Seattle/Lake Washington Corridor Urban Partnership Agreement: National Evaluation Report

www.its.dot.gov/index.htm

Final Report — December 2, 2014

FHWA-JPO-14-127

U.S. Department of Transportation

Research and Innovative Technology Administration

Cover photo source: WSDOT

Produced by Urban Partnership Agreement Demonstration Evaluation
U.S. Department of Transportation
Research and Innovative Technology Administration
Federal Highway Administration
Federal Transit Administration

Notice

Technical Report Documentation Page

1. Report No. **FHWA-JPO-14-127**	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Seattle/Lake Washington Corridor Urban Partnership Agreement: National Evaluation Report		**5. Report Date** December 2, 2014 **6. Performing Organization Code**
7. Author(s) Jeremy Schroeder and Theodore Smith (Battelle); Katie Turnbull, Kevin Balke, Mark Burris, and Praprut Songchitruksa (Texas A&M Transportation Institute); Brian Pessaro (Center for Urban Transportation Research); Emily Saunoi-Sandgren, (Hubert H. Humphrey School of Public Affairs); Eric Schreffler (ESTC); and Barbara Joy (Earth Matters).		**8. Performing Organization Report No.**
9. Performing Organization Name And Address Battelle 505 King Avenue Columbus, OH 43201		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-06-D-00007/ORDER 07-T-08002/ WO BA07-041
12. Sponsoring Agency Name and Address U.S. Department of Transportation Research and Innovative Technology Administration Federal Highway Administration Federal Transit Administration 1200 New Jersey Avenue, S.E. Washington, DC 20590		**13. Type of Report and Period Covered** **14. Sponsoring Agency Code**
15. Supplementary Notes		

16. Abstract

This document presents the final report on the national evaluation of the Seattle/Lake Washington Corridor (LWC) Urban Partnership Agreement (UPA) under the United States Department of Transportation (U.S. DOT) UPA Program. The Seattle UPA projects focus on reducing congestion by employing strategies consisting of combinations of Tolling, Transit, Telecommuting/TDM, and Technology, also known as the 4Ts. Those strategies including tolling all lanes of the SR 520 bridge, additional bus service in the SR 520 corridor, implementing active traffic management systems, and real-time traveler information signs on highways and at transit stops and stations. The national evaluation of the Seattle/LWC UPA projects is guided by the National Evaluation Framework, the Seattle/LWC UPA National Evaluation Plan, and individual test plans for various components. This report provides information on the use of the new Seattle/LWC UPA projects. Changes in travel speeds, travel times, trip-time reliability, park-and-ride lot use, and transit ridership are described. The results of interviews and workshops with local stakeholders, surveys of different user groups, and interviews and focus groups with Washington State Patrol officers, bus operators, and service patrol personnel are presented. The air quality, energy, and safety impacts of the Seattle/LWC UPA projects are examined. Information on changes in unemployment rates, gasoline prices, and parking costs is also summarized.

17. Key Words Urban Partnership Agreement, Congestion Reduction Demonstration, congestion pricing, tolling, congestion reduction, transit, telecommuting, evaluation	**18. Distribution Statement**

19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	**21. No. of Pages**	**22. Price**
		344	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

This page intentionally left blank

Table of Contents

List of Appendices

List of Tables

List of Figures

List of Abbreviations

4Ts	Tolling, Transit, Telecommuting, and Technology
AIS	Abbreviated Injury Score
ANOVA	Analysis of Variance
ATM	Active Traffic Management
BCA	Benefit-Cost Analysis
CATI	Computer Assisted Telephone Interviewing
CBA	Cost Benefit Analysis
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_{2e}	Carbon Dioxide Equivalent
CRD	Congestion Reduction Demonstration
CSC	Customer Service Center
CTR	Commute Trip Reduction
EB	Eastbound
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ETC	Electronic Toll Collection
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GP	General Purpose
HOV	High-Occupancy Vehicle
IRT	Incident Response Team
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LWC	Lake Washington Corridor
MOVES	Motor Vehicle Emissions Simulator
MPO	Metropolitan Planning Organization
NB	Northbound
NEF	National Evaluation Framework
NOx	Nitrogen Oxides
NRTMC	Northwest Region Traffic Management Center
$PM_{2.5}$	Particulate Matter less than 2.5 microns

PM_{10}	Particulate Matter less than 10 microns
PSRC	Puget Sound Regional Council
RITA	Research and Innovative Technology Administration
RSG	Resource Systems Group
SB	Southbound
SOV	Single Occupant Vehicle
SR	State Route
TDM	Travel demand management
TEC	Total Energy Consumption
TRAC	Washington State Transportation Center
TRB	Transportation Research Board
TRIPS	Transportation Information Planning Support
UPA	Urban Partnership Agreement
U.S. DOT	U.S. Department of Transportation
VOC	Volatile Organic Compounds
Volpe	John A. Volpe National Transportation Systems Center
VPHPL	Vehicles Per Hour Per Lane
VMT	Vehicle Miles Traveled
VSL	Variable Speed Limit
WB	Westbound
WSDOT	Washington State Department of Transportation
WSP	Washington State Patrol
WSTC	Washington State Transportation Commission

Acknowledgements

A number of representatives from the Seattle area partnership agencies provided information critical to the development of this final report. The assistance of the following individuals is both recognized and appreciated: Tyler Patterson, Matt Beaulieu, Jennifer Charlebois, Patty Rubstello, Sara Cassou, and Kathy Leotta, Washington State Department of Transportation; Charlie Howard, Benjamin Brackett, and Matthew Kitchen, Puget Sound Regional Council; Ron Posthuma, Peter Heffernan, John Toone, and Carol Cooper, King County Metro Transit; and Anil Mudigonda, Paul Barney, and Rhett Harper, Jacobs Engineering.

This page intentionally left blank

Executive Summary

This report presents the national evaluation of the Seattle/Lake Washington Corridor (LWC) Urban Partnership Agreement (UPA) projects under the U.S. Department of Transportation (U.S. DOT) UPA program. It summarizes information from the pre-deployment period and one full year of operation of the majority of Seattle/LWC UPA projects.

Background

In 2006, the U.S. DOT, in partnership with select metropolitan areas, initiated the UPA program to demonstrate congestion reduction through the implementation of pricing activities (e.g., tolling) combined with necessary supporting elements. Six sites around the U.S., including the Seattle/LWC as well as Miami, Los Angeles, Atlanta, Minneapolis, and San Francisco, were selected through a competitive process to conduct either UPA or Congestion Reduction Demonstration (CRD) program improvements. The selected sites were awarded funding for implementing congestion reduction strategies based on four complementary strategies known as the 4Ts: Tolling, Transit, Telecommuting (as well as additional travel demand management [TDM] strategies), and Technology.

The U.S. DOT sponsored the UPA and CRD national evaluation, with the overall conduct of the national evaluation being the responsibility of the Research and Innovative Technology Administration's (RITA's) Intelligent Transportation Systems Joint Program Office (ITS JPO). Representatives from the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) are actively involved in the national evaluation. The Battelle team was selected by the U.S. DOT to conduct the national evaluation through a competitive procurement process.

The purpose of the national evaluation was to assess the impacts of the UPA/CRD projects in a comprehensive and systematic manner across all sites. The national evaluation generated information and produced technology transfer materials to support deployment of the strategies in other metropolitan areas. The national evaluation also generated findings for use in future federal policy and program development related to mobility, congestion, and facility pricing. The Battelle team developed a National Evaluation Framework (NEF) to provide a foundation for evaluation of the UPA/CRD sites. The NEF is based on the 4T congestion reduction strategies and the questions that the U.S. DOT seeks to answer through the evaluation. The NEF was used to develop the Seattle/LWC UPA National Evaluation Strategy, the Seattle/LWC UPA National Evaluation Plan, and ten Test Plans. These plans guided the Seattle/LWC UPA National Evaluation.

The Seattle/Lake Washington Corridor UPA

The Seattle/LWC UPA partners included the Washington State Department of Transportation (WSDOT), the Puget Sound Regional Council (PSRC), and King County, Washington. These partners coordinated planning, implementation, and/or operation of various UPA projects with a number of other local agencies, such as the City of Seattle and Sound Transit.

The Seattle/LWC UPA projects focused on reducing traffic congestion on SR 520 between Interstate-405 and Interstate-5, a heavily-traveled, east-west commuter route across Lake Washington. The lake separates the city of Seattle from eastside communities like Redmond and Bellevue. The centerpiece of the UPA projects was the initiation of tolling on an existing facility: the SR 520 bridge that is in need of replacement. A replacement bridge would have been opened as a toll bridge anyway, but early tolling allows the generation of revenue in advance to serve as a down payment on the new bridge and reduce financing costs for a new bridge that will improve mobility and safety for local users.

Intelligent transportation systems (ITS) technologies underlie many of the Seattle/LWC UPA projects, including those dealing with tolling and real-time traffic and transit information. Seattle/LWC UPA projects that were operational by the end of 2011 include variable tolling on all lanes of the SR 520 bridge across Lake Washington, enhanced bus services, transit real-time information signs and passenger facilities, real-time multi-modal traveler information, and active traffic management (ATM) signage. The Redmond Park-and-Ride/Transit Oriented Development was completed much earlier than the other UPA projects (in July 2009), while the South Kirkland Park-and-Ride lot was completed after most other UPA projects; neither were included in this evaluation.

The implementation of the Seattle/LWC UPA projects occurred after a spike in the unemployment rate in early 2010. The unemployment rate for the area counties and state generally decreased through the evaluation period. The unemployment rate for King County in particular ranged from a high of 8.9 percent in January and February 2011 to a low of 6.1 percent at the end of the post-deployment period in December 2012. These trends could attenuate the UPA projects' effectiveness and be reflected in the observed travel patterns.

In addition, the price of a gallon of regular conventional gasoline fluctuated during the pre-deployment to post-deployment periods. In the pre-deployment period before the beginning of tolling on the SR 520 bridge in December 2011, the price ranged from $3.19 to $4.06. For the post-deployment period, gasoline prices were more volatile, but ranged between $3.37 and $4.33. These changes in gasoline prices may have influenced travel behavior and use of the Seattle/LWC UPA projects.

The Seattle/LWC UPA analysis was complicated by the nature of the projects and other non-UPA improvements occurring in the SR 520 corridor at the same time as the evaluation. In particular, the Eastside Transit and HOV Project on SR 520 began in January 2011 and continued through the end of the post-deployment period. Being immediately to the east of the SR 520 bridge, this construction project disrupted traffic in the corridor and included all-weekend closures of all lanes of SR 520 on numerous occasions, influencing travel patterns in the corridor, transit operating speeds, and travel times. These changes could affect travel speeds, travel times, throughput, and safety.

Another component of the UPA in the Seattle area was the deployment of ATM strategies, including variable speed limits. The use of enforceable variable speed limits results in lower speeds being posted in advance of congestion and incidents in an effort to smooth traffic, increase throughput, and reduce secondary incidents by increasing driver awareness and shortening the needed reaction time to reduce speeds. Possible changes in traffic patterns on I-90 caused by tolling the SR 520 bridge may have been lessened by ATM strategies on that corridor, while the combined effects of the UPA projects and other improvements on SR 520 could compound individual benefits of increased speeds, reduced travel times, improved trip-time reliability, and increased throughput. However, it was not possible to fully assess the impacts of these individual strategies separately.

The following points highlight the evaluation findings of the major elements of the UPA projects that were the focus of the national evaluation:

- **Tolling.** Variable tolling on the SR 520 bridge was activated on December 29, 2011, utilizing electronic toll collection with no toll booths. The *Good to Go!* program provides multiple payment options including pass accounts, Pay By Plate accounts, Short Term accounts, and Pay By Mail. Individuals using the Pay By Mail option do not need to open a *Good to Go!* account. Of the 243,123 SR 520 toll bridge *Good To Go!* accounts opened from February 2011 to December 2012, 89 percent were pass accounts, 9 percent were Pay By Plate accounts, and 2 percent were Short Term accounts. Toll rates ranged from $1.10 to $3.59 during the evaluation period for users with *Good to Go!* passes, with higher rates for travelers utilizing the Pay By Mail option. Overall, WSDOT reported traffic volumes approximately 34 percent lower in the post-deployment period than pre-toll levels on SR 520. Monthly toll transactions on the SR 520 bridge remained relatively constant in 2012, averaging between 1 million and 1.5 million. The tolling system is used primarily by frequent travelers making daily trips and infrequent users making only a few trips a year. The results of surveys of travelers in the corridor indicate that many pre-deployment bridge users continue to travel on the bridge and pay a toll, but that some have changed travel routes and travel modes due to the tolling system.
- **Transit.** Bus service along SR 520 was expanded by adding 90 one-way peak period trips on bus routes operated by King County Metro Transit. Two park-and-ride lots were modified, the South Kirkland lot located at the I-405/SR 520 interchange and the Redmond lot located farther east. The Seattle UPA demonstrated strong increases in ridership and park-and-ride lot usage as well as improvements in bus travel times. Specifically, ridership on the SR 520 bridge increased 28 percent, while ridership on SR 520 near Bellevue increased 46 percent. Customer satisfaction with the transit service as a whole remained good. On-time performance across the SR 520 bridge improved in the eastbound direction from 47 to 67 percent and from 40 to 57 percent in the a.m. and p.m. peak periods, respectively. Bus travel times across the SR 520 bridge improved after tolling. The passenger surveys showed that the Seattle/LWC UPA has helped to shift some commuters to transit. Of new riders, 55 percent said they were influenced to take transit because of the tolls. When asked how they used to make their trip across the SR 520 bridge, 41 percent of new riders said they used to drive alone.
- **TDM.** While the UPA did not provide funding for TDM projects, local and state agencies, along with employers have already provided a wide array of programs for many years intended to reduce trips in the SR 520 corridor. These activities are not new as a result of the UPA project but support the UPA objectives related to TDM. Minimal changes were identified for SOV travel, telecommuting, and carpooling in the LWC as a result of the UPA project. The various data sources paint slightly different pictures of nominal shifts in certain modes, especially bike and walk. Vanpooling, as managed by regional providers, doubled in the SR 520 corridor in the post-deployment corridor. However, carpooling was deemed to decrease very slightly (<1 percent) at both CTR worksites using the SR 520 corridor and among SR 520 travelers captured in the Volpe household travel survey.
- **Technology.** Advanced technologies, e.g., ITS, play a significant role in almost all of the Seattle/LWC UPA projects. Two specific technology projects were implemented. Active Traffic Management (ATM) systems were installed on SR 520 and I-90, consisting of a series of electronic variable speed-limit, lane status, and mini-dynamic messaging signs (DMS) over each lane on the corridors. Second, real-time travel time signs in the SR 520 corridor provided comparative travel times (e.g., for alternate routes) for travel to Seattle. The implementation of signs with real-time travel times via SR 520 and I-90 to downtown Seattle

did not influence a change in VMT on the two facilities. The ATM and travel time signs on SR 520 and I-90 did not result in major changes in travel times or travel speeds on SR 520 and I-90. There were no statistically significant changes in crashes resulting from the implementation of the ATM signs on SR 520 and I-90, although additional years of crash data are necessary to identify changes. The impact of the ATM and travel time signs on the duration of congestion-causing incidents on SR 520 and I-90 was mixed and requires further study covering a longer period of time. The duration of incidents increased with the implementation of the ATM and travel time signs, but declined after tolling on the SR 520 bridge was implemented. After tolling was initiated, the ratio of incident to non-incident travel times improved on SR 520, but were worse in I-90.

The safety analysis revealed changes in the number of crashes on the SR 520 and I-90 corridors that reflect a VMT shift from SR 520 to I-90 after the initiation of tolling. Additional crash analysis including a longer period of time post-tolling is required to verify these findings. The environmental analysis indicated reductions of over 30 percent in both emissions and fuel use on SR 520, as well as decreases for other routes in the study area. Non-technical success factors included building upon existing strong working relationships. Early tolling on the SR 520 was accepted publicly and politically through the deliberate outreach and communications of top agency leadership. The local media was objective and kept the tolling project visible, although reporting sometimes tended to be negative. The public tended to be more supportive of tolling and the UPA projects in the post-deployment period. Finally, the Seattle/LWC UPA projects had a benefit-to-cost ratio of 1.76. The calculated net societal benefit was positive due to travel time savings and reduced emissions in the study area, which were assumed to be directly attributable to the UPA project.

