual detection of vehicles via detectors embedded in the roadway. Evidence of the importance of changing cycle lengths is clear particularly during the holiday season when traffic volumes differed significantly from a typical day during the rest of the year. The adaptive signal system allocates green time more efficiently as traffic volumes change and is able to operate much longer cycle lengths when demand is high and much shorter cycle lengths when demand is low.</td>
</tr>
<tr>
<td><strong>OBJECTIVE 1 MET</strong></td>
</tr>
<tr>
<td><strong>Objective 2: Reduce travel time by 10 percent or more over normal time of day coordinated plans</strong></td>
</tr>
<tr>
<td>Average travel times along analysis route one of the Burnside Road corridor were reduced by 11 percent (33.8 seconds) during the weekday (considering both travel directions) and by 9 percent (27.2 seconds) during the weekend.</td>
</tr>
<tr>
<td><strong>OBJECTIVE 2 MET</strong></td>
</tr>
<tr>
<td><strong>Objective 3: Maintain or reduce side street delay</strong></td>
</tr>
<tr>
<td>Average minor street delay was reduced by 5 percent at the intersection of Burnside Road/Eastman Parkway and reduced by one percent at the intersection of Burnside Road/Cleveland Avenue. At the intersection of Burnside Road/3rd Street, average minor street delay increased by 43 percent under adaptive operations. Considering the volume of vehicles at all three intersections, average delay per vehicle along the minor streets increased by 4 percent (+4.79 seconds) under adaptive operations compared to existing traffic signal operations.</td>
</tr>
<tr>
<td><strong>OBJECTIVE 3 MET</strong></td>
</tr>
<tr>
<td><strong>Objective 4: Decrease overall corridor delay (side street, left turn and mainline combined) by 5 percent or more</strong></td>
</tr>
<tr>
<td>Average delay along the mainline decreased by 32 percent (-25.5 seconds) and average protected left turn movement delay was reduced by 16 percent (-9.1 seconds) with the adaptive signal system. Results along the minor street were mixed, with average delay decreasing at two of three intersections analyzed. Overall corridor delay was reduced with the implementation of the adaptive signal system compared to existing operations, with the exception of delay increasing along the minor street approach at one intersection.</td>
</tr>
<tr>
<td><strong>OBJECTIVE 5 MET</strong></td>
</tr>
<tr>
<td><strong>Objective 5: Decrease overall system stops by 5 percent or more</strong></td>
</tr>
<tr>
<td>The average number of stops decreased by 23 percent during the weekday and by 22 percent during the weekend. The stop reduction was greater in the eastbound direction.</td>
</tr>
<tr>
<td><strong>OBJECTIVE 5 MET</strong></td>
</tr>
<tr>
<td><strong>Objective 6: Reduce the number of cycle failures for protected left turns and side streets</strong></td>
</tr>
<tr>
<td>Cycle failures at protected left turn movements were reduced by 50 percent and the number of denied vehicles was reduced by 10 percent with the adaptive signal system.</td>
</tr>
<tr>
<td><strong>OBJECTIVE 6 MET</strong></td>
</tr>
<tr>
<td><strong>Objective 7: Maintain or reduce the number of complaints from the public about signal operations</strong></td>
</tr>
<tr>
<td>Based on input from City of Gresham staff, the number of complaints has been similar to those received under existing signal operations. In fact, staff has actually received several compliments about the adaptive operations which is a rare occurrence with regards to signal operations.</td>
</tr>
<tr>
<td><strong>OBJECTIVE 7 MET</strong></td>
</tr>
</tbody>
</table>
Table 3: Summary of Goal 2 Objectives

<table>
<thead>
<tr>
<th>Goal 2: Provide a Reliable System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective 1: Improve travel time reliability</strong></td>
</tr>
<tr>
<td>Overall, the standard deviation in travel times was reduced by 26 percent (19.5 seconds) during the weekday and by 26 percent (16.8 seconds) during the weekend. Similarly, 95th percentile travel times were reduced by 12 percent (49 seconds) during the weekday and by 4 percent (14.7 seconds) during the weekend. This indicates that motorists may have better confidence in their trip planning along the Burnside Road corridor.</td>
</tr>
<tr>
<td>OBJECTIVE 1 MET</td>
</tr>
</tbody>
</table>

| Objective 2: Implement a system that has been installed and operating in at least three other locations |
| The SCATS adaptive signal system is currently operational in both the western and eastern United States as well as many countries throughout the world. In the western United States alone, there have been five successful installations, primarily in the state of California. The Gresham installation is the first in the northwest. |
| OBJECTIVE 2 MET |

| Objective 3: Implement a system that has been installed and operating for at least one year |
| The SCATS adaptive signal system has been in operation worldwide since the mid 1970’s. There are multiple SCATS systems in the U.S. operating for more than one year. |
| OBJECTIVE 3 MET |

| Objective 4: Implement a system with positive user feedback regarding vendor support |
| City of Gresham staff has had a positive experience with SCATS support staff from TransCore. Training was well done and ongoing support has been available when needed. |
| OBJECTIVE 4 MET |

| Objective 5: Implement a system that requires a low cost ($15,000 or less) annual maintenance contract |
| Several options exist from ongoing maintenance and support options, but it is not a requirement. |
| OBJECTIVE 5 MET |
Table 4: Summary of Goal 3 Objectives

| Objective 1: Implement a system that city and county staff feel comfortable using within an acceptable period of time |
| City of Gresham staff were able to learn the system with few weeks’ training and are comfortable managing the system through the windows graphical user interface (GUI). Staff found the GUI easy to use and understand. |

**OBJECTIVE 1 MET**

**Objective 2: Implement a system that can be operated with existing staff levels (two traffic engineers and three signal technicians)**

The City of Gresham did not add additional staff with the Burnside Road installation. Although the SCATS system requires additional attention beyond the existing time of day system, the existing engineers and technicians manage and operate the SCATS system in addition to the existing traffic signals within the city.

**OBJECTIVE 2 MET**

Table 5: Summary of Goal 4 Objectives

| Objective 1: Implement a system on a corridor that could apply to other similar corridors in the region |
| Burnside Road is a five-lane major arterial and serves as the primary route connecting the Portland metropolitan area to US 26 and destinations at Mt. Hood and central Oregon. The corridor carries approximately 30,000 vehicles per day and has locations with major crossing arterials. The corridor features daily fluctuations in traffic volumes similar to other corridors in the region. |

**OBJECTIVE 1 MET**

**Objective 2: Implement a system that is expandable to other jurisdictions in the Portland metropolitan area**

The SCATS adaptive signal system implemented along the Burnside Road corridor is compatible with the existing regional TranSuite central signal system and local controller hardware shared within the region.

**OBJECTIVE 2 MET**
### Table 6: Summary of Goal 5 Objectives

<table>
<thead>
<tr>
<th>Objective: Implement a system that provides the benefits described in Goal #1 within the project budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>The SCATS adaptive signal system implemented along the Burnside Road was installed within the project budget and provides benefits greater than the associated costs to implement the system. The adaptive installation results in a benefit to cost ratio of 1.4 for the first year and 4.2 over five years.</td>
</tr>
<tr>
<td>OBJECTIVE 1 MET</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective: Implement a system (detectors and communications) that can be maintained by the existing staff levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Although the system does require additional staff time than traditional time of day systems, the city operates the SCATS system effectively with existing staff.</td>
</tr>
<tr>
<td>OBJECTIVE 2 MET</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective: Deploy a system that maximizes the use of existing infrastructure (detectors, controllers, cabinets and software)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The SCATS adaptive signal system uses existing traffic signal controllers, cabinets, and copper twisted pair communications infrastructure. However, modifications to signal controllers, communications, and vehicle loop detector placement were required. Modifications to loop detectors included installing new stop bar detection zones in each lane while modifications to traffic signal controllers included installing new central processing unit cards. Modifications to communications included revision of communication channels.</td>
</tr>
<tr>
<td>OBJECTIVE 2 MET</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective: Implement a system that can share information with the existing TranSuite traffic signal system or at a minimum does not restrict the future ability to share information with the existing TranSuite</th>
</tr>
</thead>
<tbody>
<tr>
<td>The SCATS adaptive signal system has the ability to share information with the existing TranSuite central traffic signal system. From the TranSuite main map, the user is able to see the status of intersections operating SCATS.</td>
</tr>
<tr>
<td>OBJECTIVE 2 MET</td>
</tr>
</tbody>
</table>
1.5 Lessons Learned

The City of Gresham’s installation of the SCATS adaptive traffic signal control system is the first of its kind in the northwest. As a result, the project provided opportunity to test the systems performance and assess whether the system is appropriate for other corridors in the region. Several important lessons were learned from the installation in Gresham:

- The commitment of city staff to the project and the emphasis on paying attention to all the details that give the system the best chance for success paid off in the long run. These details included:
  - Repaving sections of the roadway where new loops would be installed and poor pavement conditions existed
  - Utilizing a substantial base of existing, reliable equipment that city staff were familiar with (copper twisted pair, traffic signal cabinets, controller hardware, Model 400 modems)
  - Detailed testing of the local intersection personalities prior to installation in the field

- Commit at least one hour each day to operate the system. SCATS provides powerful signal timing tools that were unavailable in the previous time of day signal system. To use these tools effectively requires staff time. According to the city lead electrician, “The extra work put into SCATS all focuses on making the corridor operate more efficiently….to get the best benefit out of SCATS you have to put more time into it.”

- A systems manager approach for implementation of an adaptive traffic signal control system was highly successful. Gresham conducted a detailed assessment of the corridor and adaptive system prior to committing to a deployment. Once committed the arrangement of System Manager (DKS Associates), System Integrator (TransCore) and System Operator/Maintainer (City of Gresham) formed a solid, knowledgeable team with local corridor experience and exceptional knowledge of the SCATS system.

- The benefits analysis could have focused on recording side street delays on the shoulders of the peak periods when SCATS could operate shorter cycle lengths than a time of day coordinated plan designed for the peak hour. The project sought to improve travel times on the main route and maintain or reduce side street delays. These could be considered competing objectives because travel times can be improved on the mainline by operating a longer cycle length, but this results in increased delays to side street traffic. The city also was willing to sacrifice some delay to the side street in favor of providing better progression for the significant volume on the mainline. This analysis could still be accomplished because video was collected for 12 hour periods. However, due to time and budget constraints this analysis may need to be conducted at a later time.
1.6 Conclusion

The City of Gresham is committed to reducing traffic congestion in their city and has sought to achieve this through an ongoing program of providing time of day coordinated signal timings since 1995. All major arterial roadways in the city with closely spaced traffic signals currently operate in coordinated mode. Even with this commitment to reducing travel times, delays, and stops with coordinated signal timings activated by time of day, the city felt that more could be done. In 2007, Gresham implemented the SCATS adaptive traffic signal control system on Burnside Road. This system adjusts cycle length, split times, and offset based on measurement of vehicle volumes in real-time as opposed to just based on time of day.