Chapter 1 Introduction

This report presents the national evaluation of the Seattle/Lake Washington Corridor (LWC) Urban Partnership Agreement (UPA) sponsored by the U.S. Department of Transportation (U.S. DOT) UPA program. The Seattle/LWC is one of six locations selected by the U.S. DOT to implement a suite of strategies aimed at reducing congestion under the UPA and the Congestion Reduction Demonstration (CRD) programs. A cross-cutting final report that documents the UPA/CRD programs at all six locations will be generated at the conclusion of the evaluation periods.

The Seattle/LWC UPA included projects focusing on the 4T congestion reduction strategies: tolling, transit, telecommuting/travel demand management (TDM), and technology in the LWC area of the Seattle metropolitan area. U.S. DOT selected a team led by Battelle to conduct an independent evaluation of the UPA projects. This document presents the Seattle/LWC UPA National Evaluation Final Report developed by the Battelle team in cooperation with the Seattle/LWC UPA partners and the U.S. DOT. The report presents information from the pre- and post-deployment periods that encompasses a full year following the initiation of tolling on the SR 520 bridge on December 29, 2011.

This report is divided into five sections following this introduction. Chapter 2.0 summarizes the UPA and CRD programs. Chapter 3.0 highlights the Seattle/LWC UPA local agency partners and projects. Chapter 4.0 presents the national evaluation methodology and the data used in the evaluation. Chapter 5.0 describes the various impacts from the projects and the major findings from the evaluation. Chapter 6.0 highlights the overall conclusions from the national evaluation of the Seattle/LWC UPA projects. Appendix A through Appendix K present more detailed information on each of the analysis areas. Appendix L contains the hypothesis and questions guiding the Seattle/LWC UPA national evaluation.

The evaluation report is intended to serve the needs of a variety of readers. For a reader seeking an overall understanding of the strategies used in the Seattle/LWC UPA and the key findings about their effectiveness and impact, Chapters 3.0 and 6.0 will be most useful. Readers interested in specific types of transportation projects, such as transit, should consult the pertinent project descriptions in Chapter 3.0, along with the associated analysis in Chapter 5.0. For analysis of cross-cutting effects, such as equity and benefit-cost analysis (BCA), readers will find those results in Chapter 5.0. Readers interested in an in-depth understanding of the evaluation should consult the appendices, each of which focuses on a different aspect of the evaluation, along with previously-published evaluation planning documents.

This page intentionally left blank

Chapter 2 The UPA/CRD Programs

The Seattle/LWC was one of six sites awarded a grant by the U.S. DOT in 2007 and 2008 for implementation of congestion reduction strategies under the UPA and the CRD programs. The other areas are Atlanta, Los Angeles, Miami, Minnesota, and San Francisco. A set of coordinated strategies known as the 4Ts incorporate tolling, transit, telecommuting/TDM, and technology tailored to the needs of each site. The UPA and CRD programs sought to aggressively use these strategies to relieve congestion in urban areas and raise revenues to support needed transportation improvements.

The national evaluation is assessing the impacts of the UPA and CRD projects in a comprehensive and systematic manner across all sites. The objective is to document the extent to which congestion reduction is realized from the 4T strategies and to identify the associated impacts and contributions of each strategy. The evaluation also seeks to determine the contributions of non-technical success factors – outreach, political and community support, and institutional arrangements – to the success of the projects and the overall net benefits relative to costs. Detailed documentation of the national evaluation framework (NEF) and the evaluation planning documents specifically for the Seattle/LWC UPA can be found at http://www.upa.dot.gov/.

This page intentionally left blank

Chapter 3 Seattle/Lake Washington Corridor Urban Partnership Agreement

This chapter presents the Seattle/LWC UPA, describing the Seattle/LWC UPA partners, the transportation system and underlying congestion issues in the Seattle metropolitan area, and the Seattle/LWC UPA projects and deployment schedule.

The Seattle/Lake Washington Corridor UPA Partners

The Seattle/LWC UPA partners included the Washington State Department of Transportation (WSDOT), King County, Washington, and the Puget Sound Regional Council (PSRC). These partners coordinated planning, implementation, and/or operation of various UPA projects with a number of other local agencies, such as the City of Seattle and Sound Transit.

WSDOT was responsible for the overall project schedule and financial management, coordinating project activities and reporting to federal agencies. WSDOT led the SR 520 variable tolling, real-time travel time signage, and SR 520/I-90 active traffic management projects.

King County operates the King County Metro Transit service, which comprises the majority of the transit service in the SR 520 corridor. Sound Transit provides express bus, light rail, and commuter rail service in the Puget Sound region. King County led the Seattle/LWC UPA transit projects, consisting of enhanced bus service along SR 520, real-time information signs at transit stations, and expansion of two existing park-and-ride facilities.

The PSRC is the Metropolitan Planning Organization for the Seattle urban area including King, Pierce, Snohomish, and Kitsap Counties, PSRC led the telecommuting/TDM projects, which are part of the UPA but are being implemented without federal UPA funds.

The Transportation System in the Seattle Urban Area

Congestion levels in the Seattle area have tended to increase, although the growth of congestion has slowed in recent years. According to WSDOT's *Managing and Reducing Congestion in Puget Sound Performance Audit Report*[1], over 40 percent of the traffic traveling in either the a.m. or p.m. peak periods is traveling below 45 mph. The report also states that 49 to 79 percent of the commuters in the area (depending upon the route) drive alone. The Texas A&M Transportation Institute's *2012*

[1] *Washington State Department of Transportation Managing and Reducing Congestion in Puget Sound Performance Audit*. Prepared by Talbot, Korvola, and Warwick for the Washington State Auditor. October 2007. Available at: http://www.sao.wa.gov/auditreports/auditreportfiles/ar1000006.pdf. Accessed September 27, 2013.

Urban Mobility Report[2] ranks Seattle 9th nationally in terms of yearly delay per auto commuter and 13th in terms of total travel delay, based on 2011 data. The report also estimates that 47 percent of the lane-miles in the Seattle area are congested.

Both SR 520 and I-90, which cross Lake Washington, represent major east-west commuting corridors in the Seattle area, linking communities east of Lake Washington (such as Bellevue, Redmond, and Issaquah) with downtown Seattle. Downtown Seattle remains the region's major center of population and employment, supporting approximately 500,000 jobs annually.[3] Over the past 50 years, the Seattle population has increased from 467,591 in 1960 to 634,535 in 2012[4]. Over the same time period, however, the Eastside communities have experienced tremendous growth, primarily supported by the SR 520 bridge and I-90 bridge. Between 1960 and 1970, the population of the Eastside cities of Bellevue, Redmond, and Issaquah alone more than tripled from 24,184 to 84,287. From 1970 to 2012, the population in these cities more than doubled, growing to a population of 215,633, with similar growth trends in other Eastside communities.[4] Even more substantial has been the growth of employment in the Eastside. Today, the SR 520 and I-405 corridors support some of the major high-tech businesses, bringing thousands of workers to the Eastside. As a result, the morning commute from Seattle to Eastside is just as important to the region's economic vitality as the commute from the Eastside to Seattle.[3]

The following additional information on SR 520 is excerpted from WSDOT's Request for Proposals for the SR 520 Toll Collection System:

> "SR 520 currently consists of two lanes eastbound and two lanes westbound…The three major access points to the SR 520 Corridor are the I-5, I-405, and SR 908/Bellevue Way NE interchanges.
>
> …The SR 520 Bridge opened to traffic in 1963 and was initially designed for a capacity of 65,000 vehicles per day, although it currently carries approximately 110,000 vehicles per day. Moreover, about seven times the number of vehicles cross the SR 520 Bridge than when it opened in 1963, and the traffic demand in both directions often exceeds the capacity during rush hours. Traffic on SR 520 grew steadily between the years 1975 and 2000, but has leveled off since then.
>
> SR 520 traffic volumes have been relatively balanced in both directions since the late 1980s. Since 1993, however, peak morning traffic volumes have been slightly higher eastbound, and peak afternoon traffic volumes have been slightly higher westbound.
>
> Travel times are not reliable on SR 520 due to traffic volume, incidents, weather, and special events, all which negatively affect congestion. Furthermore, congestion on this east-west corridor negatively affects the two major north-south corridors in the region (I-5 and I-405), as

[2] D. Schrank, B. Eisele, and T. Lomax. *2012 Urban Mobility Report.* Texas A&M Transportation Institute, The Texas A&M University System, December 2012. Available at: http://mobility.tamu.edu/ums/report/. Accessed September 27, 2013.

[3] *SR 520 Bridge Replacement and HOV Project: Draft Environmental Impact Statement.* Report No. FHWA-WA-EIS-06-02-D. Washington State Department of Transportation. August 18, 2006. http://www.wsdot.wa.gov/projects/sr520bridge/DraftEIS.htm. Accessed September 27, 2013.

[4] U.S. Census Bureau. http://www.census.gov/. Accessed September 27, 2013.

> well as local arterials. As with most corridors, however, demand is not consistent throughout the day, which results in periods when the bridge is not being used to its capacity."[5]

In general, the SR 520 corridor requires numerous upgrades, including the SR 520 bridge, which is in need of replacement. Construction on the WSDOT Eastside Transit and HOV Project on SR 520 (which is not a UPA project) began in 2011 and will upgrade SR 520 to a six-lane facility with two general purpose lanes and one transit/HOV lane in each direction to the east of the SR 520 bridge when it is completed in late 2014.[6]

Several agencies provide transit services throughout the entire Seattle area, but the two service providers with the greatest ridership in the LWC are King County Metro Transit and Sound Transit. King County Metro Transit is the area's largest public transit provider, serving over 2 million residents in King County. Through its nearly 1500 vehicle fleet of standard and articulated coaches, electronic trolleys, dual-powered buses, hybrid diesel-electric buses, and streetcars, King County Metro Transit services an annual ridership of 118 million passengers within a 2,134 mile area. King County Metro Transit also operates the nation's largest publicly owned commuter vanpool program with about 1,300 vans.[7] The other major transit provider in the LWC is Sound Transit, which was created in 1996 and provides regional express bus, commuter rail, and light rail services between major commuting destinations in the region. Sound Transit operates a total of 26 express bus routes with 8 routes directly utilizing SR 520, I-90, and SR 522.

According to the WSDOT congestion report[1], one possible reason why eastbound trips out of Seattle did not change between 2005 and 2007 was the dramatic increase in transit ridership. Sound Transit and King County Metro Transit bus routes heading eastbound out of Seattle experienced a ridership increase of approximately 23 percent and 12 percent during that time, respectively.

The Seattle/LWC UPA projects shown in Figure 3-1 represent one of many efforts being pursued in the Seattle area to fight the growth of congestion. Other initiatives include expansion of bus, light rail, and ferry services, use of innovative traffic management and traffic control procedures, improvement in travel demand and telecommuting services, and the elimination of capacity bottlenecks.

---

[5] *Request for Proposal ACQ-2009-0530-RFP, Supply, Install, Maintain a Toll Collection System, Appendix 2-Project Description*, WSDOT, July 15, 2009.

[6] *SR 520 – Medina to SR 202: Eastside Transit and HOV Project*. Washington State Department of Transportation. 2014. Available at: http://www.wsdot.wa.gov/projects/sr520bridge/medinato202/. Accessed March 19, 2014.

[7] *About Metro.* King County Metro Transit. 2013. Available at: http://metro.kingcounty.gov/am/metro.html. Accessed September 27, 2013.

Source: WSDOT.

Figure 3-1. Seattle/LWC UPA Tolling and Technology Projects

Tolling Project

The centerpiece of the Seattle/LWC UPA was the deployment of variable tolling on the SR 520 bridge, which was activated on December 29, 2011. The SR 520 bridge is in need of replacement, and a replacement bridge would have been opened as a toll bridge anyway. Early tolling allows the generation of revenue in advance to serve as a down payment on the new bridge and reducing financing costs for a new bridge that will improve mobility and safety for local users. The tolling system, shown in Figure 3-2, utilizes a single toll collection point for travel in both directions, located on the far eastern portion of the bridge span. The tolling system is electronic and does not include toll booths, therefore motorists continue at normal speeds and do not stop to pay.

Source: WSDOT.

Figure 3-2. The SR 520 Bridge Tolling System

There are four ways to pay tolls on the SR 520 bridge under the *Good To Go!* Program:

- *Good To Go! Pass Account* – At least one *Good To Go!* Vehicle pass and license plate number required. Up to 6 vehicles and/or *Good To Go!* Passes per account. There are also commercial pass accounts, government agency pass accounts, and unregistered accounts with different requirements.
- *Good To Go! Pay By Plate Account* – Does not require a *Good To Go!* vehicle pass. Requires registration of each vehicle's license plate on account.
- *Good To Go! Short Term Account* – Does not require a *Good To Go!* vehicle pass. Registration of vehicle license plate required. Valid up to 14 days – account automatically closes after 14 days.
- *Pay By Mail* – No account is needed. License plates are read electronically and a bill is mailed to the vehicle owner.

Individuals can open *Good To Go!* accounts on-line, by telephone, by mail, and at three customer service centers in Seattle, Bellevue, and Gig Harbor. *Good To Go!* sticker passes may also be purchased at participating retail stores in the region, which are listed on the SR 520 bridge website.

As vehicles drive through the toll gantries on SR 520, images of the front and rear license plates are taken. The toll equipment detects a *Good To Go!* pass and deducts the appropriate toll from a *Good To Go!* account. If a pass is not detected, the system matches the image of the license plate to an account. When an account is located by plate, the toll is posted as the Pay By Plate toll rate, which is the *Good To Go!* toll rate plus a $.25 cent photo fee per transaction. If an account is not located, it means that the plate is not on an account or an account has a negative account balance. In this case, a toll bill is mailed to the registered owner of the vehicle.

The SR 520 bridge toll rates are established by the Washington State Transportation Commission (WSTC) working with WSDOT and the public. The WSTC reviews SR 520 bridge traffic performance and revenue each winter to assess if changes in the toll rates are necessary to cover operating costs and debt payments. New toll rates are implemented the following July, if necessary.

The toll rates vary by time-of-day, type of vehicle, and by toll payment option. Toll rates vary based on historical traffic demand, with higher toll rates during peak travel periods and lower toll rates during off peak travel periods. Tolls are currently not charged between 11:00 p.m. and 5:00 a.m. until the new bridge is open to traffic to accommodate construction as the corridor is rebuilt. There are separate tolling rates for two-axle, three-axle, four-axle, five-axle, and six-axle vehicles, with toll rates increasing by the number of axles. Tolls are nominally $1.50 higher for travelers using the Pay By Mail option.

The toll rate structure on the SR 520 bridge is intended to encourage motorists to either shift their travel times from the peak periods into less congested periods; shift their travel mode from single occupant vehicles (SOVs) to either HOV or transit; or even cancel or consolidate some or all of their trips or to take an alternate route altogether.

Transit Projects

The Seattle/LWC UPA transit projects are shown in Figure 3-3. Bus service along SR 520 was expanded by adding 90 one-way peak period trips on bus routes operated by King County Metro Transit. Service expansion included purchasing 44 new buses. King County Metro Transit added transit service to SR 520 in two stages prior to tolling. In October 2010, service was added to the existing Metro Routes 255, 265, and 271, and the new Sound Transit Route 542 was begun. In February 2011, more service was added to the Metro Routes 255 and 311. Also in February 2011, Metro added a new peak service route on SR 522, the Route 309. Although most of the UPA-funded service was in the peak period, some of the funds did go toward additional midday and evening service on Route 271 and additional midday service on Route 255. The UPA also included funding for the Route 309, a new peak period service on SR 522.

Two park-and-ride lots were modified, the South Kirkland lot located at the I-405/SR 520 interchange and the Redmond lot located farther east. At both locations, existing surface lots were being replaced by new parking garages. The Kirkland location will not be complete until 2014 after the UPA evaluation data collection has been completed and so it is not included in the evaluation. Converting the existing surface lot to garage parking made room for the addition of a transit-oriented residential and commercial development. In conjunction with this project a new transit center is being developed adjacent to the parcel. The transit center features new passenger amenities and loading facilities. Collectively, these projects are intended to increase ridership on the SR 520 corridor due to better passenger facilities and ridership from the adjacent transit-oriented development. Other transit improvements included new real-time transit travel time information at bus shelters/stations.

Source: King County Metro.

Figure 3-3. Seattle/LWC UPA Transit Service Improvements

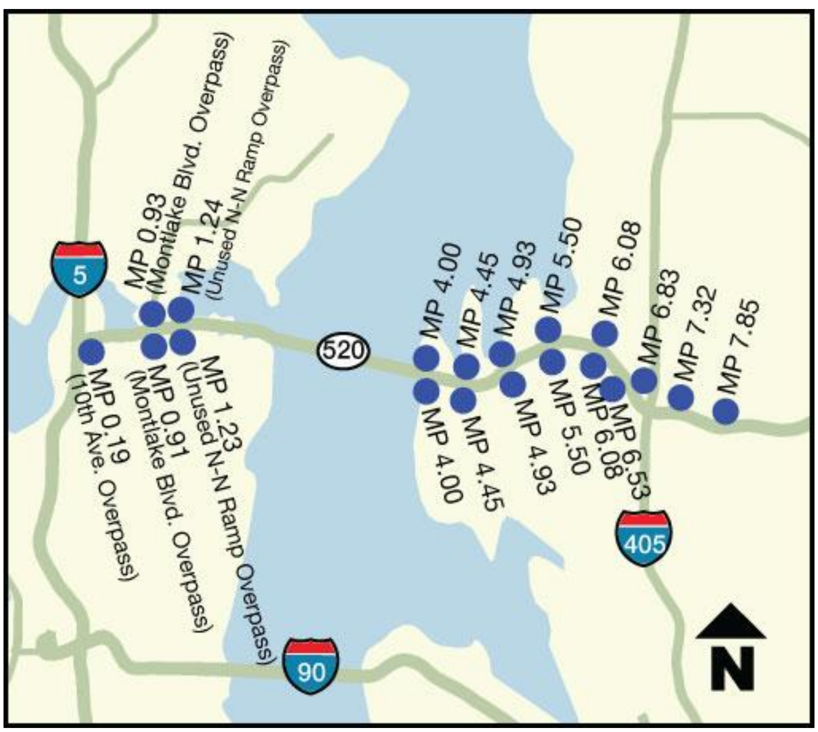
TDM Projects

While the UPA did not provide funding for TDM projects, local and state agencies, along with employers have already provided a wide array of programs for many years intended to reduce trips in the SR 520 corridor. These activities are not new as a result of the UPA project but support the UPA objectives related to TDM. In addition, the Seattle/LWC UPA partners considered several regional TDM strategies that complemented UPA projects in the SR 520 corridor. Further, King County Metro offered a free Orca card to all *Good to Go!* pass applicants containing $6.00 in E-purse value (equal to one round trip bus fare across the bridge). Some 1,213 Orca cards were distributed in this manner from March to September 2011.

Additionally, there was new, UPA-related targeted marketing and outreach. The marketing and communication strategy for the SR 520 tolling project and other UPA projects included information specifically targeted to promotion of travel alternatives. This marketing and communication was coordinated with TDM marketing activities to employers, growth centers and commuters. The marketing did not include any new services or incentives, but was designed to inform affected commuters as to alternatives to paying the full toll on SR 520. King County Metro Transit developed and implemented a comprehensive outreach program to employers and commuters to help inform them of commute options available to avoid or lessen the tolls paid on SR 520. The campaign, marketed as —Save More Time Doing Something Else – was focused on promoting alternatives to driving alone of SR 520 (and the SR 99 Alaskan Way Viaduct).

Technology Projects

Advanced technologies, e.g., ITS, play a significant role in almost all of the Seattle/LWC UPA projects. In addition to the pervasive, enabling role for technology throughout the deployment, two specific technology projects were implemented. The first project was the Active Traffic Management (ATM) system that was installed on SR 520 and I-90 (an ATM system was also installed on I-5 although it is not included in the UPA). The system consisted of a series of electronic variable speed-limit, lane status, and mini-DMS over each lane on the SR 520 and I-90 corridors across Lake Washington. Figure 3-4 and Figure 3-5 show the SR 520 and I-90 ATM gantry locations. Figure 3-6 shows an image of a gantry with variable speed limits (VSLs) displayed.



Source: WSDOT Website, http://www.wsdot.wa.gov/Projects/LkWaMgt/LkWaATM/map.htm.

Figure 3-4. Location of ATM Signs on SR 520

Source: WSDOT Website, http://www.wsdot.wa.gov/Projects/LkWaMgt/LkWaATM/map.htm.

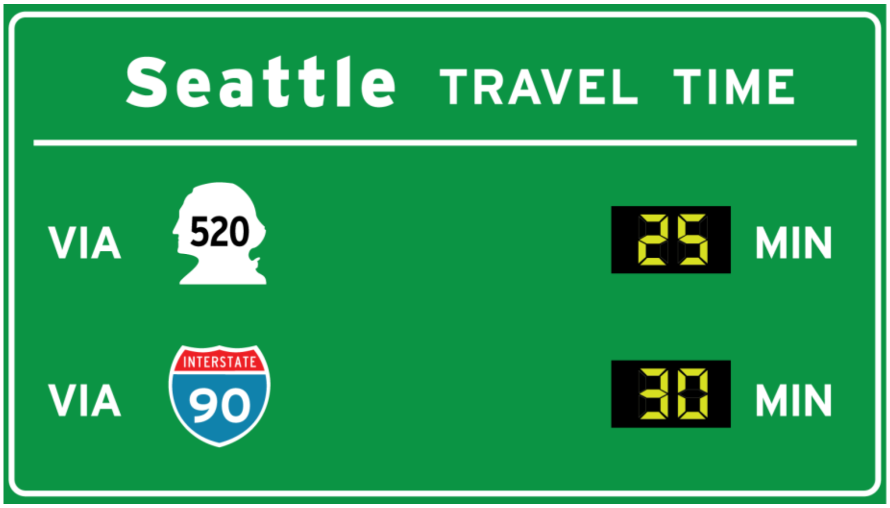
Figure 3-5. Location of ATM Signs on I-90

Source: Texas A&M Transportation Institute.

Figure 3-6. ATM Signs Displaying Variable Speed Limits on nearby I-5

The second type of UPA technology project was real-time traveler information. This consisted of several new travel time signs in the SR 520 corridor. The signs provide up-to-the-minute, comparative travel times (e.g., for alternate routes) for travel to Seattle, as depicted in Figure 3-7. The information is also intended to signal drivers to use alternative routes. Signs were installed at three locations shown in Figure 3-8:

- Westbound SR 520 in Bellevue – one mile east of I-405;
- Southbound I-405 at NE 72nd Place in Kirkland (1.3 miles north of SR 520); and
- Westbound SR 522 at the SR 202 overpass in Woodinville (1 mile east of I-405).



Source: WSDOT Website, http://www.wsdot.wa.gov/Projects/LkWaMgt/LkWaATM/map.htm.

Figure 3-7. Example of SR 520 Real-Time Travel Time Sign

Source: WSDOT.

Figure 3-8. Location of the Real-time Travel Time Signs

Seattle/LWC UPA Project Deployment Schedule

Table 3-1 presents the deployment dates for the various Seattle/LWC UPA projects. Tolling of the SR 520 became operational on December 29, 2011, and was the project that initiated the post-deployment period. Transit enhancements became operational in October 2010 and February 2011. ATM signage was activated on SR 520 in November 2010, partially on I-90 in June 2011, and remaining I-90 locations in May 2012.

Table 3-1. UPA Project Go-Live Dates

UPA Project	Go Live Date
Redmond Park and Ride	July 6, 2009
Phase 1 Bus Service Enhancement	October 2, 2010
SR 520 ATM	November 16, 2010
Phase 2 Bus Service Enhancement	February 5, 2011
I-90 ATM partial (WB plus first four gantries EB)	June 8, 2011
Highway Travel Time Signs (SR 520 and SR 522)	April 14, 2011
Highway Travel Time Signs (I-405)	June 1, 2011
SR 520 Tolling	December 29, 2011
I-90 ATM EB (remaining)	May 1, 2012
Transit Real-Time Information Displays	2012*

*The first two signs became operational in 2012. Two other signs are to be deployed in 2014.

Source: Battelle.

Chapter 4 National Evaluation Methodology and Data

This section highlights the national UPA/CRD evaluation methodology and the data used in conducting the Seattle/LWC UPA national evaluation. An overview of the national UPA/CRD evaluation methodology is presented first in Section 4.1. The four objective questions posed by the U.S. DOT to guide the national evaluation are described, along with the associate analysis. The major data sources used in the Seattle/LWC UPA national evaluation are presented in Section 4.2.

Four U.S. DOT Evaluation Questions

The national evaluation is assessing the impacts of the UPA/CRD projects in a comprehensive and systematic manner across all sites. The Battelle team developed a national evaluation framework (NEF) to provide a foundation for evaluation of the UPA/CRD sites. The NEF was based on the 4T congestion reduction strategies and the questions that the U.S. DOT sought to answer through the evaluation. The NEF defined the questions, analyses, measures of effectiveness, and associated data collection for the entire UPA/CRD evaluation. The framework was a key driver of the site-specific evaluation plans and test plans, and served as a touchstone throughout the project to ensure that national evaluation objectives were supported through the site-specific activities.

Table 4-1 presents the four U.S. DOT objective questions[8] and the analysis areas used in the Seattle/LWC UPA evaluation to address these questions. As noted in the table, the analysis focused on the overall reduction in congestion, the performance of the 4Ts, and associated impacts. Elements of the analysis are presented in Sections 5.0 and 6.0. Appendix A through J presents detailed information on the 10 analyses. Appendix K summarizes information on changes exogenous factors.

[8] "Urban Partnership Agreement Demonstration Evaluation – Statement of Work," United States Department of Transportation, Federal Highway Administration; November 29, 2007.

Table 4-1. U.S. DOT Objective Questions and Seattle/LWC UPA Evaluation Analyses

U.S. DOT 4 Objective Questions	Evaluation Analyses
#1 – How much was congestion reduced?	Congestion
#2 – What are the associated impacts of the congestion reduction strategies?	**Strategy Performance**
	Strategy Performance: Tolling
	Strategy Performance: Transit
	Strategy Performance: Telecommuting/TDM
	Strategy Performance: Technology
	Associated Impacts
	Associated Impacts: Safety
	Associated Impacts: Equity
	Associated Impacts: Environmental
#3 – What are the non-technical success factors?	Non-Technical Success Factors
#4 – What is the overall cost and benefit of the strategies?	Benefit Cost Analysis

Source: Battelle.

Seattle/Lake Washington Corridor UPA Evaluation Process and Data

The Seattle/LWC UPA evaluation involved several steps. Members of the national evaluation team worked closely with the local partners and U.S. DOT representatives on the following activities and products:

- Project kick-off conference call, site visit, and workshop;
- Seattle/Lake Washington Corridor National Evaluation Strategy;
- Seattle/Lake Washington Corridor UPA National Evaluation Plan;
- 10 Seattle/Lake Washington Corridor UPA test plans;
- Collection of one year of pre-deployment and one year of post-deployment data;
- Analysis of the collected data, surveys, and focus groups; and
- Interim Seattle/Lake Washington Corridor UPA National Evaluation Report and a National Evaluation Findings Report.

A wide range of data was collected and analyzed as part of the Seattle/LWC UPA. Table 4-2 presents the data, the data sources, and related analysis areas used in the Seattle/LWC UPA national evaluation. Each appendix presents detailed descriptions of the data sources and the analysis techniques.

Members of the Battelle team worked with representatives from the Seattle/LWC UPA partnership agencies and the U.S. DOT on all aspects of the national evaluation. This team approach included the participation of local representatives throughout the process and the use of site visits, workshops, conference calls, and e-mails to ensure ongoing communication and coordination. The local agencies were responsible for data collection and conducting surveys, focus groups, and interviews. The Battelle team was responsible for analyzing the local data and survey results.

Table 4-2. Seattle/LWC UPA National Evaluation Data Sources

Data	Source	Evaluation Analyses
Traffic Sensor Data	WSDOT	• Congestion Analysis • Technology • Environmental Analysis • Equity Analysis
Vehicle Occupancy Counts	Washington State Transportation Center (TRAC)	• Congestion Analysis
Good To Go! Registered Accounts, Toll Transaction Data, Revenue Data, and General Information on Toll Rates and Toll Account Types	WSDOT	• Tolling Analysis • Equity Analysis
Bus Ridership Data	King County Metro Transit	• Congestion Analysis • Transit Analysis
Bus Travel Times, Bus Revenue Miles and Hours, Park-and-Ride Lot Counts	King County Metro Transit	• Transit Analysis
Major Transit Changes	King County Metro Transit	• Transit Analysis • Exogenous Factors
Vanpool Data and Telecommuting Outreach Statistics	King County Metro Transit	• TDM Analysis
ATM and Travel Time Sign Location, Operations, and Component Information	WSDOT	• Technology Analysis
Operator Incident and Dispatching Logs	WSDOT	• Technology Analysis
Crash Data	WSDOT	• Technology Analysis • Safety Analysis • Benefit Cost Analysis
Emissions Rates	PSRC	• Environmental Analysis • Equity Analysis
Socio-Economic Data	U.S. Census Bureau	• Equity Analysis
News and Media Coverage	Hubert H. Humphrey School of Public Affairs	• Non-Technical Success Factors Analysis
UPA Partnership Documents and Outreach Materials	WSDOT	• Non-Technical Success Factors Analysis

Table 4-2. Seattle/LWC UPA National Evaluation Data Sources (Continued)

Data	Source	Evaluation Analyses
Capital, Operating, and Maintenance Costs of UPA Projects	WSDOT	• Benefit Cost Analysis
Projected 10-Year Changes in Travel Time, Vehicle Operating Costs, and Emissions	PSRC	• Benefit Cost Analysis
Unemployment Rates – National, State, and Metro Area	Washington State Employment Security Department	• Exogenous Factors
Gasoline Prices	U.S. Energy Information Administration	• Exogenous Factors
Major Road Construction, Events, and Weather Events	WSDOT	• Exogenous Factors
Volpe Household Travel Survey	Volpe	• Congestion Analysis • Tolling Analysis • Transit Analysis • TDM Analysis • Equity Analysis • Non-Technical Success Factors Analysis
SR 520 Bridge Tolling Surveys	WSDOT	• Congestion Analysis • Tolling Analysis • Safety Analysis • Equity Analysis • Non-Technical Success Factors Analysis
On-Board Transit Survey	King County Metro Transit	• Tolling Analysis • Transit Analysis • Equity Analysis • Non-Technical Success Factors Analysis
Commute Trip Reduction (CTR) Survey	WSDOT	• TDM Analysis
Washington State Patrol (WSP), Incident Response Team (IRT) Operators, and King County Metro Transit Operators Focus Groups	WSDOT	• Congestion Analysis • Transit Analysis • Technology Analysis • Safety Analysis • Non-Technical Success Factors Analysis
Stakeholder Interviews and Workshops	Hubert H. Humphrey School of Public Affairs	• Non-Technical Success Factors Analysis

Source: Battelle.

Chapter 5 Major Findings

This section highlights the major findings from the national evaluation of the Seattle/LWC UPA projects. The contextual changes occurring in the Seattle metropolitan area during the evaluation period – including the decrease in the unemployment rate – are highlighted in Section 5.1. The Seattle/LWC UPA's use of the 4Ts – tolling, transit, telecommuting, and technology – are described in Section 5.2. Information on changes from the pre- and post-deployment periods is also presented. A summary of the impacts of the Seattle/LWC UPA projects by the four U.S. DOT objective questions and 10 evaluation analyses is provided in Section 5.3. The timing of UPA projects coming on-line and the evaluation period is presented in Table 5-2.

Table 5-1. UPA Project Dates

UPA Project	Go Live Date
Redmond Park and Ride	July 6, 2009
Phase 1 Bus Service Enhancement	October 2, 2010
SR 520 ATM	November 16, 2010
Phase 2 Bus Service Enhancement	February 5, 2011
I-90 ATM partial (WB plus first four gantries EB)	June 8, 2011
Highway Travel Time Signs (SR 520 and SR 522)	April 14, 2011
Highway Travel Time Signs (I-405)	June 1, 2011
SR 520 Tolling (Beginning of Post-Deployment Evaluation Period)	December 29, 2011
I-90 ATM EB (remaining)	May 1, 2012
Transit Real-Time Information Displays	2012*
End of Post-Deployment Evaluation Period	December, 2012

*The first two signs became operational in 2012. Two other signs are to be deployed in 2014.