Based on results of the benefits analysis, the adaptive system has outperformed the previous time of day coordinated signal timings on Burnside Road. The following conclusions can be made:

- The SCATS adaptive system improved the performance of the Burnside Road corridor compared to performance under time of day coordinated plans. Improved performance is supported by reduced average travel times, stops, and delay along primary analysis route one.
- The SCATS adaptive system is a reliable system and has also improved the reliability of the Burnside Road corridor. Improved reliability is supported by reduced 95th percentile travel times and standard deviation in travel times along analysis route one of the Burnside Road corridor.
- The SCATS adaptive system is a user friendly system and does not require additional staff to manage and monitor. However, it does require additional staff time. According to the Gresham lead electrician responsible for signal operations, “SCATS is a phenomenal program, it has all the tools needed to make signal operations better and adjusts based on the amount of cars not on historical data”.
- The SCATS adaptive system is expandable and interfaces with existing traffic signal controllers, cabinets, and copper twisted pair communication infrastructure. The system interfaces with the existing TranSuite central signal system.
- The SCATS adaptive system is a cost effective system. A first year benefits to costs ratio of 1.4 indicates that the system pays for itself within the first year of operation. Similarly a five year benefits to cost ratio of 4.2 indicates that the quantifiable benefits provided to motorists outweigh the implementation and maintenance costs. Importantly, the benefits tabulated as part of this analysis only capture those associated with delay and fuel usage. Other benefits typically associated with traffic signal improvements such as emissions, stops, travel time, and accidents were not accounted for in this analysis.
2 INTRODUCTION

2.1 Project Description

In 1995, the City of Gresham, Oregon completed a traffic signal system and communications master plan\(^2\). This master plan recommended installing a central traffic signal system and coordinating traffic signals throughout the city. The plan presented a phased plan for coordinating traffic signals on major arterial corridors in an effort to reduce motorist travel times, stops, and delay. Since the completion of the traffic signal system master plan in 1995, the City of Gresham has established communications to over 90 traffic signals with over 50 of them currently operating in coordination. Coordinating traffic signals along major arterials within the city has been cost effective and has produced significant savings for motorists in terms of travel time, stops, and delay when compared to other signal operating modes (actuated uncoordinated and pre-timed).

The coordinated traffic signal system installed since 1995 has used pre-programmed timing plans that change based on the time of day. This form of traffic signal coordination provides significant benefits and noticeable improvements to the traveling public, but it does not account for frequent changes in vehicle volumes or a traffic volume condition that was not anticipated when the timing plans were developed. Vehicle volumes can change as a result of an incident, weather, time of year, special event, or changes in development. The timing plans developed in the office by an engineer cannot respond to these dynamic changes. Due to changes in traffic volume, time of day coordination plans need to be updated every three to five years to maintain their effectiveness.

In 2001, during the city's update of the traffic signal system and communications master plan, the city identified the potential to further improve arterial traffic signal operations with a traffic signal system that automatically adjusts to changes in traffic volumes. This is known as an adaptive traffic signal system. Adaptive traffic signal systems have been used worldwide since the 1970's, but there were no successful adaptive traffic signal system installations in the Northwest. The city made it a priority to demonstrate that an adaptive traffic signal system could be implemented successfully and reduce travel time, stops, and delay above and beyond traditional time of day traffic signal coordination. In 2004, the City of Gresham received Federal dollars to assist with the implementation of an adaptive traffic signal system through the Portland Metropolitan Transportation Improvement Program.

With the funding in place, the city carefully evaluated available adaptive traffic signal systems and selected the Sydney Coordinated Adaptive Traffic System (SCATS) for implementation on Burnside Road. Project design, construction, and integration took place in 2006 and 2007 and the adaptive system was activated in March 2007.

This report summarizes findings of the evaluation of the SCATS adaptive traffic signal control system that was implemented along Burnside Road. The evaluation assesses how

the adaptive signal system has performed compared to the previous time of day coordinated timing plans. This chapter presents the project study area, project team, project goals and objectives, existing system description, adaptive system description, evaluation purpose, evaluation approach, previous evaluation documents and the structure for the remainder of this report. Chapter three presents the benefits analysis methodology and results while chapter 4 answers the question whether it was worth installing the adaptive signal system.

2.2 Project Study Area

Burnside Road between Eastman Parkway and Powell Valley Road was selected as the corridor best suited for the adaptive signal system because a) it is a major truck route b) has the highest daily traffic volume in the city c) provides a connection between Interstate 84 and Mt. Hood/Central Oregon destinations, and d) the corridor has had a long history of signal coordination. Due to the long history of improvements, the city has substantial records from previous travel time surveys along this section of Burnside Road. It is expected to be a tough test for an adaptive traffic signal system. Figure 2 provides an illustration of the project corridor.

The adaptive signal system was installed at eleven signalized intersections, identified on the figure, over a two mile section of Burnside Road. This section of Burnside Road is a five lane major arterial that carries an average daily traffic (ADT) volume of 31,000 on the east section (Hogan Drive to Powell Valley Road) and approximately 28,000 ADT on the west section (Eastman Parkway to Hogan Drive). Burnside Road is a growing commercial and retail district that serves as a main through route between Interstate 84 (to the north) and State Highway 26 (to the south) leading to Mt. Hood in the Cascade mountain range. Average daily traffic volumes tend to be approximately 10 percent higher on Friday’s likely due to recreational users heading to destinations on Mt. Hood and in central Oregon. Burnside Road also serves as a key freight connection between Interstate 84 and State Highway 26. The posted speed within the study area is 35 miles per hour (mph).

The key to this corridor is the “triangle” located in the center formed by Division Street at Hogan Drive, Division Street at Burnside Road, and Burnside Road at Hogan Drive. These three intersections are closely spaced (approximately 1,000 feet apart) and the volumes are significant along each of the three roadways (greater than 25,000 vehicles per day on each leg of the triangle. The close spacing of the intersections means traffic signal coordination is a must, but vehicle queues can exceed the 1,000 foot storage space if the signal timings are not set properly.

---

3 Time of day traffic signal coordination was first implemented on Burnside Road in 1995. The coordinated timing plans were updated in 1998 and 2005.

4 Roadway tube counts conducted along Burnside Road between 1st Street and 3rd Street and between Cleveland Avenue and Kelly Avenue (February and April 2007).
2.3 Project Team

The project team includes individuals responsible for the system evaluation, implementation, and benefits evaluation stages of the adaptive signal system along Burnside Road. The project team members responsible for the system evaluation stage provided valuable input that led to the selection of the adaptive system. Team members responsible for the implementation stage provided expertise with field installation and integration of adaptive signal operations. Team members responsible for the benefits evaluation stage performed the evaluation of system benefits.

2.3.1 System Evaluation

Jay McCoy, City of Gresham, Project Manager
Jeff Shelley, City of Gresham
Tony Sepich, Multnomah County
Jim Gelhar, Multnomah County
Bikram Raghubansh, Multnomah County
Pam Maki, City of Beaverton
Willie Rotich, City of Portland
John Dorst, City of Gresham
Doug Anderson, ODOT
Nelson Chi, ODOT
Nathaniel Price, FHWA
Robert Fijol, FHWA
Chris Christoferson, Clackamas County
Vaughn Lewis, Washington County
Abbas Shaffii, Washington County
Ali Eghtedari, City of Vancouver
Jim Peters, DKS Associates
Peter Coffey, DKS Associates
Robert Spierling, DKS Associates
Kevin Fehon, DKS Associates
Kent Kacir, Siemens ITS
Warren Tighe, Siemens ITS

2.3.2 Implementation

Neil Gross, TransCore
Travis White, TransCore
John Haigwood, TransCore
Tony Sepich, City of Gresham
Larry Skinner, City of Gresham
2.3.3 Benefits Evaluation
Jim Peters, DKS Associates
Steven Boice, DKS Associates
Robert Spierling, DKS Associates
Mike Mauch, DKS Associates
Robert Bertini, Portland State University
Chris Monsere, Portland State University
Li Huan, Portland State University
Maisha Mahmud, Portland State University
Sandeep Puppalo, Portland State University
Jim Gelhar, City of Gresham
Tony Sepich, City of Gresham
Jay McCoy, City of Gresham
Quality Counts
TrafStats
2.4 Project Goals and Objectives

The goals and objectives for the project were specifically established so that they would be measurable following system implementation. The project goals address system performance, reliability, user interface, expandability, and cost effectiveness. The five goals and detailed supporting objectives for each of the goals of the adaptive system include:

2.4.1 Goal 1: Improve performance of existing system
- Timing plans (splits, cycles, offsets) adjust based on input from detectors on the street monitoring traffic conditions
- Reduce travel time by 10 percent or more over normal time of day coordinated plans
- Maintain or reduce side street delay
- Decrease overall corridor delay (side street, left turn and mainline combined) by 5 percent or more
- Decrease overall system stops by 5 percent or more
- Reduce the number of cycle failures for protected left turns and side streets
- Maintain or reduce the number of complaints from the public about signal operations

2.4.2 Goal 2: Provide a reliable system
- Improve travel time reliability
- Implement a system that has been installed and operating in at least three other locations
- Implement a system that has been installed and operating for at least one year
- Implement a system with positive user feedback regarding vendor support
- Implement a system that requires a low cost ($15,000 or less) annual maintenance contract

2.4.3 Goal 3: Provide a user friendly system
- Implement a system that city and county staff feel comfortable using within an acceptable period of time
- Implement a system that can be operated with existing staff levels (two traffic engineers and three signal technicians)

2.4.4 Goal 4: System shall be expandable for the rest of the region
- Implement a system on a corridor that could apply to other similar corridors in the region
- Implement a system that is expandable to other jurisdictions in the Portland metropolitan area
2.4.5 Goal 5: Implement a cost effective traffic signal system

- Implement a system that provides the benefits described in Goal #1 within the project budget
- Implement a system (detectors and communications) that can be maintained by the existing staff levels
- Deploy a system that maximizes the use of existing infrastructure (detectors, controllers, cabinets and software)
- Implement a system that can share information with the existing TranSuite traffic signal system or at a minimum does not restrict the future ability to share information with the existing TranSuite

2.5 System Description

The following sections discuss the existing time of day coordinated and new adaptive signal system along the Burnside Road corridor. Discussion of the operations and infrastructure in place for both signal systems is included.

2.5.1 Time of Day Coordinated Signal System

Prior to the installation of the adaptive signal system, the Burnside Road corridor operated under a time of day actuated coordinated signal system. The actuated coordinated signal system consisted of pre-programmed signal timing plans that were activated and deactivated at certain times of day.

This method of signal operations was previously implemented along the Burnside Road corridor because it has proven to provide benefits such as reduced travel time, stops, and delay when compared to other signal timing operating methods such as pre-timed and actuated uncoordinated. Time of day signal operations can however be inefficient on the shoulders of peak volume periods and unless specifically designed for a known event, do not account for fluctuations in traffic. In order to accommodate changes in traffic volumes and patterns time of day timing plans need to be updated every three to five years to maintain their effectiveness.

Under the previous time of day coordinated timing plans, the eleven study intersections operated as a single coordinated group during the morning, midday, and weekend time periods; however, between 1:15 PM and 6:15 PM on weekdays the corridor operated in two separate groups. The two groups included one on the west end (Eastman Parkway to Cleveland Avenue) and one on the east end (Division Street to Eastman Parkway). Two intersection groups were used because the traffic signals on the west end of the Burnside Road corridor operated more efficiently at a shorter cycle length than the east end.

Intersection Characteristics:

All signalized intersections used Wapiti firmware on model 170E controllers from various manufacturers housed in type 332 traffic signal controller cabinets. All of the study area intersections were connected to the TranSuite central traffic signal system (formerly TransCore Series 2000).
Inductive loop detectors (six foot round) were used for vehicle detection and pedestrian phases were called by push buttons. The intersections had inductive loops in all lanes on all approaches, but no stop line loops on Burnside Road (mainline). Burnside Road had advanced loops generally located about 300 feet from the stop line. All intersections had stop line loops on the minor street generally located five and 15 feet from the stop-line. All project intersections include protected left turn signal phasing on the mainline, except for Burnside Road/Hogan Drive where left turns are not allowed from Burnside Road. The side street signal phasing is a mixture of protected left turn phasing, permissive left turn phasing, and one intersection with split phasing (Burnside Road/Hogan Drive). Time of day coordination plans operated between 6 AM and 9 PM.