Source: Battelle.

Contextual Changes During the Evaluation Period

The implementation of the Seattle/LWC UPA projects occurred after a spike in the unemployment rate in early 2010. The unemployment rate for the area counties and state generally decreased through both the pre- and post-deployment periods. The unemployment rate for King County in particular ranged from a high of 8.9 percent in January and February 2011 to a low of 6.1 percent at the end of the post-deployment period in December 2012. These trends could attenuate the UPA projects' effectiveness and be reflected in the observed travel patterns.

In addition, the price of a gallon of regular conventional gasoline fluctuated during the pre-deployment to post-deployment periods. In the pre-deployment period before the beginning of tolling on the SR 520 bridge in December 2011, the price ranged from $3.19 to $4.06. For the post-deployment period, gasoline prices were more volatile, but ranged between $3.37 and $4.33. These changes in gasoline prices may have influenced travel behavior and use of the Seattle/LWC UPA projects.

Use of the Seattle/Lake Washington Corridor UPA Projects

The implementation and use of the Seattle/LWC UPA projects, along with their possible influence on the transportation system in the Seattle area are highlighted in this section. The Seattle/LWC projects represent a suite of strategies aimed at expanding mobility options for travelers crossing Lake Washington by tolling an existing facility in an effort to improve travel time and trip reliability; providing enhanced transit service as an alternative to paying the toll; enhancing TDM strategies to promote transportation alternatives; and using innovative technologies to improve operations. The local partners undertook the major challenge of implementing tolling of an existing facility in order to fund the replacement of the SR 520 bridge. The following sections reveal how the strategies performed in achieving their objectives.

Tolling

Variable electronic tolling on the SR 520 Bridge was implemented in December 2011. The *Good to Go!* program provides different methods for paying tolls, including pass accounts, Pay By Plate accounts, Short Term accounts, and Pay By mail. Individuals using the Pay By Mail option do not need to open a *Good To Go!* account.

WSDOT provided the National Evaluation Team with files on new *Good To Go!* accounts by type and *Good To Go!* transactions by account type. The breakdown of new tolling accounts by type throughout the evaluation period is shown in Table 5-2, while Table 5-3 presents the transactions per month by account type from December 2011 to December 2012. This file included data from 342,879 individual transponders. The Pay By Plate option was utilized by about 9 percent of users, but accounted for only 5 percent of the transactions. Short Term accounts, which are valid for only 14 days, accounted for almost 2 percent of total accounts, and approximately 0.05 percent of total transactions. Government agency accounts represented 0.1 percent of total accounts and 2.2 percent of transactions. King County Metro Transit buses, Access vehicles, and vanpools probably account for a large share of the government transactions. Unregistered accounts represented 0.1 percent of total accounts and .07 percent of total transactions.

Table 5-2. New SR 520 Toll Bridge Accounts by Type

Month Purchased	*Good To Go!* Pass Account		Government Agency Pass Account		Unregistered Pass Account		Commercial Pass Account		Pay By Plate Account		Short Term Account		Grand Total
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
2011													
February	13,583	96.0%	4	0.03%	5	0.04%	79	0.6%	485	3.4%			14,156
March	24,660	95.6%	27	0.1%	11	0.04%	166	0.6%	928	3.6%			25,792
April	21,776	96.1%	24	0.1%	20	0.1%	112	0.5%	739	3.3%			22,671
May	4,788	91.0%	48	0.9%	5	0.1%	45	0.9%	378	7.2%			5,264
June	4,825	90.9%	41	0.8%	7	0.1%	32	0.6%	401	7.6%			5,306
July	3,513	89.9%	8	0.2%	1	0.0%	15	0.4%	369	9.4%			3,906
August	3,292	79.7%	8	0.2%	4	0.1%	25	0.6%	802	19.4%			4,131
September	2,251	76.9%	4	0.1%	2	0.1%	11	0.4%	660	22.5%			2,928
October	2,048	87.8%	1	0.0%	2	0.1%	9	0.4%	273	11.7%			2,333
November	3,687	92.3%	6	0.2%	4	0.1%	18	0.5%	281	7.0%			3,996
December	44,037	93.6%	26	0.06%	49	0.1%	299	0.6%	2,525	5.4%	101	0.2%	47,037
2012													
January	33,833	91.1%	17	0.05%	60	0.2%	109	0.3%	2,761	7.4%	354	1.0%	37,134
February	12,510	85.1%	12	0.08%	21	0.1%	44	0.3%	1,781	12.1%	337	2.3%	14,705
March	10,152	82.9%	12	0.10%	5	0.0%	35	0.3%	1,675	13.7%	374	3.1%	12,253
April	8,265	82.4%	4	0.04%	4	0.0%	25	0.2%	1,393	13.9%	335	3.3%	10,026
May	8,200	80.4%	1	0.01%	7	0.1%	26	0.3%	1,553	15.2%	407	4.0%	10,194
June	7,702	80.0%	4	0.04%	6	0.1%	20	0.2%	1,427	14.8%	463	4.8%	9,622
July	6,907	78.8%	1	0.01%	4	0.0%	24	0.3%	1,284	14.6%	546	6.2%	8,766
August	6,636	77.1%	1	0.01%	7	0.1%	20	0.2%	1,303	15.1%	635	7.4%	8,602
September	6,341	78.8%	2	0.02%	3	0.0%	25	0.3%	1,226	15.2%	455	5.7%	8,052
October	5,456	76.8%	5	0.07%	1	0.0%	15	0.2%	1,207	17.0%	423	6.0%	7,107
November	4,495	76.8%	5	0.09%	4	0.1%	14	0.2%	976	16.7%	362	6.2%	5,856
December	4,166	76.2%	1	0.02%	4	0.1%	7	0.1%	941	17.2%	351	6.4%	5,470
Grand Total	243,123	88.3%	262	0.10%	236	0.1%	1,175	0.4%	25,368	9.2%	5,143	1.9%	275,307

Source: WSDOT.

Table 5-3. *Good To Go!* Transactions by Account Type

Month	Good To Go! Pass Account		Government Agency Pass Account		Unregistered Pass Account		Commercial Pass Account		Pay By Plate Account		Short Term Account		Grand Total
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
Dec-2011	69,179	88.6%	1,780	2.3%	46	0.06%	5,302	6.8%	1,794	2.3%	12	0.02%	78,113
Jan-2012	929,213	89.3%	22,793	2.2%	615	0.06%	63,678	6.1%	23,242	2.2%	497	0.05%	1,040,038
Feb-2012	1,111,533	88.6%	26,293	2.1%	903	0.07%	81,280	6.5%	33,558	2.7%	526	0.04%	1,254,093
Mar-2012	1,253,184	88.2%	27,928	2.0%	972	0.07%	85,343	6.0%	52,294	3.7%	601	0.04%	1,420,322
Apr-2012	1,180,657	87.8%	28,598	2.1%	883	0.07%	76,530	5.7%	58,020	4.3%	563	0.04%	1,345,251
May-2012	1,337,415	87.7%	30,985	2.0%	988	0.06%	84,436	5.5%	71,409	4.7%	600	0.04%	1,525,833
Jun-2012	1,237,365	86.7%	31,715	2.2%	827	0.06%	80,499	5.6%	76,503	5.4%	735	0.05%	1,427,644
Jul-2012	1,177,602	85.8%	31,126	2.3%	860	0.06%	77,665	5.7%	83,552	6.1%	893	0.07%	1,371,698
Aug-2012	1,252,067	86.0%	33,112	2.3%	972	0.07%	85,928	5.9%	83,359	5.7%	814	0.06%	1,456,252
Sep-2012	1,169,549	86.6%	28,052	2.1%	978	0.07%	76,230	5.6%	74,851	5.5%	816	0.06%	1,350,476
Oct-2012	1,331,783	86.7%	34,515	2.2%	999	0.07%	90,307	5.9%	77,413	5.0%	597	0.04%	1,535,614
Nov-2012	1,201,258	86.9%	31,744	2.3%	905	0.07%	78,826	5.7%	69,850	5.1%	469	0.03%	1,383,052
Dec-2012	1,213,723	87.1%	30,366	2.2%	876	0.06%	74,323	5.3%	73,269	5.3%	504	0.04%	1,393,061
Grand Total	14,464,528	87.2%	359,007	2.2%	10,824	0.07%	960,347	5.8%	779,114	4.7%	7,627	0.05%	16,581,447

[1] Tolling on the SR 520 bridge was implemented on December 29, 2011, resulting in the lower number of transactions for December.

Source: WSDOT.

Table 5-4 presents the SR 520 toll rates for two-axle vehicles for the time-period covered in the national evaluation. As noted, the toll rates increased slightly on July 1, 2012. Toll rates ranged from $1.10 to $3.59 during the evaluation period for users with a *Good to Go!* Pass account, and higher rates for the Pay By Mail option.

Table 5-4. SR 520 Two-Axle Toll Rates for January 1, 2012 through December 31, 2012

Monday – Friday	*Good To Go!* Pass		Pay By Mail	
	1/1/12 – 6/30/12	7/1/12 – 12/31/12	1/1/12 – 6/30/12	7/1/12 – 12/31/12
Midnight to 5 a.m.	$0.00	$0.00	$0.00	$0.00
5 a.m. to 6 a.m.	$1.60	$1.64	$3.10	$3.18
6 a.m. to 7 a.m.	$2.80	$2.87	$4.30	$4.41
7 a.m. to 9 a.m.	$3.50	$3.59	$5.00	$5.13
9 a.m. to 10 a.m.	$2.80	$2.87	$4.30	$4.41
10 a.m. to 2 p.m.	$2.25	$2.31	$3.75	$3.84
2 p.m. to 3 p.m.	$2.80	$2.87	$4.30	$4.41
3 p.m. to 6 p.m.	$3.50	$3.59	$5.00	$5.13
6 p.m. to 7 p.m.	$2.80	$2.87	$4.30	$4.41
7 p.m. to 9 p.m.	$2.25	$2.31	$3.75	$3.84
9 p.m. to 11 p.m.	$1.60	$1.64	$3.10	$3.18
11 p.m. to 11:59 p.m.	$0.00	$0.00	$0.00	$0.00
Weekends and Holidays	***Good To Go!* Pass**		**Pay By Mail**	
Midnight to 5 a.m.	$0.00	$0.00	$0.00	$0.00
5 a.m. to 8 a.m.	$1.10	$1.13	$2.60	$2.67
8 a.m. to 11 a.m.	$1.65	$1.69	$3.15	$3.23
11 a.m. to 6 p.m.	$2.20	$2.26	$3.70	$3.79
6 p.m. to 9 p.m.	$1.65	$1.69	$3.15	$3.23
9 p.m. to 11 p.m.	$1.10	$1.13	$2.60	$2.67
11 p.m. to 11:59 p.m.	$0.00	$0.00	$0.00	$0.00

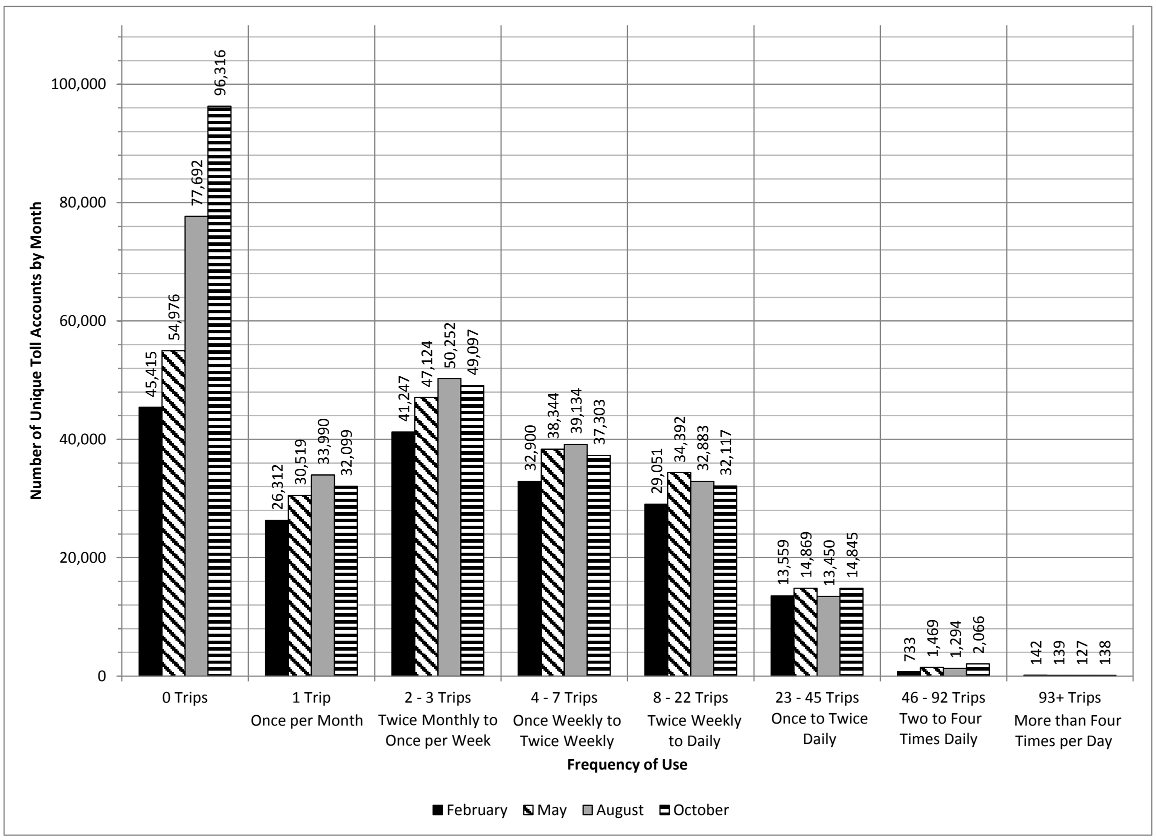
Source: WSDOT SR 520 Bridge Website.

Figure 5-1 presents the total toll transactions per month for 2012, which is the post-deployment period. Monthly transactions were relatively constant through the year, with some fluctuation reflecting inclement weather in January, closures on the SR 520 bridge due to construction and maintenance activities, seasonality and holidays.

Toll transactions are higher during the work week and lower on weekends. The highest level of transactions by day of week occurred on Thursdays, followed by Wednesdays, Tuesdays, and Fridays. Mondays had the lowest level of weekday transactions.

Examining the average morning and afternoon toll transactions by time-of-day for non-holiday weekdays, the highest average hourly toll transactions occurred during the morning and afternoon peak periods. The average transactions for all time periods during the year are relatively constant.

Figure 5-1 presents the frequency of trips by toll transactions by month for February, May, August, and October 2012. The column representing zero trips in the month reflects the number of active accounts not recording a transaction during the month, which has continued to increase. The months were selected to provide examples of use during different times of the year. Figure 5-1 reflects the different groups using the SR 520 bridge. The toll tags recording more than four trips during the tolling period, as well as those with two-to-four daily trips, probably represent mostly King County Metro Transit buses and commercial or business vehicles used for multiple trips across the bridge. Transponders in the next three sets of columns, or those tags recording transactions once-to-twice weekly to once-to-twice daily, probably reflect individuals making work and school trips on a regular basis. The remaining columns reflect infrequent use groups. The continued increase in *Good To Go!* pass accounts may reflect individuals signing up for accounts, knowing they will use the bridge infrequently.



Source: Texas A&M Transportation Institute, based on data from WSDOT, July 2012.

Figure 5-1. Trip Frequency by Toll Transactions for Selected Months in 2012

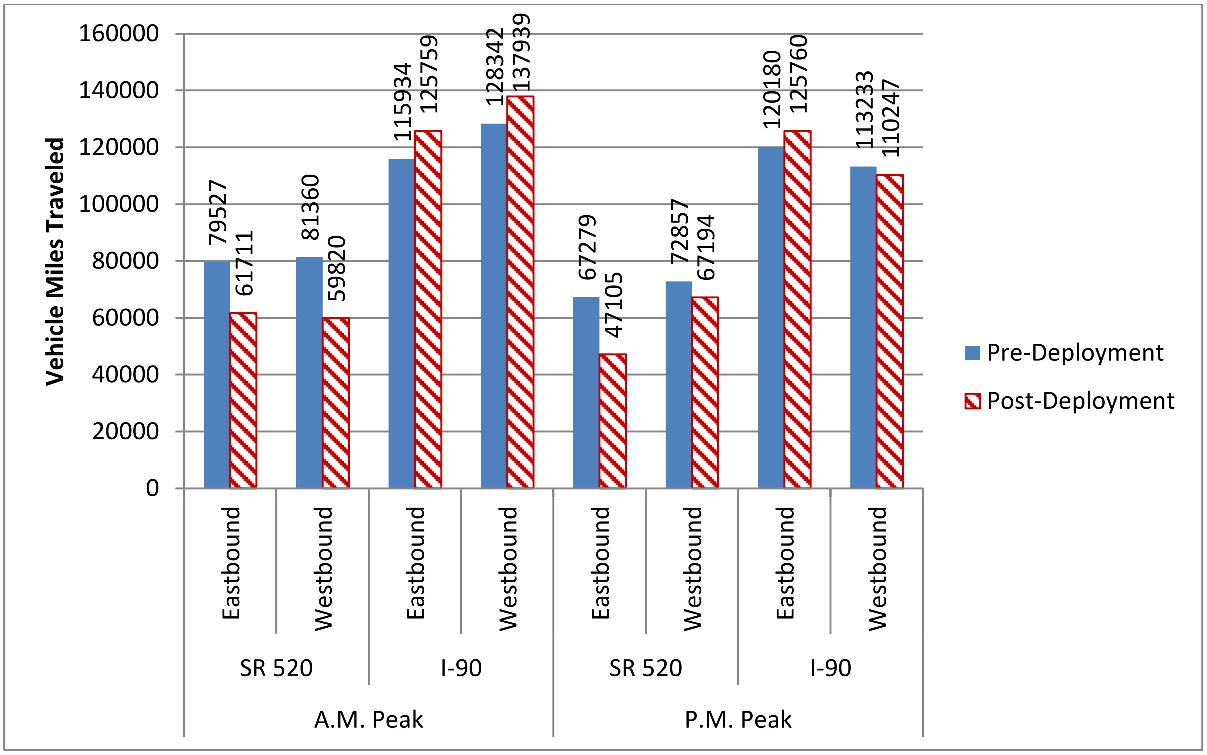
The tolls collected on the SR 520 bridge are maintained in a separate account within the state treasury that is dedicated to the SR 520 program. Spending from the account is appropriated by the Washington State Legislature and monitored by the Office of Financial Management. Table 5-5 presents the gross toll revenues reported by quarter. Gross toll revenues equaled almost $55 million in 2012. Additional revenues were received from toll transponder purchases and other sources.

Table 5-5. Gross Tolling Revenues by Quarter for 2012

Quarter	Gross Toll Revenue
January-March	$11,648,744
April-June	$14,173,251
July-September	$13,867,862
October-December	$15,180,548
Total	**$54,870,405**

Source: Texas A&M Transportation Institute, based on data from the Division of Accounting and Services, July 2013.

As anticipated, tolling on the SR 520 Bridge resulted in lower traffic volumes on the bridge and in travelers using alternative routes, primarily I-90. Overall, WSDOT reported post-tolling traffic volumes approximately 34 percent lower than pre-tolling levels on SR 520. As highlighted in Figure 5-2, vehicle miles of travel (VMT) on I-90 in the morning peak period increased slightly in both the eastbound and westbound direction of travel. In the afternoon peak period, VMT increased slightly in the eastbound direction and decreased slightly in the westbound direction. On SR 520, VMT declined in both directions of travel in both the morning and afternoon peak periods.

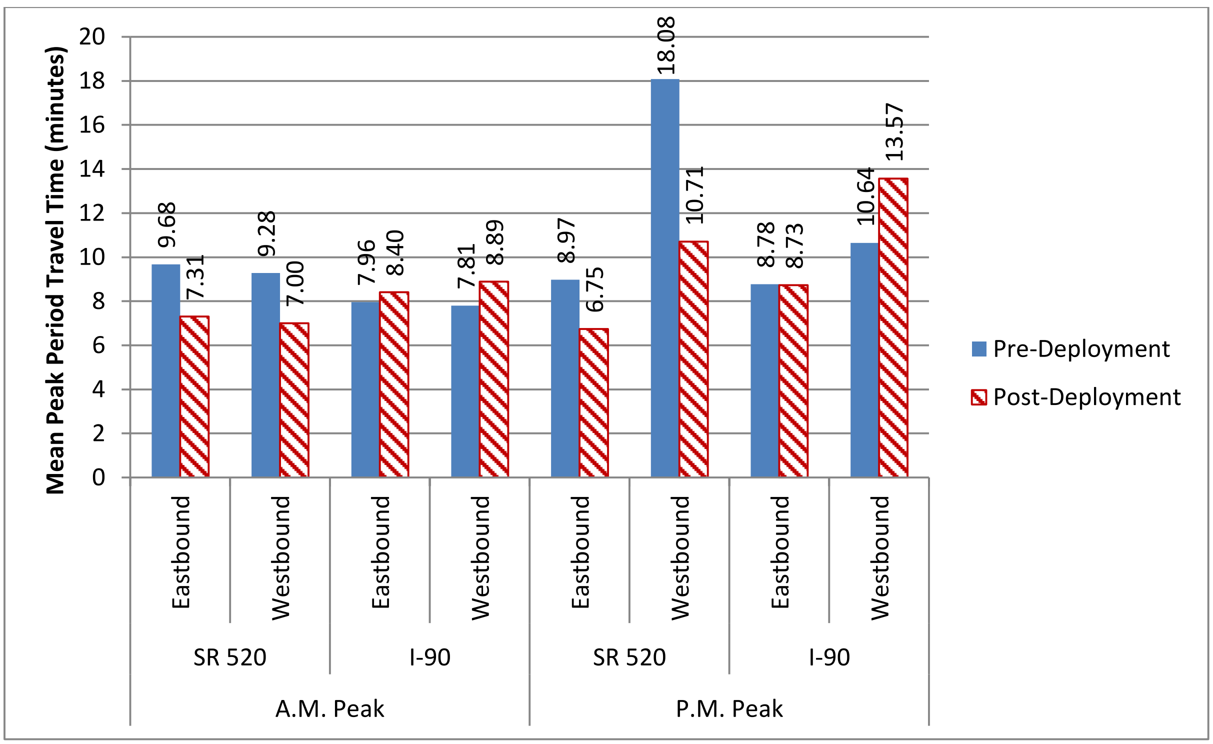


Source: Texas A&M Transportation Institute.

Figure 5-2. Comparison of Vehicle Miles Traveled for SR 520 and I-90

Changes in VMT on the SR 520 and I-90 corridors also impacted mean travel time and trip reliability. Figure 5-3 highlights the mean travel times on SR 520 and I-90 between I-405 and I-5 crossing Lake Washington, in the morning and afternoon peak periods in both directions of travel. The mean morning peak-period travel time on SR 520 was reduced by approximately 2 minutes in each direction after toll operations began. While that change may appear to be inconsequential, it does equate to almost a 30 percent reduction in travel times. During the a.m. peak period, average travel speed on SR 520 increased from 45 mph to 56 mph in the eastbound direction, and from 47 mph to 58 mph in the westbound direction. In the afternoon peak-period, travel times on SR 520 decreased by approximately 2 minutes and 8 minutes in the eastbound and westbound directions, respectively. This equates to an increase in average speeds of 47 mph to over 60 mph in the eastbound direction and from an average speed of 27 mph to approximately 45 mph in the westbound direction.

In contrast, implementing tolling had little impact on mean travel times and mean speeds on I-90. Even with increases in traffic volumes and VMT on I-90, travel times and travel speeds remained relatively unaffected after tolling was implemented. Average peak period travel times on I-90 increased by approximately 1 minute only in both the eastbound and westbound direction during the a.m. peak. Average peak period travel speed on I-90 during the a.m. peak remained relatively constant, with travel speeds averaging well over 55 mph throughout the duration of the peak period. Only during the p.m. peak did average travel speed in the westbound direction decrease below 45 mph on I-90.

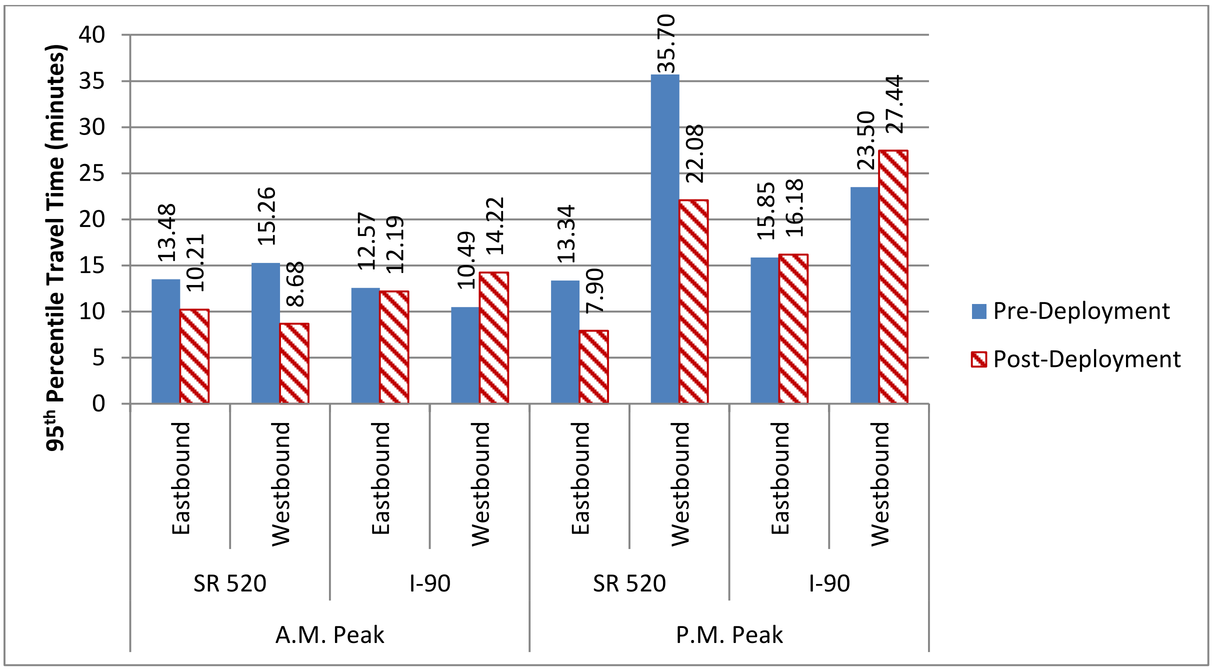


Source: Texas A&M Transportation Institute.

Figure 5-3. Mean Peak Period Travel Times (in Minutes) on SR-520 and I-90

Figure 5-4 illustrates the 95th percentile travel times for both directions of travel during the morning and afternoon peak periods for SR 520 and I-90 crossing Lake Washington. The morning peak period 95th percentile travel time for the eastbound and westbound directions of travel on SR 520 declined by approximately 3 and 6 minutes, respectively. In the afternoon peak period, the 95th percentile travel time changes were more dramatic for SR 520. The 95th percentile travel times on SR 520 declined by approximately 6 minutes in the eastbound direction and by over 13 minutes in the westbound direction, equating to declines of 40 and 38 percent, respectively. These reductions in 95th percentile travel time mean that overall travel on SR 520 became more stable and reliable after tolling was implemented. Tolling created excess capacity on SR 520 that allowed minor turbulence in travel to be absorbed without causing traffic conditions to generally deteriorate into a stop-and-go mode.

In comparison, the 95th percentile travel times on I-90 for the same time periods tended to stay the same or increase slightly. This implies that even though a significant portion of traffic that was using SR 520 diverted to I-90, the facility was able to absorb this demand.



Source: Texas A&M Transportation Institute.

Figure 5-4. 95th Percentile Travel Time (in Minutes) on SR 520 and I-90 for the A.M. and P.M. Peak Periods

Another source of data to measure the impact of the UPA comes from the Volpe household travel survey, which is described in more detail in Appendix A – Congestion Analysis. A comparison of the pre-deployment (Wave 1) and post-deployment (Wave 2) survey results and travel diaries provides insight into the use of the SR 520 tolling system, changes in travel behavior resulting from the tolling, and vehicle access to SR 520 due to the tolling. A total of 3,356 households completed the surveys and diaries in Wave 1 and 2,063 households completed the surveys and diaries in Wave 2. Examples of these changes are highlighted below.

- The number of reported trips in the LWC declined. Travel on SR 520 recorded in the diaries declined by 43 percent, while travel on I-90 declined 13 percent. An offsetting increase in non-corridor travel did not occur.

- The share of corridor trips on SR 520 declined, while share of corridor trips for I-90 and SR 522 increased. Avoiding the SR 520 bridge toll was the reported motivation for 86 percent of those noting a change from SR 520 to I-90 or SR 522.
- Changes did occur among respondents reporting using SR 520 as their primary route in Wave 1. In Wave 2, 55 percent of those individuals were still using SR 520 as the primary route, 24 percent had changed to using I-90 as their primary route, 7 percent had switched to SR 522, 8 percent had changed to riding the bus, 4 percent had changed to another route or mode, and 1 percent stopped making trips across the lake on a regular basis. Males, members of lower income households, and individuals with limited flexibility in their work schedules were more likely to switch from using SR 520 to using I-90.
- Trip satisfaction, as reported for each trip on a 7-point scale (1 = strongly disagree, 3 = neutral, 7 = strongly agree), increased on SR 520 in Wave 2. The mean score for satisfaction with peak period travel speeds on the SR 520 bridge increased from 3.4 to 5.2 from Wave 1 to Wave 2. The satisfaction with trips on I-90 declined slightly. The statement “Tolling on SR 520 has improved my travel” received a mean score of 3.3 in Wave 2. The question was not asked in Wave 1.

WSDOT sponsored several surveys and focus groups as part of implementing the SR 520 bridge tolling system. The responses to questions related to the tolling of the SR 520 bridge are summarized here.

- Reported use of the SR 520 bridge declined from two pre-deployment surveys, to the post-deployment survey. Individuals reporting four or more trips a week declined from 13 percent in the baseline survey to 11 percent in the final survey. Individuals reporting using the bridge two-to-three times a week declined from 14 percent to 9 percent, travelers using the bridge one-to-three times per month declined from 33 percent to 31 percent. On the other hand, travelers reporting using the bridge less than one time a month increased from 28 percent to 40 percent.
- The majority of respondents, 69 percent, reported they had not changed their time of travel on the SR 520 bridge, but 32 percent indicated they had changed their time of travel. Of those reporting a change in travel time, 50 percent indicated they had done so to use the bridge when the toll was lower, while 19 percent did so to use the bridge when traffic was lighter. There was a slight decline – from 25 percent to 23 percent – in reported travel during the weekday morning peak period (5:00 a.m. to 9:00 a.m.) and in the evening (after 7:00 p.m. and before 10:00 p.m.) – 34 percent to 31 percent. Mid-day travel (after 9:00 a.m. and before 3:00 p.m.) remained constant at 53 percent, while reported travel in the afternoon peak period (3:00 p.m. to 7:00 p.m.) increased slightly from 40 percent to 43 percent.
- Survey respondents reported a perception that traffic congestion had decreased on the SR 520 bridge. Approximately half, 51 percent, of the respondents in the final survey indicated that the SR 520 bridge was not congested at all since tolling was implemented, compared to 21 percent in the baseline survey. The majority of respondents, 62 percent, in the final survey reported their trips were faster across the bridge since tolling began.

- Survey respondents indicated a perception that safety on the SR 520 bridge had improved. 62 percent of the respondents in the final survey indicated their driving experience was very safe on the SR 520 bridge, compared to 34 percent in the midpoint survey.

Transit

Transit represented a key element of the Seattle/LWC UPA. Transit enhancements included 44 new buses and 90 additional one-way peak period trips; improvements to transit stops and park-and-ride lots; and new travel time signs. King County Metro Transit added transit service to SR 520 in two stages prior to tolling. In October 2010, service was added to the existing Metro Routes 255, 265, and 271, and the new Sound Transit Route 542 was begun. In February 2011, more service was added to the Metro Routes 255 and 311. Also in February 2011, Metro added a new peak service route to SR 522, the Route 309. Overall, transit performance improved and ridership increased as a result of the UPA projects.