Communication Characteristics:
The existing communication infrastructure to the project area intersections was provided via a 12 pair copper cable. The copper cable provided communications from the intersection traffic signal controllers to a communication server located at the City of Gresham City Hall. The central traffic signal system server is located at the City of Portland building in downtown Portland. Communication to the central signal system server from the city’s communication server was provided via shared regional fiber optic cable infrastructure.

2.5.2 Adaptive Signal System
Adaptive traffic signal control was developed based on the premise that signal timings could be adjusted incrementally using real time traffic volume and speed information collected from detectors on the street. Adaptive traffic signal control can automatically respond to special events or other unpredictable incidents that cause significant changes in traffic volumes and speeds without intervention by a traffic engineer because the system constantly monitors the level of congestion. Adaptive traffic signal control does not use pre-programmed plans, instead changes splits, offsets, and cycle lengths based on current traffic conditions.

To support the installation of the SCATS system, modifications to the field intersections and central infrastructure was required:

- **Install all new vehicle detection.** The SCATS system requires a stop bar detection zone of 16 feet long in each approach lane.
- **Install new central processing units.** The SCATS system can operate on the existing Model 170E controllers, but with a new central processing unit.
- **Reconfigure the copper twisted pair.** Communications between the SCATS central server and the field intersections can be provided over copper twisted pair, but the communications channels had to be modified.
- **Install a new SCATS signal system server.** The SCATS system requires a separate central server from the previous TransCore (now TranSuite) central traffic signal system. The new server is located at Gresham City Hall.
2.5.3 Sydney Coordinated Adaptive Traffic System (SCATS) Operation

The SCATS system was developed by the Roads and Traffic Authority of New South Wales, Australia (originally for the City of Sydney) and has been deployed on arterial roadways and in downtown grids in most major Australian and New Zealand cities, as well as major cities in Asia. There are approximately 20,000 intersections worldwide operating with SCATS and approximately 1,000 of those intersections are in the United States.

SCATS operates in real-time, adjusting signal timing parameters (splits, cycle length and offsets) at each intersection based on variation in traffic demand and system capacity. The SCATS system optimizes cycle length using a sloped linear relationship between cycle length and degree of saturation. The user can change the slope of the segments of the linear relationship to change the “sensitivity” of the subsystem. SCATS optimizes splits by seeking to provide the same degree of saturation on each approach, for an approximately 85 percent degree of saturation.

SCATS measures the degree of saturation of departing traffic as it crosses the stop line detectors for each critical movement and uses this information from each intersection to automatically adjust the cycle length, phase splits, intersection offsets and signal groupings. Offsets are pre-determined by an engineer for cycle length ranges and the SCATS system will move between a range of offsets as the cycle length changes.

The SCATS system relies on a central computer and constant second-by-second communication to intersection controllers. The central computer processes data collected from all traffic signal controllers in the system in real time and sets the cycle length, splits and offsets for each signal controller. The central computer also determines the intersection groupings that should be used based on the current traffic conditions. The duration of each phase is determined based on the intersection detectors and the presence of vehicle actuations can extend or the lack of vehicle actuations can terminate the phase.

The local intersection controllers store all of the local and coordinated timings needed to operate the intersection. If communications between the central server and intersection controller is broken, the intersection controller will fall-back to local operation and will use time of day coordination plans. The system operation for SCATS depends on detection, and communications between the local controllers and the central server.

Detector Requirements

The SCATS adaptive system requires stop bar detectors within each lane. The preferred configuration of the SCATS stop bar detectors is 6 feet by 16 feet located so the trailing edge of the detection zone is three feet in advance of the stop line. The detection technology can be any form of detection that provides presence detection; inductive loops and video are the most common. If video cameras are used, the preferred location of the cameras is over the stop line because the SCATS system uses the space between detector actuations (space time) to determine the level of congestion and a downstream camera will not provide an accurate measurement of space time. Downstream video cameras can be used but the system will lose some efficiency.

SCATS detectors are used to call and extend a phase, and to collect strategic data. Strategic data includes total-space time (occupancy) and the headway (number of
vehicles) and is used to determine the level of congestion by lane. The strategic data is collected only while the phase is green and is used by the adaptive algorithm to set the phase splits, system cycle length, and offset.

The Gresham installation uses inductive loops, forming a 6x16 foot stop bar detection zone.

**Field hardware and software requirements**
The field hardware and software includes the intersection controllers, intersection control software and communications.

**Controllers**
Controller options for the SCATS system include a hardware/software conversion kit for the Model 170 controller, and a software only kit for the 2070 controller. The 2070 software can operate on both Model 2070 and 2070N controllers.

For the Model 170 controller, the SCATS system requires a new processor board with embedded SCATS controller firmware. The conversion kit can be fitted to Safetran 170E and McCain 170E controllers. The front panel of the Model 170 controller cannot be used with SCATS. A separate handheld terminal server is required for the interface to the Model 170 controller running SCATS. The front panel of the Model 2070 controller is used to interface to the SCATS system.

The Gresham system uses Model 170 controllers with handheld terminal servers.

**Firmware**
SCATS uses proprietary firmware for both Model 170 and Model 2070 controllers. The Gresham system uses SCATS firmware for Model 170 controllers.

**Communications**
SCATS can operate with both multi-drop and dedicated lines. The dedicated line arrangement requires a two-wire link to each intersection to support the 300 bits per second (bps) data rate.

SCATS communications is heavily dependent on communications between the local intersection controller and a central server. The intersection controllers report field conditions to the central server and the central server provides cycle lengths, phase splits and offsets for the intersection controllers. SCATS does not require peer-to-peer communications.

The Gresham system uses copper twisted pair wire with no more than four intersections per communications channel. Three communications channels are provided for the 11 project intersections.
Central Hardware Requirements
The central server for a SCATS installation requires a standard PC server running the Windows operating system. Multiple region systems can be implemented with PCs as illustrated in Figure 3.

The Gresham installation uses a single server to support center to field communications, SCATS processing and SCATS data storage.

![Diagram of SCATS System Architecture](image)

Source: TransCore, 2000

Figure 3: Example of a SCATS System Architecture

2.6 Evaluation Purpose
The purpose for the evaluation of project benefits is to determine whether the adaptive signal system installation achieved the project goals and supporting objectives set during the system evaluation phase. Assessing and documenting the performance of the adaptive system compared to the project goals will seek to answer the question:

- Was it worth it to install an adaptive signal system versus maintaining the existing time of day coordinated timing plans?

2.7 Evaluation Approach
This adaptive installation is the first of its kind in the northwestern United States. Therefore, the data is presented in a format that is intended to be useful for other agencies considering implementation of an adaptive system. Project goals and objectives were developed by the project team prior to selection and installation of the adaptive system. These goals and objectives are similar to what any public agency seeking to reduce congestion through improved traffic signal operations would consider. The project team developed the adaptive system goals and objectives so that they would be measurable.
This evaluation compares the performance of the SCATS adaptive signal control system (hereafter called adaptive system) to the previous signal control system that used pre-programmed coordinated signal timing plans that changed based on the time of day (hereafter called existing system).

Comparing the performance of the adaptive system to the existing system requires consideration of several operating scenarios:

- Time of day
- Direction of travel
- Amount of traffic volume
- Varied routes through the traffic signal network

For this reason, data was collected during a variety of field conditions and a variety of times of day including AM peak, midday, PM peak, and Saturday. The evaluation collected the AM peak data outside the normal peak traffic conditions to compare the performance of the adaptive system to the existing system during periods on the shoulder of the peak periods. This approach was chosen to compare the affects of the adaptive system during periods of non-peak traffic volumes.

Data for the adaptive system was collected between April 17th and April 21, 2007, while data for the existing system was collected between February 11 and February 22, 2007. Traffic volume data was collected on the same days as the travel time surveys to provide a data comparison of the traffic volume difference on the data collection days.

Comparison of traffic volumes along Burnside Road under existing and adaptive operation showed that volumes were similar. Supporting information is included in Appendix L.

In addition to the transportation system performance measures, the evaluation considered other performance measures including reliability, usability, expandability and cost effectiveness. The evaluation compares the existing and adaptive system for these performance measures using a combination of the field data and interviews with Gresham operations personnel.

The cost comparison includes construction, deployment, integration, and ongoing maintenance and operation of the system. The Gresham project included an evaluation of adaptive systems prior to selecting and installing SCATS. The cost associated with the initial system selection effort is intentionally left out of this system benefits evaluation because system selection costs should not be required to expand the system within the Portland region.

The benefits and costs of the adaptive system are compared to the previous time of day coordinated signal system. Time of day coordinated signal timings on the Burnside Corridor were originally developed in 1995 and updated in 1998 and 2005. The costs of the existing system assume signal timings on the Burnside corridor would continue to be updated every five years.

5 Data was collected during the following time periods: AM peak (8 to 10 AM), midday (12 to 2 PM), PM peak (4 to 6 PM), and Saturday (10 to 12 PM and 2 to 4 PM).
2.8 Previous Evaluation Documents

Previous corridor evaluation documents include:

- **Summary of Traffic Adaptive Signal Control System Evaluation, Final Report October 2005** – This report documents the process and conclusions of the alternative traffic signal control system evaluation.

- **Request For Information for Implementation of an Adaptive Traffic Signal Control System on Burnside Road in the City of Gresham, Oregon** – Responses to this request for information assisted the city with their decision to deploy an adaptive traffic signal control system.

- **Gresham Burnside Road Travel Time Surveys, Driver Handout** – This handout provides instructions for conducting the travel time surveys.

- **Portland State University Statement of Work and Delivery Schedule for Evaluation of SCATS Adaptive Traffic Signal Control System** – This document provides the scope of services for Portland State University’s contribution to the benefits analysis.

- **Field-Based Evaluation of Corridor Performance after Deployment of an Adaptive Signal Control System in Gresham, Oregon** – This document provides preliminary results of signal system assessment. This document was submitted to and presented at the 2008 Transportation Research Board (TRB) conference in Washington D.C.

These documents are included in Appendix M.

2.9 Structure of Report

The remainder of the report presents the results of the adaptive system evaluation and is organized based on the five project goals:

- **Goal 1: Assess adaptive system performance**
- **Goal 2: Assess system reliability**
- **Goal 3: Document system usability**
- **Goal 4: Document system expansion capabilities**
- **Goal 5: Document cost components of the adaptive system**
3 BENEFITS ANALYSIS

3.1 Methodology
To evaluate the project goals and objectives previously identified in section 2.4, multiple traffic surveys were conducted over multiple days along the Burnside Road study corridor. Surveys were conducted while the eleven study intersections operated in two traffic signal operating modes:

- Time of day actuated coordination – Using time of day plans implemented and fine tuned in March 2005 (existing condition)
- SCATS adaptive traffic signal control (adaptive condition)

The traffic surveys used as part of this evaluation were:

- Travel time surveys
- Intersection delay surveys
  - Mainline
  - Minor street
- Number of stops surveys
- Cycle failure surveys
  - Mainline protected left turn
  - Minor street

The data collected from these surveys was analyzed to quantitatively determine if each project goal and objective was achieved with the implementation of the adaptive signal system. The data collection under existing signal operations took place in February 2007, just prior to the adaptive signal system deployment in March 2007. The time of day plans were developed for the Burnside Road study corridor in 2004 and implemented and fine-tuned in the spring of 2005. The adaptive signal operations data collection took place in April 2007 after implementation and fine tuning in March 2007. The following sections describe each of the traffic surveys used as part of this analysis.

3.1.1 Travel Time Surveys
Travel time is the total time it takes a vehicle to traverse from point A to point B. To collect the travel time information, probe vehicles were deployed along pre-determined analysis routes equipped with handheld computers running ITS-GPS, a custom data collection application designed in the Intelligent Transportation Systems Lab at Portland State University. Drivers of the probe vehicles were instructed to use the floating car technique. For floating car surveys, the driver “floats” with the traffic by attempting to

---

safely pass as many vehicles as pass the probe vehicle. This ensures that the probe vehicle acts as the average vehicle in the traffic stream. Probe vehicle locations (latitude and longitude) were logged at one second intervals as they traversed the study corridor.