On-time performance improved greater in the eastbound direction both mornings and afternoons. From Summer 2010 to Summer 2012, it improved from 47 percent to 67 percent in the morning peak and from 40 percent to 57 percent in the afternoon peak. In the westbound direction, on-time performance improved from 63 percent to 67 percent in the morning peak but dropped from 51 percent to 47 percent in the afternoon peak. A closer look at the monthly data showed that the improvements in on-time performance did not occur immediately after tolling. For example, morning on-time performance in the westbound direction was not noticeably better until March 2011, three months after tolling began. In the eastbound direction, it was not noticeably better until June 2012, six months after tolling. June 2012 is also the first month of the summer service change. It is possible that the improvement in on-time performance was due to a combination of schedule adjustments and improved traffic flow from the variable tolls. Peak period travel times across the bridge decreased between Summer 2010 and Summer 2012. They decreased the most in the eastbound direction. Travel times in the eastbound direction were 0.9 minutes shorter in the morning peak period and 1.7 minutes shorter in the afternoon peak period. Bus travel times improved in the non-peak shoulder periods also.

Table 5-6 shows the average weekday ridership across the SR 520 bridge for the three analysis periods. The numbers for Summer 2011 include the UPA funded transit service that was added in October 2010 and February 2011. The percentage increases in ridership from Summer 2010 to Summer 2012 ranged from 26 percent to 43 percent depending on the time and direction.

Table 5-6. Average Daily Ridership on SR 520

Time Period	Direction	Summer 2010	Summer 2011	Summer 2012	% Change 2010 - 2012
6:00-9:00 a.m.	Eastbound	1,603	1,787	2,020	26%
6:00-9:00 a.m.	Westbound	3,098	3,586	4,236	37%
3:00-7:00 p.m.	Eastbound	3,313	3,954	4,675	41%
3:00-7:00 p.m.	Westbound	1,947	2,336	2,775	43%
Total		**9,961**	**11,663**	**13,706**	**38%**

Source: King County Metro Transit.

Ridership on the SR 520 bridge was compared to ridership on other corridors to see if the percentage changes were similar or dissimilar. In terms of percentages, average daily ridership on the SR 520 bridge increased 38 percent from Summer 2010 to Summer 2012 while average daily ridership on the I-90 bridge increased 23 percent. It increased by an even larger margin when compared to the rest of King County Metro bus service (38 percent versus 8 percent).

Total bus revenue hours represent the amount of time the vehicles are available to the general public. Findings show that while there was a 26 percent increase in revenue hours on the SR 520 bridge, there was only a 4 percent increase across King County Metro Transit system-wide. In other words, the increase in bus service on the SR 520 bridge from Summer 2010 to Summer 2012 was six times greater than the rest of King County Metro Transit. This explains, at least partially, why the ridership gains on the SR 520 bridge were higher than the other corridors.

The transit evaluation included two on-board surveys of SR 520 bus riders conducted by King County Metro, one before and one after tolling. In the post-toll survey, most riders (81 percent) had been riding the bus prior to tolling, however among riders that only began taking transit after the start of tolls, 55 percent said they were influenced to take transit because of the tolls. A portion of the UPA funds were used to equip bus stops with real time bus information technology. A majority responded that the information was both very useful (60 percent) and very easy to understand (73 percent). Some of the on-board survey results were compared to the results of the Wave 2 household travel survey conducted by the Volpe Center. Table 5-7 compares the findings. It is not a perfect comparison because the Volpe surveys also included a limited number of I-90 bus riders. The level of satisfaction with travel time, reliability, and wait time was positive in both surveys. There was a significant difference in the percentage of riders who agreed with the statement that tolls on the SR 520 Bridge have improved their travel. In the on-board survey, 57 percent agreed with that statement, but in the Wave 2 household travel survey, only 35 percent agreed. A likely reason for the difference is that the latter survey included a limited number of responses from I-90 bus riders.

Table 5-7. Post-Deployment Transit Rider Survey Findings

Statement	On-Board Survey			Volpe Wave 2 Survey		
	Rating	Frequency	Percent	Rating	Frequency	Percent
Tolling on SR 520 has improved my travel	Agree	1,083	57%	Agree	227	35%
	Neutral	506	26%	Neutral	144	22%
	Disagree	324	17%	Disagree	277	43%
		1,913	**100%**		**648**	**100%**
Perception of Travel Time	Good to Very Good	1,686	85%	Somewhat to Very Satisfied	832	72%
	Fair	250	13%	Neutral	133	12%
	Poor to Very Poor	39	2%	Somewhat to Very Dissatisfied	182	16%
		1,975	**100%**		**1,147**	**100%**
Perception of Reliability	Good to Very Good	1,642	83%	Somewhat to Very Satisfied	876	76%
	Fair	255	13%	Neutral	118	10%
	Poor to Very Poor	83	4%	Somewhat to Very Dissatisfied	152	13%
		1,980	**100%**		**1,146**	**100%**
Perception of Wait Time	Good to Very Good	1,433	73%	Somewhat to Very Satisfied	869	76%
	Fair	455	23%	Neutral	112	10%
	Poor to Very Poor	84	4%	Somewhat to Very Dissatisfied	166	14%
		1,972	**100%**		**1,146**	**100%**

Source: Volpe; CUTR based on data from King County Metro Transit.

The UPA included funding for improvements at two park-and-ride lots. These two lots are located at the Redmond and South Kirkland Transit Oriented Developments. The Redmond parking garage opened in July 2009 and the South Kirkland parking garage will open in 2014 after the UPA evaluation is complete. The total capacity of the Redmond garage is 385 spaces on three above-ground floors. It includes 377 regular commuter parking spaces and 8 ADA accessible spaces on the first level. The garage has allowed for construction of a mixed-use housing project on the remaining two-thirds of the former park-and-ride site. In September 2010, it was 86 percent occupied. In September 2011 and 2012 it was 100 percent and 99 percent occupied, respectively.

Besides the Redmond parking garage, the evaluation included eleven other park-and-ride lots that provide bus service across the SR 520 Bridge. Table 5-8 shows the data for the Redmond garage and these other eleven lots. Parking demand increased steadily during the three-year evaluation. In September 2010, only one of the twelve lots (Kingsgate) was over 90 percent occupied. In September 2011, the number increased to six, and in September 2012, it increased again to eight.

Table 5-8. Park-and-Ride Lot Usage

	September 2010			September 2011			September 2012		
Park-and-Ride Lot	**Total Spaces**	**Spaces Occupied**	**Percent Occupied**	**Total Spaces**	**Spaces Occupied**	**Percent Occupied**	**Total Spaces**	**Spaces Occupied**	**Percent Occupied**
Redmond (UPA funded)	377	326	86%	377	376	100%	377	373	99%
Bear Creek Park and Ride	283	251	89%	283	287	101%	283	291	103%
Brickyard	443	220	50%	443	295	67%	443	404	91%
Evergreen Point	51	45	88%	19	35	184%	19	44	232%
Grace Lutheran Church	50	42	84%	50	48	96%	50	49	98%
Houghton	470	147	31%	470	161	34%	470	196	42%
Kingsgate	502	506	101%	502	473	94%	502	490	98%
Overlake Transit Center	170	147	86%	170	175	103%	222	226	102%
Overlake Park and Ride	203	39	19%	203	55	27%	203	91	45%
South Kirkland	596	531	89%	596	523	88%	465	485	104%
St. Thomas Episcopal Church	52	21	40%	33	28	85%	64	21	33%
Woodinville	438	202	46%	438	162	37%	438	178	41%

Source: King County Metro Transit.

TDM

There are no TDM projects that are funded through the UPA, although ongoing and expanded TDM programs likely played a key role in supporting the UPA projects. Relatively minimal changes were identified for single occupancy vehicle (SOV) travel, telecommuting, vanpooling, and carpooling in the LWC.

The Commuter Trip Reduction (CTR) survey results indicate changes in assumed[9] travel for the SR 520 corridor, presented in Table 5-9. Despite minimal changes in SOV travel assumed for the SR 520 corridor, SOV trips estimated to be in the I-90 corridor showed a fairly significant rise of 2.1 percent, along with a small increase in assumed SOV trips on SR 522 of 0.3 percent. Additional information on this survey and analysis can be found in Appendix D – TDM Analysis.

Table 5-9. Pre- and Post-Deployment Assumed Work Travel Modes for CTR Employees in the SR 520 Corridor

Travel Mode	Pre-Deployment 2010	Post-Deployment 2012	Change	Percent Change
Drive Alone	43.70%	42.59%	-1.11%	-2.5%
Carpool	10.65%	9.99%	-0.66%	-6.2%
Vanpool	1.97%	1.92%	-0.05%	-2.5%
Transit[10]	32.47%	32.64%	+0.15%	+0.4%
Bike or Walk	5.84%	7.31%	+1.47%	+25.2%
Compressed Work Week	0.34%	0.32%	-0.02%	-5.9%
Other	1.25%	1.34%	+0.09%	+7.2%
Telecommute	3.75%	3.90%	+0.15%	+4.0%

Source: ESTC based on data from WSDOT.

A summary of the Volpe household travel survey results on travel mode choice is presented in Table 5-10. The emphasis of the Volpe household travel survey on users of SR 520, contrasted with the CTR survey of employees using any facility (which includes those who do not use SR 520 or perhaps any of the freeway facilities) appears to be the most likely reason for differences noted when comparing the findings of these surveys.

[9] CTR data includes only O-D data, thus the specific facility used for commuting is assumed based on O-D locations.

[10] Includes bus, train, and ferry. Original CTR results report each individually; total transit is summarized here.

Table 5-10. Pre- and Post-Deployment Measurements of Travel Mode from Volpe Survey

	Pre-Deployment	Post-Deployment	Percent Change
Travel Minutes per Day	95	84	-11.6%
Trips per day	8,101	6,681	-17.5%
Drive Alone	76%	69%	-7.0%
Average Passenger Vehicle Occupancy	1.48	1.56	-0.08%
Carpooling	14%	13%	-1.0%
Transit	15%	18%	+3.0%
Telecommute	15%	15%	0.0%

Source: Volpe.

Baseline Volpe household travel survey results noted a typical SR 520 commute drive alone rate of 79 percent with carpooling at 15 percent and bike/walk at 1 percent. Follow-on questions about telecommuting showed that 16 percent of travelers telecommute at least one day per week and that telecommuting frequency was positively correlated with higher incomes. Seventy-five percent of travelers have some degree of flexibility in their work schedule, thus potentially making it easier to adjust their commute behavior in response to tolling. Additionally, 26 percent of travelers said that their employer offered free or discounted vanpooling (with another 20 percent not sure), and 3 percent of the respondents said they had used this benefit.

There was no reported increase in regular carpooling in the Volpe household travel survey. Only 9 percent of new carpoolers specifically mentioned sharing toll costs as one of the reasons that they began carpooling, though it is possible that the salience of the tolls drew commuters' attention to the overall costs of driving. Although regular carpooling did not increase, there is also no evidence that the newly free-flowing conditions on SR 520 led directly to any drop in carpooling. Only 3 respondents said that they stopped carpooling because it was now faster to drive alone on SR 520.

Overall, the UPA project does not appear to have increased telecommuting in the affected corridor, based on the Volpe household travel survey. Results from King County Metro Transit's telework outreach effort, WorkSmart, reveal modest success. Six employers, representing a significant number of employees, impacted by the tolling project agreed to work with King County Metro Transit during the course of the UPA project. Training of staff and managers and development of policies continued to be ongoing at the conclusion of the post-deployment period. Program managers noted that the outreach effort was affected by the delays in the start of tolling, with outreach perhaps starting too early. Additionally, employers shared that telecommuting is not necessarily viewed as a response to tolling, but is more important as a business practice and employee benefit.

Data from the vanpool operators Kings County Metro Transit, as well as Pierce, Community, and Kitsap Transit show substantial growth in vanpooling from 2010 to 2012. Table 5-11 presents the documented numbers of vans and vanpool participants between May, 2010 and December, 2012. These statistics show a 35 percent overall increase in the number of vanpoolers on the three main facilities crossing Lake Washington. Growth in the number of vans and riders on SR 520 where the tolls were implemented and on I-90, which grew as an alternative post-tolling was substantial; the number of riders more than doubled on SR 520 and nearly doubled on I-90.

Table 5-11. Vanpool Statistics for SR 520, I-90 and SR 522 from 2010–2012

Period	SR 520		I-90		SR 522		Total for LWC	
	Vans	Riders	Vans	Riders	Vans	Riders	Vans	Riders
May, 2010	72	583	56	445	94	791	222	1,819
September, 2011	98	785	82	643	88	742	268	2,170
April, 2012	125	1,004	98	805	95	796	318	2,605
December, 2012	166	1,205	116	827	95	773	377	2,805
Change 2010 – 2012	+130%	+107%	+107%	+86%	+1.1%	-2.4%	+47%	+35%

Source: ESTC based on data from King County Metro Transit.

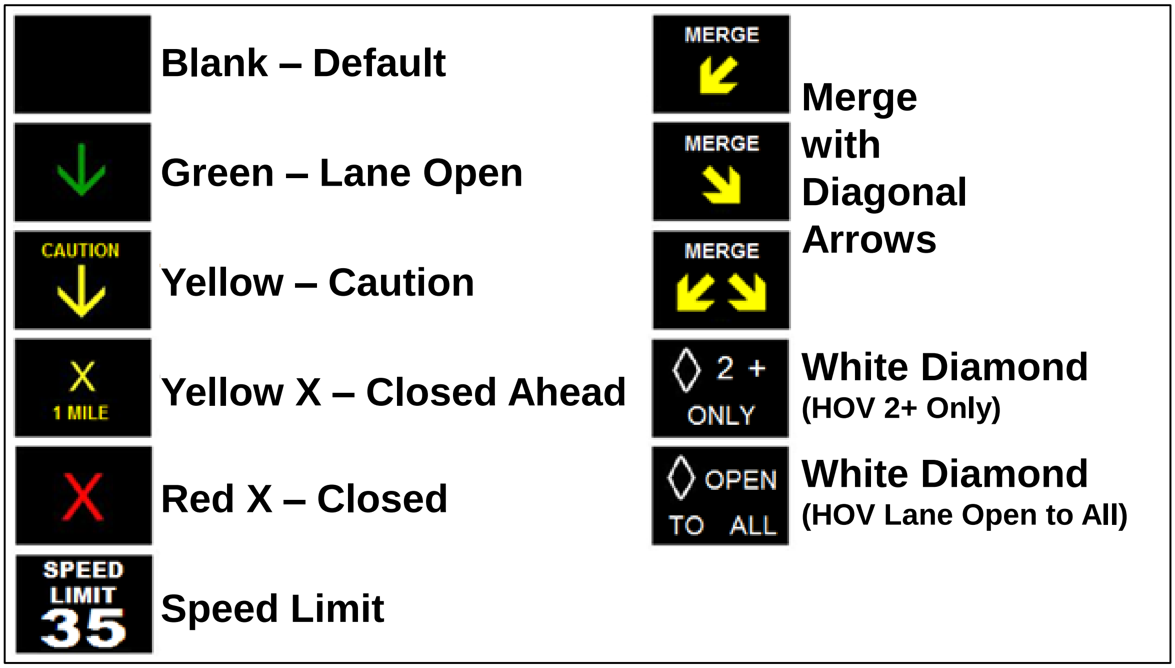
Technology

Technology was an important supporting element of the Seattle/LWC UPA projects and included the deployment of ATM systems on SR 520 and I-90 and real-time travel time signs in several highway locations. Overall, the evaluation showed mixed results from the ATM and travel time signs, with larger effects resulting from the initiation of tolling on the SR 520 bridge. Note that ongoing construction activities in the LWC could have impacted the findings.

ATM operations on SR 520 were implemented in November 2010, with 70 new signs at 19 locations in the 8-mile corridor. There are no signs in the 2.75-mile section that includes the SR 520 bridge. Most of the ATM system on I-90 was implemented in June 2011, with remaining signage on eastbound I-90 becoming operational in May 2012. The I-90 ATM operations include 25 sign locations containing 129 new signs along a 9-mile corridor.