Based on the Burnside Road corridor conditions, three analysis routes were selected for evaluation as was shown in Figure 1. Eastbound route one starts at Eastman Parkway near Gresham City Hall and travels along Burnside Road to Powell Valley Road. This route traverses 10 signalized intersections and features no turn movements. Routes two and three were designed to include left and right turning movements in order to capture vehicles entering and exiting the adaptive signal system. Eastbound route two starts on Hogan Drive and turns left on Burnside Road and left again onto Powell Valley Road. This route travels through six signalized intersections. Eastbound route three starts on 223rd Avenue, turns left onto Burnside Road and left again onto Division Street. This route travels through five signalized intersections. For westbound evaluations, all routes were reversed.

A total of five time periods were studied along each analysis route as shown in Table 7. The weekday 8-10 AM time period was selected to capture the morning peak hour (7:20-8:20) and the start of average traffic conditions. Generally, time of day plans are optimized for the peak hour and not for the shoulders of the peak. The weekday PM peak period of 4-6 PM captures both ends of the PM peak hour (4:40-5:40). The weekday midday time period (12-2 PM) is intended to capture benefits during the moderate to off peak period. The weekend time periods were selected to be analyzed because typically a weekday peak period time of day plan would be implemented on the weekends between 10:00 AM to 6:00 PM as was the case on the Burnside Road corridor. Typically, weekend time of day plans are not optimized and fine tuned to the degree of weekday time of day plans. Additionally, hourly volume profiles along the Burnside Road corridor are nearly flat on Saturday and Sunday between 12 PM and 5 PM. The peak two-hour period occurs between 2 PM and 4 PM and the volumes drop off after 5 PM.

Probe vehicles departed from each end of the route on 10 minute headways on the weekday and five minute headways on the weekend. The probe vehicles completed several runs during each time period (both westbound and eastbound) along each route. All of the data collected were exported to local desktop computers and prepared for analysis. A programming script was prepared to extract the relevant performance measures from the probe data.

Table 7: Travel Time Data Collection Time Periods

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AM</td>
</tr>
<tr>
<td>Weekday (Monday-Friday)</td>
<td>8-10 AM</td>
</tr>
<tr>
<td>Weekend (Saturday-Sunday)</td>
<td>10-12 PM</td>
</tr>
</tbody>
</table>

Note: Weekday adaptive surveys conducted on April 17 and 18. Weekend adaptive surveys conducted on April 21. Weekday existing surveys conducted on February 13-14, 21 and March 1 and 6. Weekend existing surveys conducted on February 11 and March 3.
3.1.2 Intersection Delay Surveys

Intersection delay was measured along Burnside Road and along the minor street approaches at select intersections under existing and adaptive operations. Each is discussed in the following sections.

Mainline Intersection Delay

Total delay is the difference between the actual travel time and the free flow travel time (travel time at posted speed with no obstructions) from point A to point B. Delay results from traffic signals, turning vehicles, pedestrians, and congestion. Delay was extracted from the travel time survey data collected via GPS using a programming script at each intersection. Intersection delay was recorded as the total time the probe vehicle spent at or less than five miles per hour (mph) while approaching a signalized intersection. Intersection delay was measured during the same weekday and weekend time periods as the travel time surveys.

Minor Street Intersection Delay

Minor street delay was measured along the minor street approaches at three study intersections. Vehicle delay was measured at the intersections of:

- Burnside Road/Eastman Parkway
- Burnside Road/Cleveland Avenue
- Burnside Road/3rd Street

Minor street delay at each intersection was measured over a two day period during the weekday morning (8-10 AM) and evening (4-6 PM) time periods. Table 8 summarizes the data collection time periods. Vehicle delay was measured as the duration of time between when the vehicle slowed to five 5 mph or less to the time the vehicle crossed the stop bar.

Both the northbound and southbound approaches at the intersection of Burnside Road/Eastman Parkway include of two through lanes and a protected left turn. The minor street geometry along both minor street approaches at the intersections of Burnside Road/Cleveland Avenue and Burnside Road/3rd Street include one through lane and a permissive left turn lane. The delay for the permissive left turns at these intersections was measured to the time the vehicle executed the left turn movement and crossed into the opposing traffic’s path.

Table 8: Minor Street Delay Data Collection Time Periods

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekday (Monday-Friday)</td>
<td>8-10 AM</td>
</tr>
</tbody>
</table>

Note: Weekday adaptive surveys conducted on April 19 and 20. Weekday existing surveys conducted on April 26 and 27.
3.1.3 Number of Stops Surveys
This survey was designed to measure and compare the number of stops on the travel time route. A stop at a signalized intersection was defined as the total number of occurrences when the probe vehicles speed reached five miles-per-hour (mph) or less. The number of stops for each analysis route, direction, and time period was extracted from the travel time survey data collected via GPS using a programming script. The number of stops was measured during the same weekday and weekend time periods as the travel time surveys.

3.1.4 Cycle Failure Surveys
Cycle failure surveys were designed to compare how well the existing and adaptive operations serve existing demand. A cycle failure occurs when a vehicle arriving at the stop bar or back of an existing queue of vehicles on the red indication at an intersection approach does not clear the intersection on the cycle it arrived on. The vehicle must wait for the next cycle to proceed through the intersection.

Cycle failures were measured at select protected left turn movements along Burnside Road and along minor street approaches at select intersections under existing and adaptive operations. Methodology for measuring cycle failures at protected left turns and minor street approaches is presented below.

Mainline Protected Left Turn Cycle Failures
Cycle failures were extracted from the travel time surveys for protected left turn movements and are measured by number of traffic signal cycles. Cycle failure surveys were collected at:

- Burnside Road/Main Avenue – Southbound left turn (Analysis Route two eastbound)
- Burnside Road/Division Street – Eastbound left turn (Analysis Route two eastbound)
- Burnside Road/Hogan Drive – Southbound left turn (Analysis Route three eastbound)
- Burnside Road/Powell Valley Road – Eastbound left turn (Analysis Route three eastbound)

Minor Street Cycle Failures
In place of cycle failures, the total number of denied vehicles was recorded along the minor street approaches. Denied vehicles represent the number of vehicles that failed to travel through the intersection on the cycle they arrived on. Denied vehicles were extracted from the minor street delay surveys conducted at the intersections of:

- Burnside Road/Eastman Parkway
- Burnside Road/Cleveland Avenue
- Burnside Road/3rd Street

This value is of greater importance than cycle failures alone, because it accounts for the number of vehicles experiencing cycle failures.
3.2 Data Evaluation

The purpose of the adaptive signal system benefits evaluation is to address the following question:

- Was it worth it to install the SCATS adaptive signal system as opposed to updating existing time of day plans along the Burnside Road study area?

To answer this question, the evaluation considers the goals and objectives established during the signal system evaluation stage. These goals and objectives were used to select a control system for the City of Gresham and were intentionally configured so they could be measured.

The benefits evaluation has been designed to measure whether the goals and objectives were achieved. The remainder of this chapter is formatted in the order of goals and objectives to document how the deployed adaptive signal system did at meeting the project goals and objectives.

3.2.1 Goal 1: Improve Performance of the Existing System

The primary goal of this project was to implement a traffic signal system that would improve the performance of the Burnside Road corridor beyond the existing time of day coordinated timing plans. This corridor is the busiest corridor in the City of Gresham with an average daily traffic (ADT) volume of 31,000 on the east section (Hogan Drive to Powell Valley Road) and approximately 28,000 ADT on the west section (Eastman Parkway to Hogan). The City of Gresham has maintained and updated coordinated timings on Burnside Road since 1995 in an attempt to provide the most efficient operations. Coordinated traffic signal timings were originally installed on Burnside Road in 1995, updated in 1998, updated again in 2004 before installing the SCATS adaptive system in 2007.

To evaluate whether system performance has improved under adaptive signal operations, several objectives supporting this goal were established (see section 2.4). The evaluation compares the performance of the adaptive system versus the time of day system by comparing traffic data collected under both existing and adaptive signal operations. Primary objectives include comparing travel time, stops, and delay. The remainder of this section summarizes the assessment of each objective supporting this goal.

Objective: Timing plans (splits, cycles, offsets) adjust based on input from detectors on the street monitoring traffic conditions.

Since the Sydney Coordinated Adaptive Traffic System (SCATS) is an adaptive signal system, it has the ability to automatically adjust key traffic signal timing parameters such as cycle length, phase split times, and intersection offsets based on actual traffic conditions measured via detectors on the street. The unique ability to adjust these signal timing parameters is useful when frequent changes in traffic volumes from special events, holidays, peak 15-minute demand, weather, and incidents occur. The previous time of day coordinated signal system did not have the ability to change parameters based on current traffic conditions; therefore, it was not as efficient when traffic volumes changed or special events took place.
Typically, traffic engineers assume that traffic conditions are similar from one week to the next. Archived data from the SCATS system reporter\(^7\) clearly shows how different traffic conditions on two subsequent Sunday’s can be. Figure 4 highlights how the adaptive signal system has adjusted its cycle length to the changing volumes at the intersection of Burnside Road/Hogan Drive on two Sunday’s in May, 2007. The upper chart shows adaptive and previous time of day cycle lengths for Sunday May 13, 2007 (Mothers Day) while the bottom figure shows cycle lengths for Sunday May 20 (typical Sunday).

Under previous time of day plans, all study intersections ran free (actuated uncoordinated) on Sunday until 11:00 AM when plan 2 (110 second cycle length) was activated. The cycle length chart from May 13, 2007 (Mother’s Day) indicates an increase in adaptive cycle length beginning around 10:30 AM. The increase in adaptive cycle length was due to the increase in traffic volumes associated with Mother’s Day morning brunch. Note that this increase in volume would not be representative of a typical Sunday as shown in the bottom figure from May 20, 2007.

Additionally, adaptive cycle lengths peaked at approximately 140 seconds during the lunch hour on Mother’s Day. This is attributed to the large surge in traffic volumes associated with the holiday lunch. The 140 second cycle length is 30 seconds greater than the 110 second cycle length that would have run under previous time of day plans.

![Burnside Road/Hogan Drive
Burnside Road/Hogan Drive](image)

**Figure 4: Cycle Length Comparison (Mothers Day versus Typical Sunday)**

Comparing cycle lengths from other holidays, the adaptive system clearly shows how different traffic conditions can be during the holiday season. Figure 5 illustrates adaptive

---

\(^7\) Application of SCATS that allows for retrieval and display of SCATS archived data.
cycle lengths compared to cycle lengths that would have run under previous time of day plans on Thursday November 22, 2007 (Thanksgiving Day) and on Thursday November 15, 2007 (typical Thursday) at the intersection of Burnside Road/Hogan Drive.

The upper portion of the figure indicates that adaptive cycle lengths rarely exceeded 90-seconds on Thanksgiving Day, whereas, the cycle lengths that would have run on this day under previous time of day plans would have been 20 to 44 seconds greater than this. The adaptive system had the ability to recognize that traffic volumes along the corridor were lower on Thanksgiving Day than a typical Thursday, and was able to run a much shorter cycle length. The shorter cycle lengths reduced unnecessary delay and vehicles were able to travel much more efficiently through the Burnside Road corridor.

The bottom portion of Figure 5 shows the adaptive and time of day cycle lengths on a typical Thursday. The adaptive cycle lengths increased to a peak of approximately 150-seconds during the PM peak period. The longer cycle lengths maintain mobility along Burnside Road with the large demand during this time.

![Figure 5: Cycle Length Comparison (Thanksgiving versus Typical Thursday)](image)

Figure 6 illustrates adaptive cycle lengths compared to previous time of day cycle lengths on Christmas Day (Tuesday December 25, 2007) and on a typical Tuesday (December 18, 2007) at the intersection of Burnside Road/Hogan Drive. Adaptive cycle lengths on Christmas Day rarely peaked above 90-seconds. Again, the adaptive system was able to run a much shorter cycle length on this day due to lower traffic volumes along the corridor than a typical Tuesday.
Other features that indicate how the adaptive signal system is adapting to real-time traffic conditions are within the SCATS graphical user interface (GUI). A screen shot of the SCATS GUI is shown in Figure 7. The GUI supports real-time monitoring of the SCATS system and provides graphical displays and functions for manual intervention. From this interface, the operator can see the changing cycle lengths, split times, and offsets for each cycle.

Figure 6: Cycle Length Comparison (Christmas Day versus Typical Tuesday)
Objective Met? Archived data provides evidence that the system adapts to changing volumes by adjusting its cycle length, split times, and offsets along the Burnside Road corridor. These changes are made based on actual detection of vehicles via detectors embedded in the roadway. Evidence of the importance of changing cycle lengths is clear particularly during the holiday season when traffic volumes differed significantly from a typical day during the rest of the year. The adaptive signal system allocates green time more efficiently as traffic volumes change and is able to operate much longer cycle lengths when demand is high and much shorter cycle lengths when demand is low.
Objective: Reduce travel time by 10 percent or more over normal time of day
coordinated plans

This objective focused on reducing average travel time along the Burnside Road study
corridor by 10 percent or more over previous time of day actuated coordinated timing
plans. Figure 8 summarizes the average eastbound and westbound travel times along
analysis route one of the Burnside Road corridor. The figure indicates that the travel
time objective was met for the eastbound (EB) direction during the weekday and
weekend time periods. Travel time improvements were achieved in the westbound (WB)
direction, but were not as significant as the eastbound direction. This is partially by
design because the city and consultant team decided to favor the eastbound Burnside
Road movement and the southbound to eastbound Hogan Drive movement during most
time periods. For comparison, the free-flow travel time along route one through the study
corridor at posted speed (35 MPH) is approximately 193 seconds.

The travel time results indicate adaptive signal operations reduced the average weekday
travel time by 6 to 15 percent (19.4 to 48.2 seconds). Similarly, adaptive signal
operations reduced the average weekend travel time by 4 to 14 percent (12.8 to 41.4
seconds).

![Figure 8: Average Travel Time Comparison – Burnside Road Route 1 (Weekday/Weekend)](image)

Travel time surveys were conducted on a total of three routes, but results for analysis
route one are only shown because this is the most heavily travelled route of the Burnside
Road corridor. Analysis routes two and three were selected to measure the impact to side
street movements and left turn movements as opposed to strictly travel time. In total,
route one includes 10 signalized intersections and carries the most traffic of the three

---

8 Results shown for the weekday time periods are the average of surveys conducted between 8-10 AM, 12-
2 PM, and 4-6 PM and between 10-12 PM and 2-4 PM for the weekend time periods.
routes analyzed (approximately 30,000 vehicles per day). Weekday and weekend results by route are shown by evaluation time period and direction in Appendix A. Statistical analysis of travel time results for each of the three analysis routes are included in Appendix D. And, average vehicle probe trajectories for analysis route one, which identify where savings in travel time occurred along the route are included in Appendix E.

Objective Met? Average travel times along analysis route one of the Burnside Road corridor were reduced by 11 percent (33.8 seconds) during the weekday (considering both travel directions) and by 9 percent (27.2 seconds) during the weekend.

Objective: Maintain or reduce side street delay
This objective focused on maintaining or reducing side street (minor street) delay along the Burnside Road study corridor with the implementation of the adaptive signal system. With overall improvements in average travel time measured along analysis route one (mainline), it is important to recognize that benefits along the mainline may be a result from degrading conditions along the minor street approaches. This may occur when green time is reduced on the minor street and allocated to the mainline in order to keep mainline traffic flowing.

This section summarizes results of minor street delay surveys conducted at three signalized intersections to verify whether the decrease in average travel times measured along the mainline were a result of degrading conditions along the minor streets. Side street delay was measure at:

- Burnside Road/Eastman Parkway
- Burnside Road/Cleveland Avenue
- Burnside Road/3rd Street

Figure 9 summarizes average delay per vehicle along the minor street approaches at the intersection of Burnside Road/Eastman Parkway under both existing and adaptive traffic signal operations. Results documented for the northbound and southbound approaches are the average for all approach movements during the weekday 8-10 AM and 4-6 PM analysis period. Both the northbound and southbound approaches at this intersection consist of two through lanes and one protected left turn lane. The percentage change in average delay per vehicle is also indicated in the figure.

As shown, average delay per vehicle decreased by five percent along the northbound approach and increased by 10 percent along the southbound approach under adaptive operations. Taking both travel directions into account (northbound and southbound), the average delay per vehicle along the minor street approaches decreased by 1 percent (-0.5 seconds per vehicle) at this intersection. This value was determined by dividing the total number of vehicles by the total delay measured over the two day evaluation period.
Figure 9: Average Minor Street Delay Comparison – Burnside Road/Eastman Parkway

Average vehicle delay results along the minor street approaches at the intersection of Burnside Road/Cleveland Avenue are documented in Figure 10. Both the northbound and southbound approaches at this intersection consist of one through lane and one permissive left turn lane. Therefore, delay results for the permissive left turns are affected by the opposing traffic volume.

Results indicate that average delay per vehicle decreased by 16 percent along the northbound approach and increased by 14 percent along the southbound approach under adaptive operations. Considering both approaches, average minor street delay per vehicle decreased by 5 percent (-1.3 seconds per vehicle) at this intersection under adaptive operations.

Review of traffic volumes indicates that both opposing traffic volumes for left turn movements and volumes of left turning vehicles are comparable under existing and adaptive operations at this intersection.
Figure 10: Average Minor Street Delay Comparison – Burnside Road/Cleveland Avenue

Review of average vehicle delay along the minor street approaches at the intersection of Burnside Road/3rd Street indicate that average vehicle delay increased along both approaches at this intersection under adaptive operations. The results are shown in Figure 11. Both the northbound and southbound approaches at this intersection consist of one through lane and one permissive left turn lane.

As shown in Figure 11, average vehicle delay increased by 35 percent in the westbound direction and by 48 percent in the eastbound direction. Taking into account both intersection approaches, average delay per vehicle increased by 43 percent (+18.8 seconds per vehicle) under adaptive operations compared to existing signal operations.

Review of traffic volumes indicates that both opposing traffic volumes for left turn movements and volumes of left turning vehicles are comparable under existing and adaptive operations at this intersection.
Figure 11: Average Minor Street Delay Comparison – Burnside Road/3rd Street

As shown in Figures 10-12, average minor street delay decreased at two of the three intersections analyzed under adaptive signal operations. Average delay decreased at the two intersections with the largest minor street volume (Burnside Road/Eastman Parkway and Burnside Road/Cleveland Avenue) and increased at the intersection with the least volume (Burnside Road/3rd Street). Figure 12 summarizes the average number of vehicles observed along the minor street approaches at each intersection. Volumes shown are the total volumes measured over two days along the minor street approaches during the weekday analysis periods of 8-10 AM and 4-6 PM. As shown, the number of vehicles observed at each intersection under both existing and adaptive signal operations is comparable.

As indicated the volumes along the minor street approaches at the intersection of Burnside Road/3rd Street are approximately 67 percent of the volume at Burnside Road/Cleveland Avenue and 28 percent of the volume at Burnside Road/Eastman Parkway.
Results shown in this section include results by approach only. Measured average vehicle delay results for respective approach movements (through and left turn) are included in Appendix H.

**Objective Met?** Average minor street delay was reduced by 5 percent at the intersection of Burnside Road/Eastman Parkway and reduced by 1 percent at the intersection of Burnside Road/Cleveland Avenue. At the intersection of Burnside Road/3rd Street, average minor street delay increased by 43 percent under adaptive operations. Considering the volume of vehicles at all three intersections, average delay per vehicle along the minor streets increased by 4 percent (+4.79 seconds) under adaptive operations compared to existing traffic signal operations.

**Objective: Decrease overall corridor delay (side street, left turn and mainline combined) by 5 percent or more.**

This objective focused on decreasing overall corridor delay (side street, left turn, and mainline combined) by five percent or more with the implementation of the SCATS adaptive signal system. Delay measurements along the mainline and for protected left turns were measured during the travel time surveys while delay along the minor street was measured during the minor street delay surveys. The following sections present the results of the side street, left turn, and mainline delay surveys.

**Side Street**

Delay results along the minor street approaches at three intersections were documented in the previous section. Results indicate that average delay per vehicle was reduced at two of three intersections analyzed. Accounting for the delay results at all three intersections,
average minor street delay increased by 4 percent (+4.79 seconds) under adaptive operations compared to existing traffic signal operations.

**Left Turn**

Figure 13 summarizes the average delay at protected left turns experienced by probe vehicles along analysis routes two and three during the weekday and weekend.

![Figure 13: Average Left Turn Delay Comparison – (Weekday/Weekend)](image)

<table>
<thead>
<tr>
<th></th>
<th>Average Weekday Protected Left Turn Delay (sec)</th>
<th>Average Weekend Protected Left Turn Delay (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>50.7</td>
<td>56.1</td>
</tr>
<tr>
<td>Adaptive</td>
<td>50.9</td>
<td>47.0</td>
</tr>
</tbody>
</table>

As indicated, the average delay at protected left turns measured under adaptive operations remained consistent with that measured under existing operations during the weekday. On the weekend however, average delay at protected left turns was reduced by 16 percent. Combining the weekend and weekday, average delay at protected left turns decreased by 16 percent (-9.1 seconds) under adaptive operations compared to existing operations.

**Mainline**

Figure 14 summarizes the average weekday and weekend delay for each travel direction along analysis route one. Adaptive signal operations reduced the average weekday delay along route one by 35 percent in the eastbound direction and by 26 percent in the westbound direction. During the weekend, average delay along route one decreased by 39 percent in the eastbound direction and 17 percent in the westbound direction. Overall, average delay decreased by 31 percent during the weekday and by 29 percent during the weekend. Combining both directions and weekday/weekend time periods, average delay

---

9 Values for the weekend are averaged over the three respective weekday time periods (8-10 AM, 12-2 PM, and 4-6 PM) while values for the weekend are average over the two respective weekend time periods (10-12 PM and 2-4 PM).
along the Burnside Road mainline decreased by 32 percent (-25.5 seconds) under adaptive operations.

![Average Mainline Delay Comparison – Burnside Road Route 1 (Weekday/Weekend)](chart)

- **Objective Met?** Average delay along the mainline decreased by 32 percent (-25.5 seconds) and average protected left turn movement delay was reduced by 16 percent (-9.1 seconds) with the adaptive signal system. Results along the minor street were mixed, with average delay decreasing at two of three intersections analyzed. Overall corridor delay was reduced with the implementation of the adaptive signal system compared to existing operations, with the exception of delay increasing along the minor street approach at one intersection.