The ATM system includes signs over every lane that can display VSLs, lane status, merge arrows, and HOV information. The system also includes DMS with posted messages on congestion and incidents. Figure 5-5 presents the different lane status signs that can be used with the ATM system. The possible lane status signs include a green arrow for lane open, a yellow arrow for caution, a yellow X for closed ahead, and a red X for closed. Some of these lane status signs are experimental and are not MUTCD compliant[11]. The VSL signs are automated and are activated by the system in advance of congested freeway segments. The posted speeds can range in 5 mph increments from 60 mph, the highest default speed, to 30 mph, the lowest speed. Message signs are also used to alert drivers of accidents and congestion ahead.

[11] The Merge with Diagonal Arrows are not MUTCD compliant, but have received MUTCD experimental approval by FHWA. The Yellow – Caution arrow and Yellow X – Closed Ahead signs are not MUTCD compliant and have not received experimental approval from FHWA.



Source: WSDOT (modified by Battelle).

Figure 5-5. WSDOT ATM System Sign Options

The ATM system is in operation 24 hours a day, 7 days a week. The VSL signs are automated, with changes in speed activated by the system in advance of a congestion area. WSDOT operators can override the posted speed limit to better reflect actual speeds if needed. The system typically identifies an incident or slow traffic and changes to the posted speed limits before an operator would be able to make the same action. When an incident occurs, the operators use WSDOT-developed software to select and post the appropriate message on the DMS.

Additionally, three DMS were implemented as part of the Seattle/LWC UPA to display real-time travel times to downtown Seattle via SR 520 and I-90.

The national evaluation team examined the potential impact of the ATM and travel time signs on VMT, travel speeds, and incidents. Analysis indicates that little change, if any, occurred in the VMT as a result of deploying the ATM and travel times signs solely, and was affected more by tolling the SR 520 bridge. These findings are expected as the travel time signs are about providing information to travelers to lessen driver frustration. This is not to say that individual drivers may elect to change routes during any one particular trip because of the differences in travel times, but when taken on aggregate, drivers typically require additional motivation (such as tolling) to cause systematic shift in travel demands.

The distribution of incidents by type remained relatively constant throughout the evaluation period. Likewise, incident duration did not change significantly as a result of deploying the UPA improvements on either facility. The results on the effects of ATM to promote smoother flow and better throughput during incident conditions were inconclusive. The results show minor improvements in mean travel times in both directions on I-90 during incident conditions after deployment of the ATM/travel time signs. Mean travel speeds during incidents were reduced on SR 520 in the WB direction but increased in the EB direction. The analysis found that there were no statistically significant changes in crashes on SR 520 after the deployment of the ATM system prior to the initiation of and impacts caused by tolling.

The perceptions of the ATM and travel time signs by WSP troopers, IRT operators, and King County Metro Transit bus operators were mixed. Based on their observations and experiences, the IRT operators indicated that the use of the ATM VSLs and lane controls was not very effective, although they felt the real-time travel time signs were beneficial. The WSP troopers had a different perspective on the Smarter Highways signs, lane control systems, and DMS, suggesting that the signs were valuable in informing motorists of upstream incidents. They further suggested that the signs help to proactively manage traffic, providing an additional tool in managing traffic on SR 520 and I-90. King County Metro Transit bus operators indicated that the messages displayed on the Smarter Highways system signs were very clear and that motorists understood the messages. But while lower speed limit signs appear to help slow traffic, not all drivers slow down. While they feel that the ATM system and travel time signs are beneficial, the bus operators did not feel these elements had a major impact on changes in congestion levels.

Assessment of U.S. DOT Four Objective Questions

The four U.S. DOT objective questions and the 10 analysis areas used in the Seattle/LWC UPA evaluation were presented and discussed in Section 4 of this report. Appendices A though J present detailed information on the 10 analyses. This section summarizes the impacts by the hypotheses/questions for each of the 10 analysis areas.

Summary of Congestion Impacts

As highlighted in Table 5-12, the implementation of tolling on the SR 520 Bridge and other UPA projects achieved results that were consistent with the expectations of the local partners in term of congestion impacts. The impacts related to the 11 hypotheses in Table 5-12 are summarized in this section.

The national evaluation team found that all the UPA improvements were fully deployed, mean travel times reduced and travel speed increased on SR 520 in both the morning and afternoon peak periods. The morning mean peak period travel time was reduced by approximately 2 minutes in both directions of travel – a 25 percent reduction – and, mean travel speeds on SR 520 increased from approximately 45 mph to 56 mph in the eastbound direction in the morning peak period and from approximately 47 mph to 58 mph in the westbound direction. In the afternoon peak period, the mean travel time declined by 2 minutes in the eastbound direction of travel and by approximately 8 minutes in the westbound direction. This change caused mean travel speeds on SR 520 during the afternoon peak period to increase from approximately 47 mph to 60 mph in the eastbound direction and from 27 to approximately 45 mph in the westbound direction.

The evaluation also found that implementing the UPA improvements had mixed effects on travel times and average speeds on the other routes (such as I-90 and SR 522) crossing Lake Washington. Mean travel times on I-90 increased by only approximately 1 minute in both directions of travel in the morning peak-period. This means that morning peak period travel speeds on I-90 dropped slightly from approximately 60 mph to 57 mph in the eastbound direction and from 57 to 56 in the westbound direction. In the afternoon peak period, mean travel times and average travel speeds remained approximately the same in the eastbound direction; however, mean travel times on I-90 in the westbound direction increased from 10.6 minutes to 13.6 minutes and mean travel speeds declined almost 50 mph to 41 mph. This suggests that westbound travelers on I-90 experience a noticeable degradation in performance during the evening commute after the UPA deployments were implemented.

Changes in mean travel times on other freeways in the area were mixed. In general, travel times increased in the peak direction of travel and remained the same or declined slightly in the off peak direction. Similar trends occurred in changes in travel speeds. Changes in mean travel speeds on the other freeways were similar to the changes in mean travel times, with some travel speeds decreasing in the peak direction of travel on some facilities and remaining constant or increasing in the off-peak direction.

As expected, implementing the UPA improvements also resulted in improving travel time reliability on SR 520, as measured by the 95^{th} percentile travel time and the Buffer Index. The 95^{th} percentile travel time on SR 520 declined by approximately 3 minutes in the eastbound direction and 6 minutes in the westbound direction in the morning peak period, and by 6 minutes in the eastbound direction and 13 minutes in the westbound direction in the afternoon peak period. This implies that travel on SR 520 for I-5 to I-405 became more stable once the UPA improvements were implemented. The Buffer Index on SR 520 increased slightly in the eastbound direction in the morning peak period and the westbound direction in the afternoon, but declined in the morning westbound direction and afternoon eastbound direction. Travel-time reliability on I-90, I-5, I-405, and SR 522 experienced mixed changes. Except for the westbound direction in the afternoon peak period, the 95^{th} percentile travel time on I-90 were generally the same after the UPA improvements was implemented compared to the before. The Buffer Index on I-90 declined for traffic traveling eastbound in the morning peak period and westbound in the afternoon peak period, but increased for traffic traveling westbound in the morning peak period and eastbound in the afternoon peak period.

As expected by the local partners, the UPA improvements were successful at reducing travel demands on SR 520. Average vehicle throughput on SR 520 in the morning and afternoon peak period in both directions of travel declined. In the morning peak period, average vehicle throughput declined by 25 percent in the eastbound direction of travel and by 12 percent in the westbound direction. In the afternoon peak-period, vehicle throughput on SR 520 declined by 33 percent in the eastbound direction. This implies that implementing tolling on SR 520 caused travelers to seek alternate routes or cancel trips altogether over Lake Washington.

Vehicle throughput on I-90 increased in the eastbound direction in the morning peak period and the eastbound direction in the afternoon peak period, remained unchanged in the westbound direction in the morning peak period, and declined in the westbound direction in the afternoon peak period. Vehicle throughput on I-5, I-405, and SR 522 experienced similar mixed changes, with no major dramatic change. The same trends were evident in changes in person throughput on SR 520, I-90, I-5, SR 522, and I-405.

These changes in vehicle throughput caused the total person throughput for the roadways across and around Lake Washington to decline slightly between the pre- to post-deployment periods. For example, total person throughput for SR 520, I-90, and SR 522 in the morning peak period declined from 39,781 persons to 28,568 persons in the eastbound direction – a 13 percent reduction. Total combined person throughput in the westbound direction dropped by only 7 percent (from 49,182 persons to 45,627 persons) in westbound direction. The combined total afternoon peak-period person throughput on these three facilities declined by only 4 percent from 42,528 persons to 40,742 persons in the eastbound direction and by 10 percent (from 45,413 to 40,993 persons) in the westbound direction. These changes suggest that implementing the UPA improvements may have even caused some travelers to change shift their travel out of the peak periods altogether.

The analysis indicates that congestion did increase during some parts of the morning and afternoon peak periods; however, with the exception of I-90, these increases appear to be relatively minor. On I-90, there appeared to be substantial spreading of peak period congestion temporally. An analysis of travel times and travel speeds by 30 minute intervals within the peak periods showed a congestion forming earlier in the peak on I-90 particularly in the westbound direction in the p.m. peak. The duration of congestion beyond the morning and afternoon peak periods was not examined in this analysis.

The results of the Volpe household travel survey, the WSDOT-sponsored survey of corridor travelers, and the King County Metro Transit survey of bus riders indicated that users perceived that congestion levels on the SR 520 Bridge have declined since tolling was implemented. The responses to these same surveys indicated that travelers' perceived congestion was worse on I-90 as a result of tolling the SR 520 Bridge. The comments made during the WSDOT-sponsored interviews of WSP troopers, IRT operators, and King County Metro Transit bus operators also support the perception that congestion was reduced on SR 520, but increased on I-90 and SR 522. Information on perceptions of changes in congestion on I-5 and I-405 was not obtained in the surveys or interviews.

Table 5-12. Summary of Impacts Across Congestion Hypotheses

Hypotheses	Result	Evidence
Deploying the UPA projects will reduce travel times and increase speeds on SR 520 over Lake Washington between I-5 and I-405.	Supported	Travel times on SR 520 were reduced and travel speeds were increased in both directions of travel in the morning and afternoon peak periods. During the a.m. peak, mean travel time reduced by approximately 2 minutes in both direction of travel. In the p.m. peak, mean travel times reduced by over 3 minutes in the eastbound direction and by approximately 8 minutes in the westbound direction. Mean travel speeds during the a.m. peak increased from approximately 45 mph to over 55 mph in both directions. In the p.m. peak, mean travel speed increased from 47 mph to over 60 mph in the eastbound direction and from 27 mph to over 45 mph in the westbound direction. The travel time index, the ratio of median travel time to free-flow speed, showed significant improvements in both directions for each peak periods.
Deploying the UPA projects will not increase travel times or decrease speeds on I-90, I-5, SR 522, and I-405.	Supported	Except for the westbound direction during the p.m. peak, mean peak period travel times remained at or near pre-deployment level after the UPA improvement were deployed. Travel time in the westbound direction on I-90 during the p.m. peak increased from 10.6 minutes to 13.6 minutes. Changes in the mean travel times on other freeways were mixed, with increases, decreases, and no change occurring. Connecting roadways (I-5 and I-405) in the southbound direction in the p.m. peak showed the greatest increases in travel times. Due to limitations in the data, the National Evaluation Team was unable to assess the impacts of the UPA improvement on travel times and travel speeds in SR 522.
Deploying the UPA projects will improve travel time reliability on SR 520 over Lake Washington between I-5 and I-405.	Supported	The 95^{th} percentile travel time decreased in both directions of travel in both the morning and afternoon peak periods. The Buffer Index either improved or remained at or near pre-deployment levels following the full deployment of the UPA improvements.
Deploying the UPA projects will not decrease travel time reliability on I-90, I-5, SR 522, and I-405.	Mostly Supported	With the exception of the westbound direction in the afternoon peak period, the 95^{th} percentile travel time on I-90 generally remained the same after the UPA improvements were implemented. The southbound direction of both I-5 and I-405 in the southbound direction showed increases in the 95^{th} percentile travel times during the p.m. peak.

Table 5-12. Summary of Impacts Across Congestion Hypotheses (Continued)

Hypotheses	Result	Evidence
Total corridor throughput of the roadways around and over Lake Washington will remain the same or will increase as a result of deploying the UPA projects.	Mostly Supported	With the exception of the eastbound direction in the a.m. peak, the combined total vehicle throughput from SR 520, I-90, and SR 522 decreased by less than 5 percent in both the a.m. and p.m. peak. There was less than a 1 percent reduction in total corridor vehicle throughput in the eastbound direction during the a.m. peak. The combined total peak period person throughput declined for each direction in each peak. Reductions in total peak period person throughput in the eastbound direction ranged from 4 percent in the a.m. peak to 13 percent in the p.m. peak. For westbound traffic, total corridor peak period person throughput declined by 7 percent in the a.m. peak and 10 percent in the p.m. peak.
Vehicle and person throughput on SR 520 will remain the same or will increase as a result of the UPA projects.	Not Supported	As expected by the local partners, vehicle and person throughput on SR 520 declined in the post-deployment period in both directions of travel in the morning and afternoon peak periods.
The UPA projects will not reduce the vehicle and person throughput on I-90, I-5, SR 522, and I-405.	Mostly Support	With the exception of the westbound direction in the p.m. peak, peak period vehicle throughput on I-90 remained the same or increased in the post-deployment period. Westbound peak period vehicle throughput reduced by 12 percent in the p.m. peak. On I-90, peak period person throughput declined by 6 percent and 14 percent in the eastbound direction and increased by 17 percent and 10 percent in the westbound direction for each peak respectively. SR 522 experience an increased in both peak period vehicle and person throughput in both directions for both peaks in the post deployment period Changes in vehicle and person throughput on I-5 and I-405 were not examined in this study.
The UPA projects will improve average speeds on SR 520 (to be consistently above 45 mph as agreed upon in advance by the local partners and U.S. DOT.	Supported	The average travel speeds on SR 520 during the peak periods improved in the post-deployment period and remained about 45 mph except for part of the p.m. peak period. Travel speeds on SR 520 remained at or above 45 mph at least 90 percent of the time during the peak hours.
The UPA projects will not increase the temporal or spatial extent of congestion on I-90, I-5, SR 522, and I-405.	Mixed Support	Vehicle and person throughput on I-90 increased in the eastbound direction in the morning peak period and in the eastbound direction in the afternoon peak period, remained unchanged in the westbound direction in the afternoon peak-period. Other freeways exhibited similar mixed changes. The changes in person throughput also reflected these same patterns.

Table 5-12. Summary of Impacts Across Congestion Hypotheses (Continued)

Hypotheses	Result	Evidence
Travelers will perceive that congestion has been reduced in the SR 520 corridor.	Supported	The results from surveys of corridor travelers and bus riders, as well as interviews with WSP troopers, IRT operators, and King County Metro Transit bus operators, indicate that users perceive that congestion has been reduced on the SR 520 Bridge and the SR 520 corridor between I-5 and I-405.
Travelers will not perceive that congestion has increased on I-90, I-5, SR 522, and I-405.	Mixed Support	The results from the same surveys and interviews indicate that many users perceive that congestion has increased on I-90, and to a lesser extent on SR 522. Information on perceptions of changes in congestion on I-5 and I-405 is not available.

Source: Texas A&M Transportation Institute.

Summary of Tolling Impacts

Table 5-13 summarizes the findings related to the tolling aspects of the Seattle/LWC UPA projects, specifically tolling the SR 520 bridge, and details of the analysis are presented in Appendix B. The information presented in the appendix on the number of *Good To Go!* accounts opened, and toll transactions by month, day of the week, and time-of-day highlight how travelers are using the SR 520 bridge. The information in Appendix B and the congestion analysis in Appendix A highlight the improved operation of the SR 520 bridge since the tolling system was implemented. A total of 275,307 toll accounts were opened over the 23-month period from February 2011 to December 2012. As forecasted, use of the SR 520 bridge declined with the implementation of the tolling system. Use levels remained relatively constant throughout 2012, with transactions per month and by time-of-day reflecting seasonal variations. There are both frequent users of the SR 520 bridge, including individuals who use it on a daily basis, and individuals who use it only a few times a month or less. The congestion analysis in Appendix A further supports the decline in VMT and congestion on the SR 520 bridge since tolling was initiated. The results from the surveys sponsored by Volpe, WSDOT, and Metro Transit indicated that most people using the bridge before tolling continue to use it, but that some people have changed travel routes and travel modes. The survey results further indicate that travelers perceive the tolling system has reduced congestion on the SR 520 bridge and improved travel conditions on the bridge.