<table>
<thead>
<tr>
<th>Route</th>
<th>Weekday</th>
<th>Weekend</th>
</tr>
</thead>
<tbody>
<tr>
<td>EB</td>
<td>92.9</td>
<td>66.2</td>
</tr>
<tr>
<td>WB</td>
<td>77.4</td>
<td>63.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Route</th>
<th>Weekday</th>
<th>Weekend</th>
</tr>
</thead>
<tbody>
<tr>
<td>EB</td>
<td>60.0</td>
<td>40.1</td>
</tr>
<tr>
<td>WB</td>
<td>57.1</td>
<td>52.7</td>
</tr>
</tbody>
</table>

**Objective: Decrease overall system stops by 5 percent or more.**

The objective to decrease overall system stops by 5 percent or more was assessed by comparing stops extracted from the probe vehicles along each analysis route. Figure 15 summarizes the difference in average number of stops encountered by probe vehicles under existing and adaptive traffic signal operations along analysis route one of the Burnside Road corridor. Both weekday and weekend results by direction are shown. The percent change is indicated in the figure.

The average number of stops decreased along route one in both travel directions during both the weekday and weekend time periods under adaptive operations. During the weekday, the average number of stops in the eastbound direction decreased by 37 percent, while the average number of stops decreased by 6 percent in the westbound direction. During the weekend, the average number of stops decreased by 43 percent and
1 percent in the eastbound and westbound travel directions respectively. The most significant benefits were measured in the eastbound travel direction.

![Figure 15: Average Number of Stops Comparison – Burnside Road Route 1 (Weekday/Weekend)](image)

Similar to other analyses, results for route one are only shown. Average number of stop results along routes 2 and 3 are included in Appendix C. Appendix C includes further detailed analysis of average number of stop results by route, direction, and time of day. Statistical analysis is also included in Appendix G.

**Objective Met?** The average number of stops decreased by 23 percent during the weekday and by 22 percent during the weekend. The stop reduction was greater in the eastbound direction.

**Objective: Reduce the number of cycle failures for protected left turns and side streets.**

This objective focused on reducing the number of cycle failures on minor street approaches and for protected left turns along Burnside Road with the implementation of the SCATS adaptive signal system. Cycle failure measurements for protected left turns were captured during the travel time surveys, while measurements along the minor street approaches were captured during the minor street delay surveys.

**Protected Left Turns**

Results of cycle failure surveys for several protected left turn movements along Burnside Road are shown in Table 9. The values shown represent the total number of cycle failures experienced by the probe vehicles during the travel time surveys under both existing and adaptive signal operations. Values shown are the total over the time periods of 8-10 AM, 12-2 PM, and 4-6 PM when travel time surveys were conducted.
As shown in Table 9, cycle failures experienced by probe vehicles at protected left turn movements decreased or remained the same at three of the four movements analyzed. Results at the Burnside Road/Powell Valley Road eastbound left turn movement indicate that an average of one additional cycle failure was measured under adaptive operations. Although cycle failures increased for this movement, overall cycle failures experienced by the probe vehicles at protected left turns decreased by 50 percent under adaptive operations compared to existing operations. This assumes the summation of cycle failures at all four movements analyzed.

Table 9: Comparison of Cycle Failures Experienced by the Probe Vehicles during Travel Time Surveys

<table>
<thead>
<tr>
<th>Intersection Route Movement</th>
<th>Weekday Cycle Failures</th>
<th>Parameters</th>
<th>Total Cycle Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8-10 AM; 12-2 PM; 4-6 PM</td>
<td>Existing</td>
<td>Adaptive</td>
</tr>
<tr>
<td><strong>Burnside Rd/Main Ave Route 2 Eastbound Southbound Left Turn</strong></td>
<td>Cycle Failures</td>
<td>6(^1)</td>
<td>0(^2)</td>
</tr>
<tr>
<td></td>
<td>Percent Change</td>
<td>-100%</td>
<td></td>
</tr>
<tr>
<td><strong>Burnside Rd/Division St Route 2 Eastbound Eastbound Left Turn</strong></td>
<td>Cycle Failures</td>
<td>3(^1)</td>
<td>1(^2)</td>
</tr>
<tr>
<td></td>
<td>Percent Change</td>
<td>-67%</td>
<td></td>
</tr>
<tr>
<td><strong>Burnside Rd/Hogan Dr Route 3 Eastbound Southbound Left Turn</strong></td>
<td>Cycle Failures</td>
<td>3(^1)</td>
<td>3(^3)</td>
</tr>
<tr>
<td></td>
<td>Percent Change</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td><strong>Burnside Rd/Powell Valley Rd Route 3 Eastbound Eastbound Left Turn</strong></td>
<td>Cycle Failures</td>
<td>2(^1)</td>
<td>3(^4)</td>
</tr>
<tr>
<td></td>
<td>Percent Change</td>
<td>+50%</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>Cycle Failures</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Percent Change</td>
<td>-50%</td>
<td></td>
</tr>
</tbody>
</table>

1. Based on a total of 70 travel time surveys
2. Based on a total of 47 travel time surveys
3. Based on a total of 59 travel time surveys
4. Based on a total of 68 travel time surveys

Side Streets

Due to the level of data collected as part of the minor street delay surveys, total denied vehicles was measured in place of cycle failures along the minor street approaches at three intersections. Denied vehicles represent the number of vehicles unable to travel through the intersection on the cycle they arrived on.

Comparison of denied vehicles along the minor street approaches at three study intersections under existing and adaptive signal operations is shown in Table 10. Results
shown are the total denied vehicles over the weekday time periods of 8-10 AM and 4-6 PM.

Overall, the total number of denied vehicles decreased at the intersections of Burnside Road/Eastman Parkway and Burnside Road/Cleveland Avenue. However, the total number of denied vehicles increased at the intersection of Burnside Road/3rd Street. This is consistent with the results of the minor street delay surveys. The increase in denied vehicles is at 3rd Street is due to the longer cycle length operated by the adaptive system in the PM. This is also the result of decisions by the city to service the highest volume movements effectively on this section of Burnside Road.

Table 10 also presents the total number of vehicles sampled under each signal operation method. As can be seen the number of sampled vehicles is similar under both signal operations analysis periods. This supports that the analysis is comparable and that one did not have significantly different volumes.

Table 10: Comparison of Denied Vehicles on Minor Street Approaches

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Parameters</th>
<th>Weekday Denied Vehicles</th>
<th>8-10 AM; 4-6 PM</th>
<th>Total Denied Vehicles</th>
<th>Total Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burnside Rd/Eastman Pkwy</td>
<td>Denied Vehicles</td>
<td>Existing</td>
<td>667</td>
<td>8,902</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adaptive</td>
<td>501</td>
<td>9,670</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percent Change</td>
<td>-25%</td>
<td>+9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burnside Rd/Cleveland Ave</td>
<td>Denied Vehicles</td>
<td>Existing</td>
<td>357</td>
<td>3,843</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adaptive</td>
<td>323</td>
<td>3,715</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percent Change</td>
<td>-10%</td>
<td>-3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burnside Rd/3rd St</td>
<td>Denied Vehicles</td>
<td>Existing</td>
<td>52</td>
<td>2,730</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adaptive</td>
<td>148</td>
<td>2,363</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percent Change</td>
<td>+185%</td>
<td>-13%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Denied Vehicles</td>
<td>Existing</td>
<td>1,076</td>
<td>15,475</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adaptive</td>
<td>972</td>
<td>15,748</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percent Change</td>
<td>-10%</td>
<td>+2%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Total Denied Vehicles and Total Volume shown are total for both minor street approaches

**Objective Met?** Cycle failures at protected left turn movements were reduced by 50 percent and the number of denied vehicles was reduced by 10 percent with the adaptive signal system.
Objective: Maintain or reduce the number of complaints from the public about signal operations.

Based on a conversation with the Gresham lead electrician on December 21, 2007 (nine months after the adaptive system turn-on) the number of complaints regarding the Burnside Road corridor has remained constant indicating that they are comparable to those received under the existing time of day signal system.

The most common complaint regarding the adaptive installation is occasional short green times at left turns. When SCATS transitions from an emergency pre-emption or to seek an offset, it can shorten left turn movements to the minimum green time. Even though this has been a common complaint, average delay results at several left turn movements concluded that delay had actually decreased under adaptive operations.

Unlike existing signal operations, city staff has actually received compliments on the adaptive signal operations. This is typically an uncommon occurrence with respect to signal operations. In fact, the neighboring city of Sandy has complimented the adaptive signal system and has indicated that it appeared better. The city of Sandy went as far to say that they wanted it in their city.

Additionally, a number of other jurisdictions have expressed interest in the adaptive system. Jurisdictions actively seeking funding for such a system include the City of Portland, City of Beaverton, and Washington County.

Objective Met? Based on input from City of Gresham staff, the number of complaints has been similar to those received under existing signal operations. In fact, staff has actually received several compliments about the adaptive operations which is a rare occurrence with regards to signal operations.

3.2.2 Goal 2: Provide a Reliable System

This goal focused on implementing a traffic signal system that was reliable and proven to work efficiently. Research of the SCATS adaptive signal system has provided evidence of its reliability with several successful deployments in all parts of the world since its development in the 1970’s. Successful deployments range from tens to hundreds of intersections. This is important in that the city wanted a system that has been in operation at several locations for several years and has little annual maintenance costs.

Evaluation of whether the adaptive signal system improved the operational efficiency (reliability) of a congested corridor was also evaluated. In order to evaluate whether corridor efficiency has improved within the study area, evaluation of travel time reliability using traffic data collected under each traffic signal system was conducted.

This section summarizes the results of the reliability evaluation of the SCATS adaptive signal system.

Objective: Improve travel time reliability

The first objective identified to evaluate corridor efficiency was to determine whether or not the adaptive system has improved travel time reliability. Travel time reliability refers
to the consistency in travel time from point A to point B. The more reliable a given travel time, the better planning motorists can make.

Previous sections discussed average travel time along study route one of the Burnside Road corridor. It should be noted that the average travel time is simply the 50\textsuperscript{th} percentile travel time calculated from the sample size. With this, there is a 50 percent chance that one’s travel time may be higher or lower than the average travel time. The level of degree to which the travel time may vary from the average (higher than or lower than) is identified by the standard deviation of the sample size. The standard deviation defines the spread of the values of the random variable away from its average (in this case travel time). Thus, the lower the standard deviation, the more confidence one will have that there travel time will be within a particular travel time range.

Travel time reliability may be quantified by the standard deviation in travel times from a sample size or better yet by the 95\textsuperscript{th} percentile travel time. The 95\textsuperscript{th} percentile travel time is the simplest method and indicates the travel time that will not be exceeded 95 percent of the time. A driver may plan their trip with 95 percent confidence that they will not be late.

The following sections summarize the standard deviation and 95\textsuperscript{th} percentile travel times along analysis route one of the Burnside Road corridor. Analysis route one is only discussed since this is the primary analysis route and features the largest traffic volumes.

\textit{Standard Deviation in Travel Times}

Figure 16 summarizes the standard deviation in travel times along study route one of the Burnside Road corridor under adaptive and existing signal operations. Both weekday and weekend results for both the eastbound and westbound travel directions are shown along with the percentage change. The weekday standard deviation documented is for all travel times conducted during the time periods (8-10 AM, 12-2 PM, and 4-6 PM) while the weekend standard deviation documented is for all travel times conducted over the two respective weekend time periods (10-12 PM and 2-4 PM).

As can be seen in Figure 16, the variability in travel times along route one during the weekday decreased by 21 percent in the eastbound direction and by 29 percent in the westbound direction under adaptive operations compared to existing operations. The weekday travel time variability range was within one minute of the average travel time under adaptive operations. Overall, the weekday variability in travel times decreased by 26 percent (19.5 seconds).

During the weekend, the variability in travel times was slightly greater in the eastbound direction and less in the westbound direction. The standard deviation in travel time increased by 4 percent and decreased by 10 percent in the westbound direction. Overall, the weekday variability in travel times decreased by 26 percent (16.8 seconds).
Figure 16: Travel Time Standard Deviation Comparison – Burnside Road Route 1 (Weekday/Weekend)

Standard deviation in travel times by weekday and weekend time period for analysis routes 1-3 are included in Appendix I.

95th Percentile Travel Times

As previously mentioned, the 95th percentile travel time is the travel time that will only be exceeded 5 percent of the time. It can be thought of as the travel time expected during days when traffic volumes are highest.

Figure 17 documents the 95th percentile travel times measured along analysis route one in the eastbound and westbound direction. Results are for the average weekday and weekend. As can be seen, the 95th percentile travel times decreased in both travel directions under adaptive operations. The most significant decrease was measured during the weekday time periods where 95th percentile travel time decreased by 13 percent in both the eastbound and westbound travel directions. In fact, 95th percentile weekday travel times are almost one minute lower under adaptive operations.
Appendix J includes weekday and weekend 95th percentile travel time results along analysis routes 1-3 by direction and time period.

**Objective Met?** Overall, the standard deviation in travel times was reduced by 26 percent (19.5 seconds) during the weekday and by 26 percent (16.8 seconds) during the weekend. Similarly, 95th percentile travel times were reduced by 12 percent (49 seconds) during the weekday and by 4 percent (14.7 seconds) during the weekend. This indicates that motorists may have better confidence in their trip planning along the Burnside Road corridor.

**Objective: Implement a system that has been installed and operating in at least three other locations.**

The City of Gresham desired to install an adaptive system that was already proven in the field and had satisfied users. The SCATS system was selected because it has a long history of on-street operations (more than 30 years), and reference checks with other public agency users in the United States indicated a strong satisfaction with the system and the vendor support.

The SCATS adaptive signal system has had numerous successful installations worldwide. Installations range from tens to hundreds of intersections. Successful installations just in the western United States include:

- City of Sunnyvale, CA
- City of Menlo Park, CA
- City of Santa Rosa, CA
- City of Chula Vista, CA
- Park City, UT
There have also been many successful installations in the eastern United States, Australia, China, Hong Kong, Ireland, and New Zealand just to name a few. The installation in Gresham marks only the sixth successful SCATS adaptive signal installation in the western United States and first in the northwest.

The Gresham experience has been consistent with the reference checks in the system evaluation phase. The system has exceeded expectations in on-street performance and offers extensive capabilities due to the large number of available tools.

**Objective Met?** The SCATS adaptive signal system is currently operational in both the western and eastern United States as well as many countries throughout the world. In the western United States alone, there have been five successful installations, primarily in the state of California. The Gresham installation is the first in the northwest.

**Objective: Implement a system that has been installed and operating for at least one year.**

The SCATS adaptive signal system has been in operation worldwide since the mid 1970’s. Thus the signal system is not a new signal system, although is fairly new in the United States. All SCATS installations in the western United States as mentioned previously have been operational for at least one year.

**Objective Met?** The SCATS adaptive signal system has been in operation worldwide since the mid 1970’s. There are multiple SCATS systems in the U.S. operating for more than one year.

**Objective: Implement a system with positive user feedback regarding vendor support.**

There has been much positive feedback from the vendor of the SCATS adaptive signal system. During the signal system evaluation state of this project, vendor staff graciously accepted and offered a full day of their time to present the adaptive system in detail to city staff.

Two separate full day demonstrations were conducted with the vendor providing hands-on demonstrations of the system interface and functionality of their system. Review with other agencies operating the SCATS system have also expressed positive remarks towards the vendor of the system

**Objective Met?** City of Gresham staff has had a positive experience with SCATS support staff from TransCore. Training was well done and ongoing support has been available when needed.

**Objective: Implement a system that requires a low cost ($15,000 or less) annual maintenance contract**

According to SCATS vendors, an ongoing annual maintenance contract of approximately $15,000 to $20,000 is recommended for ongoing system support. The vendor recommends this contract be set on a time and material basis so the agency has the dollars
set aside to cover any support, training new staff, or purchasing replacement parts. Although recommended, discussions with other SCATS users around the country however have claimed to not have an existing ongoing maintenance contract with the vendor.

**Objective Met?** Several options exist from ongoing maintenance and support options, but it is not a requirement.

### 3.2.3 Goal 3: Provide a User Friendly System

The purpose of this goal was to ensure that the traffic signal system implemented in Gresham was user friendly. This entails that the signal system be easily learned, managed, and maintained by existing engineer and maintenance staff. Training of the system should be able to be completed ideally within a week or two. Additionally, the system should feature an easy to learn graphical user interface than can be used to manage and troubleshoot the system.

The following objectives seek to determine the user friendliness of the SCATS adaptive signal system. Objectives focus on the learning curve of the SCATS adaptive system implemented in Gresham along with how well it is able to be managed with existing staff levels.

**Objective: Implement a system that city and county staff feel comfortable using within an acceptable period of time.**

Prior implementations of adaptive traffic signal systems have indicated that some adaptive systems can take years to learn how to use. This is due to the extensive features that adaptive traffic signal systems have to offer. The City of Gresham however preferred a system that did not require multiple years to become familiar with. During the traffic signal system selection phase, the user interface of the SCATS adaptive system was examined by City of Gresham staff and was found to be reasonably easy to use and understand. One of the initial primary concerns was the history of the SCATS system interface not being user friendly and taking years to learn.

To describe the City of Gresham’s assessment of the SCATS system user friendliness, several stages of the signal system implementation are described: implementation, training, and day to day operations.

**Implementation Stage**

The SCATS implementation stage took place over a two week period between March 5th and March 16th, 2007. Prior to implementation the city verified communications, vehicle detectors, communication servers, and all physical hardware was in place and ready for installation of the local and central software. TransCore, the SCATS system representative, developed and tested the intersection personalities prior to March 5th.

Implementation beginning March 5th targeted completing the following activities:

- Testing the intersection personalities in a fully configured cabinet in the signal shop.
• Configuring the SCATS server with the SCATS software.
• Installing the new CPUs and local software in the field controllers
• Providing initial SCATS training during the testing phase of the hardware.

The personality and hardware testing phase served as a training opportunity for city staff because they had the opportunity to work with the central and local software while experienced personnel were assisting and available for questions.

Because SCATS has a windows based Graphical User Interface (GUI), city staff found it easy to pick up by just navigating through the available software menus. To gain full proficiency with all of the features within SCATS would take much more experience and time with the software. To understand how to develop an intersection personality seems to be a specialized skill and could take much longer to gain proficiency.

**Training Stage**

Training was provided in stages:

- During hardware testing prior to field installation
- In the field during fine-tuning
- Formal training at the end of the two week period
- Follow up training one year after the initial installation

It helped to have the signal technicians and engineers involved in the installation, fine-tuning and training because the technicians could focus on learning the requirements and tools available in SCATS to provide ongoing system maintenance and the engineers could focus on learning the requirements and tools available in SCATS.

**Documentation Stage**

Documentation was provided via:

- User Manuals
- Cheat sheets for electricians
- Notes created within SCATS software regarding intersection settings
- TransCore presentations

The SCATS software includes fairly detailed user manual which provides support for city and maintenance staff. Additionally, notes created within the SCATS software for specific intersections aid city staff with documentation of changes made in the field.

**Ongoing Experience**

Some perceive an adaptive system will reduce the ongoing level of effort to operate a corridor of traffic signals because time of day coordinated signal timing plans do not need to be updated every few years. The Gresham experience suggests that the SCATS system may require more day to day attention, then a traditional time of day system. That is not necessarily a bad thing because Gresham has the ability to monitor the health of the corridor via alarms and logs that SCATS provides. This results in more effective operations for changing traffic volume conditions.
Objective: Implement a system that can be operated with existing staff levels (two traffic engineers and three signal technicians).

The City of Gresham currently maintains and operates 110 traffic signals with three traffic signal technicians and two traffic engineers. The traffic engineers spend approximately 2 percent of their time on signal operations, while signal technicians spend approximately 12 percent. The city did not plan to add additional staff to manage and operate the adaptive system, so the city selected a system that was expected to not require a significant amount of additional effort to operate and maintain. During the system selection phase, the city interviewed multiple agencies that were operating the SCATS adaptive system and none of the agencies had added staff to operate the SCATS system so the city proceeded under the assumption that no new staff would be required.

Objective Met? The City of Gresham did not add additional staff with the Burnside Road installation. Although the SCATS system requires additional attention beyond the existing time of day system, the existing engineers and technicians manage and operate the SCATS system in addition to the existing traffic signals within the city.
3.2.4  Goal 4: System shall be expandable for the rest of region

Another goal of the adaptive signal installation was to ensure that the system installed would be expandable for the rest of the region. This implies that the system operate with existing regionally shared traffic signal infrastructure and communications.

Public agencies in the Portland metropolitan area have a long history of collaborating together and fostering strong relationships that support management of the transportation network as a whole. For example, the region standardized on the same controller and software type decades ago and recently standardized on a common central traffic signal system. Therefore, it is important to the steering committee to deploy an adaptive system that could be expandable to other jurisdictions in the Portland metropolitan area. This not only means the system must be capable to support this expansion, but other jurisdictions within the region must agree with the decision to select an adaptive system in the City of Gresham.

The steering committee, made up of representatives from multiple agencies within the metropolitan area, reached consensus that the SCATS adaptive system was most suitable to conditions in the Portland area. Steering committee members agreed that this system could be deployed within other jurisdictions because it supports an interface to the existing central signal system and supports regional expansion.

Objective: Implement a system on a corridor that could apply to other similar corridors in the region.

The first objective supporting that the signal system be expandable for the rest of the region was to ensure that the system implemented on the Burnside Road corridor could also be implemented on similar corridors in the region. It is fair to say that the Burnside Road corridor is representative of many other major arterial roadways in the Portland metropolitan area. There are no special events in this corridor. The corridor is a typical major arterial in the Portland metropolitan area with a five-lane cross section and shopping centers with directional flow in the morning and balanced flow for the rest of the day. The corridor is unique in that it is the primary route connecting the Portland metropolitan area to US 26 and destinations at Mt. Hood and central Oregon. The Burnside corridor experiences daily fluctuations in traffic volumes like any other corridor in the Portland metropolitan region and it has locations with major crossing arterials. The average daily traffic on the corridor is approximately 30,000.

Objective Met? Burnside Road is a five-lane major arterial and serves as the primary route connecting the Portland metropolitan area to US 26 and destinations at Mt. Hood and central Oregon. The corridor carries approximately 30,000 vehicles per day and has locations with major crossing arterials. The corridor features daily fluctuations in traffic volumes similar to other corridors in the region.

Objective: Implement a system that is expandable to other jurisdictions in the Portland metropolitan area.

This objective focused on implementing a system that would be expandable to other jurisdictions in the Portland metropolitan area. This is important since the region shares a
common central signal system, local controller hardware and software. The adaptive signal system installed on the Burnside Road corridor is compatible with the existing regionally shared central signal system, local controller hardware and software. Thus the project demonstrates show any other agencies in the region could modify a corridor to provide adaptive capabilities.

Another example of the expandability is the fact that this project used federal dollars. This is an example for other regional jurisdictions.

**Objective Met?** The SCATS adaptive signal system implemented along the Burnside Road corridor is compatible with the existing regional TranSuite central signal system and local controller hardware shared within the region.

### 3.2.5 Goal 5: Implement a cost effective traffic signal system

This goal sought to implement a traffic signal system that would not only provide benefits to motorists above and beyond the existing time of day system, but be cost effective. In order to evaluate cost effectiveness, objectives were identified to see how well the costs incurred for the design and installation of the adaptive system compared to the benefits received by the city and public from the system. Objectives focus on how well the system installed utilized existing communications infrastructure and field hardware as well as assessing how well the system is maintained by existing city staff levels. The following summarizes the assessment of the objectives identified to determine the cost effectiveness of the adaptive signal system installed in Gresham.

**Objective: Implement a system that provides the benefits described in Goal #1 within the project budget**

The first objective towards identifying whether the adaptive signal system implemented was cost effective was to assess whether or not the system was installed within the project budget. Although the adaptive signal system did cost more than a traditional signal system to design and install, it was designed and implemented within the project budget. The respective costs for the implementation of the SCATS adaptive signal system along Burnside Road in Gresham are summarized in Table 11. As shown, the cost per intersection for the adaptive signal system equaled approximately $100,000. It is important to note that much of this cost is attributed towards the licensing of intersections for the system. Licensing was equivalent to approximately $20,000 per intersection.

**Table 11: Gresham Adaptive Signal System Installation Costs**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>$477,880</td>
</tr>
<tr>
<td>Design and Integration</td>
<td>$445,845</td>
</tr>
<tr>
<td>Benefits Evaluation</td>
<td>$90,000</td>
</tr>
<tr>
<td>City of Gresham Installation Effort</td>
<td>$85,000</td>
</tr>
<tr>
<td>City of Gresham Ongoing Annual Effort</td>
<td>$15,500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$1,114,225</td>
</tr>
</tbody>
</table>
With the respective implementation costs known, the benefits provided by the adaptive signal system described in goal 1 must be quantified and compared to the cost. Once both the respective costs and benefits are known, a benefit to cost analysis can be conducted to determine the cost effectiveness of the system. For this, comparison of vehicle hours of delay and fuel usage under adaptive and existing signal operations was conducted. Although there are many other benefits associated with signal improvements such as emissions, stops, travel time, and accidents, only delay and fuel usage were compared for simplicity purposes.

Vehicle hours of delay were calculated using average vehicle delay and volume results from both the mainline (via probe vehicle surveys along Burnside Road analysis routes 1-3) and minor streets (via minor street delay surveys at three intersections). Fuel usage was calculated by using the fuel consumption equation documented within the Synchro™ analysis software. Respective values of time and fuel costs were then applied.

Calculations for weekday and weekend vehicle hours of delay and fuel usage are included in Appendix K. The summary of net benefits in terms of savings in delay and fuel usage associated with the SCATS adaptive signal system installation is summarized in Table 12.

Table 12: Gresham Adaptive Signal System Installation Benefits

<table>
<thead>
<tr>
<th>Item</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Delay (vehicle hours)</strong></td>
<td></td>
</tr>
<tr>
<td>Weekday</td>
<td>$998,043</td>
</tr>
<tr>
<td>Weekend</td>
<td>$320,431</td>
</tr>
<tr>
<td><strong>Fuel (gallons)</strong></td>
<td></td>
</tr>
<tr>
<td>Weekday</td>
<td>$111,525</td>
</tr>
<tr>
<td>Weekend</td>
<td>$111,317</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$1,541,315</td>
</tr>
</tbody>
</table>

Note: Weekend values reflect values for mainline only. Weekday includes values for mainline and minor street.

A benefit to cost ratio of 1.4 was calculated for this project by comparing the net benefits to project costs. A benefit to cost ratio greater than 1.0 indicates that the savings in terms of benefits (in this case vehicle hours of delay and fuel usage) are greater than the costs.

---

10 Total vehicle hours of delay for mainline was calculated by summing totals for analysis routes 1-3 during all weekday (8-10 AM, 12-2 PM, and 4-6 PM) and weekend (10-12 PM and 2-4 PM) time periods. Average delay was determined via probe vehicle surveys while average volume travelling each route was determined via intersection turn movement and tube counts. Values along the minor street are totals at all three intersections during weekday (8-10 AM, 4-6 PM) time periods.

11 F = Total Travel*k1 + Total Delay*k2 + Stopped * k3

12 Travel time has a value of $14.60 per person-hour and $77.10 per truck hour in 2005 (http://mobility.tamu.edu/ums/media_information/faq.stm). Accessed 1/8/2008

13 Net benefits/Net costs = $1,541,315/$1,114,225
costs associated with the implementation of the system. This indicates that the adaptive signal system project was worthwhile and that the project pays for itself within the first year of operation. A five year benefits to cost ratio of 4.2 was calculated which accounts for annual ongoing maintenance. Respective calculations are included in Appendix K.

**Objective Met?** The SCATS adaptive signal system implemented along the Burnside Road was installed within the project budget and provides benefits greater than the associated costs to implement the system. The adaptive installation results in a benefit to cost ratio of 1.4 for the first year and 4.2 over five years.

**Objective: Implement a system (detectors and communications) that can be maintained by the existing staff levels**

The City of Gresham did not plan to add additional staff to manage and operate the new adaptive signal system therefore; this objective assesses how well the adaptive signal system implemented is maintained by existing city staff levels. The city currently has three traffic signal technicians and two traffic engineers responsible for maintaining the city's traffic signals. These individuals are the same as those responsible for maintaining the time of day system.

Managing and operating an adaptive traffic signal control system requires three primary components.

- An engineer responsible for monitoring the day to day performance and managing the data from system detectors and the system reports
- A signal technician for responding to detector, communications, and/or controller failures
- Vendor support for troubleshooting system failures or general operations and for providing training

Day to day performance monitoring may include:

- Cycle length and split monitoring
- Archive data (volumes) from system detectors and the adaptive system.
- Adjustments to adaptive signal control factors such as configuring special function commands, making adjustments to the system if new signalized intersections are installed on the corridor, phasing is modified, or new lanes are added

Existing city staff has been able to carry out these primary management and monitoring tasks of the adaptive system. Although the level of effort is slightly greater than that of the existing signal system, it is not great enough to require additional staff. An interview with the city’s lead electrician indicated that he spends an average of one hour (12%) each day monitoring the system. He indicated that the system encourages you to spend time making sure the corridor is operating well. Most of the increased time is spent clearing alarms and retrieving data for review. He indicates that the extra work all focuses on making the corridor operate more efficiently. To get the best benefit out of the SCATS adaptive system you have to put more time into it.
Objective: Deploy a system that maximizes the use of existing infrastructure (detectors, controllers, cabinets and software)

This objective seeks to determine how well the adaptive signal system installed in Gresham utilized existing traffic signal infrastructure. The Gresham installation was able to utilize a large portion of existing infrastructure, although modifications to field intersections and central system infrastructure were required. The modifications needed to support the installation of the SCATS system in Gresham are listed below:

- **Install all new vehicle detection.** The SCATS system requires a stop bar detection zone of 16 feet long in each approach lane.
- **Install new central processing units.** The SCATS system can operate on the existing Model 170E controllers, but with a new central processing unit.
- **Reconfigure the copper twisted pair.** Communications between the SCATS central server and the field intersections can be provided over copper twisted pair, but the communications channels had to be modified.
- **Install a new SCATS signal system server.** The SCATS system requires a separate central server from the previous TransCore (now TranSuite) central traffic signal system. The new server is located at Gresham City Hall.

**Objective Met?** Although the system does require additional staff time than traditional time of day systems, the city operates the SCATS system effectively with existing staff.

Objective: Implement a system that can share information with the existing TranSuite traffic signal system or at a minimum does not restrict the future ability to share information with the existing TranSuite

This objective ensures that the adaptive signal system has the ability to share information with existing TranSuite traffic signal system. This is due to that the City of Gresham currently uses the TranSuite (formerly Series 2000) central traffic signal system for communications to the majority of signalized intersections within the city. The Burnside Road corridor was formerly on the TranSuite signal system prior to migration to the SCATS adaptive signal system.

Importantly, the SCATS server interfaces to the TranSuite signal system server. From the TranSuite main map, the user is able to see the status of intersections on the SCATS signal system.

**Objective Met?** The SCATS adaptive signal system uses existing traffic signal controllers, cabinets, and copper twisted pair communications infrastructure. However, modifications to signal controllers, communications, and vehicle loop detector placement were required. Modifications to loop detectors included installing new stop bar detection zones in each lane while modifications to traffic signal controllers included installing new central processing unit cards. Modifications to communications included revision of communication channels.

**Objective Met?** The SCATS adaptive signal system uses existing traffic signal controllers, cabinets, and copper twisted pair communications infrastructure. However, modifications to signal controllers, communications, and vehicle loop detector placement were required. Modifications to loop detectors included installing new stop bar detection zones in each lane while modifications to traffic signal controllers included installing new central processing unit cards. Modifications to communications included revision of communication channels.

**Objective Met?** Although the system does require additional staff time than traditional time of day systems, the city operates the SCATS system effectively with existing staff.
**Objective Met?** The SCATS adaptive signal system has the ability to share information with the existing TranSuite central traffic signal system. From the TranSuite main map, the user is able to see the status of intersections operating SCATS.
4 WAS IT WORTH IT TO INSTALL THE SCATS ADAPTIVE SIGNAL SYSTEM?

Based on the assessment of project goals and objectives documented in this report, the majority were achieved with the implementation of the SCATS adaptive signal system. Additionally, based on the benefits provided to motorists by adaptive operations, primarily in the form of savings in delay and fuel usage, compared to existing time of day operations, it can be said that it was worth it to install the SCATS adaptive signal system.

To emphasize the benefits provided by the adaptive system, Figure 18 shows the results of travel time studies in the evening weekday peak (4-6 PM) on the study section of Burnside Road (Eastman Parkway to Powell Valley Road) following the implementation of various timing improvements (including the average time for the SCATS system) since 1997. Travel time measurements taken when the corridor was running free in 1997 found the average travel time to be 405 seconds in the eastbound direction and 346 seconds in the westbound direction. When coordinated time of day plans were implemented and travel time measurements taken in 1998, travel times decreased to 368 seconds eastbound and to 318 seconds westbound. The corridor was changed back to free operation in 2004 to re-sample travel times and these surveys indicated an increase in travel times. Prior to the implementation of a new actuated coordinated time of day timing plan in 2004, travel times were measured using the 1998 plans. The travel times were higher than their implementation in 1998 indicating that the time of day coordinated plans had degraded over time as volumes changed. This same effect is evident between 2004 and 2007 when travel times conducted in February of 2007 were greater than travel times conducted in the spring of 2005 after the implementation of new time of day plans. Finally, the average travel times for the corridor are the lowest over this period for travel runs conducted with SCATS adaptive system operational. Because the corridor has been actively managed and re-timed over the previous several years, the significant improvements in average travel time shown by the SCATS system are even more compelling.

The following items support the worthiness of the SCATS adaptive installation in Gresham:

- The SCATS adaptive system improved the performance of the Burnside Road corridor compared to performance under time of day coordinated plans. Improved performance is supported by reduced average travel times, stops, and delay.
- The SCATS adaptive system is a reliable system and has also improved the reliability of the Burnside Road corridor. Improved reliability is supported by reduced 95th percentile travel times and standard deviation in travel times along the Burnside Road corridor.
- The SCATS adaptive system is a user friendly system and does not require additional staff to manage and monitor. According to the Gresham lead electrician responsible for signal operations, “SCATS is a phenomenal program, it has all the tools needed to make signal operations better and adjusts based on the amount of cars not on historical data”.


• The SCATS adaptive system is expandable and interfaces with existing traffic signal controllers, cabinets, and copper twisted pair communication infrastructure. The system interfaces with the existing TransSuite central signal system.

• The SCATS adaptive system is a cost effective system. A first year benefits to costs ratio of 1.4 indicates that the system pays for itself within the first year of operation. Similarly a five year benefits to cost ratio of 4.2 indicates that the quantifiable benefits provided to motorists outweigh the implementation and maintenance costs. Importantly, the benefits tabulated as part of this analysis only capture those associated with delay and fuel usage. Other benefits typically associated with traffic signal improvements such as emissions, stops, travel time, and accidents were not accounted for in this analysis.

![Figure 18: Comparison of Travel Times on Burnside Road between 1997 and 2008](image-url)