Table 5-13. Summary of Tolling Impacts Across Hypotheses

Question and Hypothesis	Result	Evidence
• How will travelers utilize the SR 520 tolling system?	Travelers have opened *Good to Go!* accounts and are using the SR 520 tolling system on both a regular basis and an infrequent basis.	275,307 *Good To Go!* accounts were opened over the 23-month period from February 2011 to December 2012. Use of the SR 520 bridge declined with the implementation of the toll system. Monthly transactions on the SR 520 bridge remained relatively constant in 2012, averaging between 1 million and 1.5 million. Use levels by day of the week and time-of-day also remained relatively constant through 2012. The tolling system is used by frequent users making daily trips and infrequent users making only a few trips a year. The results of the surveys of travelers in the corridor indicate that many pre-deployment bridge users continue to travel on the bridge and pay a toll, but that some have changed travel routes and modes due to the tolling system.
• Variable pricing on SR 520 will regulate vehicular access so as to improve the operation of SR 520	Supported	VMT and congestion levels on the SR 520 bridge have declined with the implementation of the tolling system. The results of surveys of bridge users and travelers in the SR 520 corridor indicate that people perceive the tolling system has reduced congestion and improved travel conditions on the bridge.

Source: Texas A&M Transportation Institute.

Summary of Transit Impacts

Table 5-14 presents a summary of the transit impacts for each of the hypotheses in the transit analysis. The Seattle UPA demonstrated strong increases in ridership and park-and-ride lot usage as well as improvements in bus travel times. Customer satisfaction with the transit service as a whole remains good, although there were some rating decreases in areas such as wait time at the stops, availability of seats, and parking availability. Ironically, some of these lower ratings may be due indirectly to the increased demand for transit service.

Ridership on the SR 520 Bridge increased 38 percent after tolling. Although rising gasoline prices and falling unemployment rates may have contributed to some of the ridership increase, the fact remains that ridership across the SR 520 Bridge increased by a greater percentage than it did across the parallel I-90 Bridge (which was 23 percent) and the rest of King County Metro bus (which was 8 percent).

On-time performance across the SR 520 Bridge improved in the eastbound direction from 47 to 67 percent in the a.m. peak period (6:00 to 9:00 a.m.). In the p.m. peak period (3:00 to 7:00 p.m.) it improved from 40 to 57 percent. There was no significant improvement in the westbound direction. In absolute terms, on-time performance remains low. Bus travel times across the SR 520 Bridge improved after tolling. Improvements were greatest in the eastbound direction where bus travel times were 0.9 and 1.7 minutes shorter.

The passenger surveys showed that the Seattle/LWC UPA has helped to shift some commuters to transit. In the first survey, which was done after the new transit service was added but prior to tolling, 19 percent of the riders said they were influenced to take transit because of the new service. In the second survey, which was done after tolling began, 19 percent of the riders said they began riding the bus after tolling began. Of these “post-toll” riders, 55 percent said they were influenced to take transit because of the tolls. This is the highest percentage observed so far in the UPA/CRD evaluations. Among “new riders” (i.e. riders who had been riding for a year or less), 33 percent said they used to drive alone before switching to the bus.

The surveys revealed important information regarding riders’ perceptions of the transit service and the tolls. The satisfaction rating for on-time performance dropped in the post-toll survey. On a 1 to 5 scale, the mean score dropped from 4.24 to 4.14. Although 4.14 still equates to a rating of good, the drop was statistically significant at the 95 confidence level. The satisfaction rating for bus travel time increased from 4.22 to 4.23 (good), but the change was not statistically significant. Overall satisfaction with King County Metro Transit increased from 3.94 to 4.03 (good). The change was statistically significant at the 95 percent confidence level. Most of the bus riders (82 percent) reported that congestion on SR 520 has been less since tolling began. When asked how their travel times have changed since tolling began, 46 percent reported faster travel times, 47 percent reported that they were the same, and only 7 percent reported longer travel times. A majority of the riders (57 percent) said that the SR 520 tolls have improved their personal travel. A smaller percentage (42 percent) said the SR 520 tolls have been good for the region. However, a majority (55 percent) also believed the SR 520 tolls are unfair to people on limited incomes. Riders with lower incomes were more likely to believe this.

Further details on the transit analysis can be found in Appendix C.

Table 5-14. Summary of Transit Impacts Across Hypotheses

Hypotheses/Questions	Result	Evidence
The Seattle/LWC UPA projects will enhance transit performance in the SR 520 corridor through reduced travel times, increased reliability, and increased capacity.	Supported	• Eastbound improved from 47 to 67 percent in the a.m. peak and improved from 40 to 57 percent in the p.m. peak; no significant improvement in the westbound direction. • Bus travel times were 0.9 to 1.7 minutes shorter in the eastbound direction after tolling.
The Seattle/LWC UPA projects will facilitate an increase in ridership and mode shift to transit on the SR 520 corridor.	Supported	• Peak period average daily ridership on SR 520 Bridge increased 38 percent. Across the I-90 Bridge, it increased 23 percent. Ridership on the rest of King County Metro's bus system increased only by 8 percent. • Redmond Park-and-Ride garage increased from 86 percent to 99 percent occupied from Sept. 2010 to Sept. 2012. • 8 of 12 park and ride lots serving bus routes crossing the SR 520 bridge were at least 90 percent occupied in Sept. 2012 (in Sept. 2010, there was only one).
The mode shift to transit will result in less congestion on the SR 520 corridor.	Supported	• 82 percent of riders reported that congestion on SR 520 has been less since tolling began. • Speeds across the bridge have increased by 14 to 18 mph.
What was the relative contribution of each Seattle/LWC UPA project element to increased ridership and mode shift to transit?	Supported	• 19 percent of new riders said they were influenced to take transit because of the additional transit service. • 55 percent of new riders said they were influenced to take transit because of the tolls. • 46 percent of all riders reported faster travel times since tolling began; 47 percent reported that they were the same; 7 percent reported longer travel times. • 57 percent said that the SR 520 tolls have improved their personal travel.

Source: CUTR.

Summary of Telecommuting Impacts

Table 5-15 summarizes the impacts of TDM elements of the Seattle/LWC UPA demonstration. As presented in the table, the TDM programs did not support both hypotheses, but without clear causality. The various data sources paint slightly different pictures of nominal shifts in certain modes, especially bike and walk. Vanpooling, as managed by regional providers, doubled in the SR 520 corridor in the post-deployment corridor. However, carpooling was deemed to decrease very slightly (<1 percent) at both CTR worksites using the SR 520 corridor and among SR 520 travelers captured in the Volpe household travel survey. Appendix A – Congestion Analysis, shows an almost 30 percent decrease in VMT in the SR 520 corridor after the advent of tolling, but it cannot be concluded that the modest mode shifts in non-motorized (CTR), transit options (Volpe), and vanpooling (King County Metro) contributed in any meaningful way to this. It should also be noted that the study area already has relatively high non-drive shares (over 50 percent), as reflected in the CTR data.

The CTR data support the ability to see changes in mode although linking the destination-based worksite data to the study corridors is imperfect. These data show that carpooling actually decreased somewhat, as well as transit use. Telecommuting changed by a small amount (3.73 percent pre-deployment to 3.84 percent post). They also suggest a very slight increase in drive alone rates (from 38.01 to 38.22 percent). Transit decreased from 38.5 to 37.2 percent and carpooling decreased from 10.46 to 9.81 percent.

The Volpe household travel survey shows slightly different results, since they are based on a different set of travelers: those who use SR 520 and I-90. The Volpe household travel survey found a drop in drive alone rates from 76 to 69 percent and slight increase in the occupancy of passenger vehicles (1.48 to 1.56), which is slightly counter to its finding that carpooling decreased by 1 percent. Possibly the number of people per carpool is responsible for the increase. The Volpe household travel survey found an increase in transit use, which rose from 15 percent to 18 percent.

Finally, specific counts of before and after vanpooling data show that vanpooling increased by 35% in all three corridors studied and the number of vanpoolers doubled on SR520 after implementation of tolling. This growth was not reflected in the CTR data and the Volpe survey did not separate out vanpoolers.

Overall, the TDM and telecommuting elements of the UPA project, coupled with ongoing CTR requirements, provide commuters on SR 520 with alternatives to driving alone and paying the full toll. However, changes in travel behavior are likely motivated by the toll itself. TDM efforts may have contributed by raising awareness of options so those motivated by tolls could determine their best travel alternative. Appendix D presents further information on the evaluation of telecommuting.

Table 5-15. Summary of TDM Impacts Across Hypotheses

Hypotheses/Questions	Result	Evidence
Promotion of commute alternatives and other options (mode, time) removes trips and vehicle miles traveled (VMT) from SR 520	Not supported	VMT decreased on SR 520 by 28.9 percent according the congestion analysis, yet very modest mode shifts to transit, bike, and walk were likely not contributing factors since these shifts were offset by small increases in drive alone and decreases in carpooling. Vanpooling did grow substantially in the study area, but was not reflected in the mode split data. Telecommuting does not seem to have increased during the evaluation period.
What was the relative contribution of the various Seattle UPA Telecommuting/ TDM initiatives on reducing SR 520 vehicle trips/VMT?	Mode shift insignificant	As stated above, the relative contribution of mode shift resulting from TDM/Telecommuting efforts was likely very small.

Source: ESTC.

Summary of Technology Analysis

The results of the technology analysis related to the hypotheses and questions are summarized in Table 5-16. The implementation of signs with real-time travel times via SR 520 and I-90 to downtown Seattle did not influence a change in VMT on the two facilities. The change in VMT occurred after tolling on the SR 520 bridge was implemented.

The ATM and travel time signs on SR 520 and I-90 did not result in major changes in travel times or travel speeds on SR 520 and I-90. The major changes occurred after tolling was implemented on the SR 520 bridge.

As presented in Appendix F – Safety Analysis, and summarized in this appendix, there were no statistically significant changes in crashes resulting from the implementation of the ATM and travel time signs on SR 520 and I-90. The analysis did indicate a statistically significant change in crashes after the SR 520 bridge tolling was implemented, however. A statistically significant increase in crashes occurred on I-90, even accounting for an increase in VMT, after tolling was implemented. However, limited crash data merits a more extensive analysis over a longer time period to fully assess the potential impacts of the ATM and travel time signs on crashes and safety, particularly since active construction projects were present on both SR 520 and I-90 during the pre- and post-deployment periods.

The impact of the ATM and travel time signs on the duration of congestion-causing incidents on SR 520 and I-90 was mixed. The duration of incidents increased after the implementation of the ATM and travel time signs, but declined after tolling on the SR 520 bridge was implemented. The analysis indicated that during the period when the ATM and travel time signs were in operation before tolling on the SR 520 bridge had been implemented, the ratio of incidents to non-incident travel times improved on I-90 in the eastbound direction and on SR 520 in the westbound direction. After tolling was initiated, the ratio of incident to non-incident travel times improved on SR 520, but were worse in I-90. Further information on the technology analysis is contained in Appendix E.

Table 5-16. Summary of Technology Impacts Across Hypotheses

Hypotheses/Questions	Result	Evidence
The travel time signs will promote a more even distribution of traffic between SR 520 and alternate routes (I-405 and SR 522)	Mixed	The results showed little change in VMT on SR 520 and I-90 between 2010 and 2011 after implementing only the travel time signs. Changes in VMT on these facilities were not observed until tolling was implemented on SR 520.
Active Traffic Management will promote smoother traffic flow and better throughput on SR 520 and I-90 during non-incident conditions	Mixed	The results of the study on the effects of ATM to promote smoother flow and better throughput during incident conditions were inconclusive. The results show minor improvements in mean travel times in both directions on I-90 during incident conditions after deployment of the ATM/travel time signs. Mean travel speeds during incident were reduced on SR 520 in the WB direction but increased in the EB direction.
Active Traffic Management will reduce the number of congestion-causing collisions on SR 520 and on I-90.	Mixed	The analysis found that there were no statistically significant changes in crashes on SR 520 as a result of deploying the ATM system. The analysis did show a shift in crashes after tolling was implemented on the SR 520 bridge, however. A statistically significant increase in crashes occurred on I-90, accounting for changes in VMT, in the post-deployment period with tolling of the SR 520 bridge.
Active Traffic Management in the Lake Washington Corridor will reduce the duration of congestion-causing incidents on SR 520 and I-90	Mixed	While incident durations increased after deployment of the ATM system, average incident duration declined after implementing tolling on SR 520. However, this may be a factor more the number of incidents than due to the implementation of the technology in the corridor.
Active Traffic Management will reduce the impact severity of congestion-causing incidents	Mixed	The analysis shows that during the time when only ATM was active in the corridor, the ratio of incident to non-incident travel times improved on I-90 in the EB direction and on SR 520 in the WB direction only. After tolling on SR 520 was initiated, the ratio of incident to non-incident travel times improved on SR 520 but became worse on I-90.

Source: Texas A&M Transportation Institute.

Summary of Safety Impacts

Table 5-17 summarizes the safety impacts across the hypotheses and questions. The analysis presented in Appendix F indicates that the UPA projects did not improve safety on SR 520 and I-90. Instead, it appears that a shift of traffic from SR 520 to I-90 following the initiation of tolling on the SR 520 bridge caused a similar shift of crashes; findings show a statistically significant decrease in the number of crashes on SR 520 and statistically significant increase in the number of crashes on I-90 between I-5 and I-405. A separate analysis of crash data showed no statistically significant effect on the number of crashes after the ATM signage was installed on SR 520. As discussed, however, more extensive analysis over a longer time period is needed to fully assess the potential impacts of the various UPA projects and other improvements on crashes and safety on SR 520, I-90, and other relevant corridors in the region, particularly since active construction projects were present on both SR 520 and I-90 during the pre- and post-deployment periods.

The analysis presented in Appendix F indicates that there were statistically significant crash increases of 66 percent for fatal plus injury crashes and 29 percent for PDO crashes when the change in VMT were accounted for on I-90 in the post-deployment period, while SR 520 saw a 7 percent increase in fatal plus injury crashes and 19 percent decrease for PDO crashes when accounting for VMT during the same period (note that the actual number of fatal plus injury crashes decreased on SR 520). The analysis indicates that the SR 520 tolling system itself did not improve safety on SR 520, but that the resultant shift of VMT from SR 520 to I-90, and consequent increases in crashes on I-90 neutralized any safety impacts. Further analysis of data over a longer time period than available for this evaluation is needed to fully assess the safety impacts of the UPA projects.

The ATM strategies appear to have a neutral impact on crash rates, although improved perceptions of safety are reported by SR 520 travelers, WSP officers, and transit operators. Almost half (46 percent) of SR 520 users agreed or strongly agreed that variable speed limits and lane indicators made for a safer driving experience, while 42 percent agreed or strongly agreed that roadways signs showing travel times on various corridors have made their driving experience safer. The WSP officers and transit operators noted benefits that the ATM signage provided by informing drivers and potentially reducing the number of crashes and crash severity. On the other hand, the IRT operators did not feel the ATM signage was very effective.

Appendix F presents additional details on the safety analysis.

Table 5-17. Summary of Impacts for Safety Hypothesis

Hypotheses/Questions	Result	Evidence
Tolling, ATM and traveler information (e.g., travel time sign) strategies that entail unfamiliar signage and which may alter existing traffic flows will not adversely affect highway safety.	Approximately neutral, but more analysis needed	Total crashes decreased by 11% on SR 520 and increased by 40% on I-90, from 2010 to 2012 when accounting for VMT. This is likely a result of VMT shift from SR 520 to I-90 after the initiation of tolling. The ATM signs had no statistically significant effect on the number of crash rates. However, more extensive analysis over a longer period is needed. Generally positive reactions on improved safety were received from the SR 520 travelers, transit operators, and WSP officers, but IRT operators did not feel the ATM signs were effective.

Source: Battelle.

Summary of Equity Analysis

Table 5-18 presents a summary of the equity analysis for the Seattle/LWC UPA projects and details of the analysis are presented in Appendix G. The impacts of tolling showed mixed results. Drivers incurred higher costs by either paying tolls on SR 520 (although also experiencing travel time improvements), experiencing slightly increased travel times on I-90, and/or making longer trips by switching to I-90 from SR 520. However, transit users tended to benefit from the implementation of tolling with improved transit travel times and on-time transit performance. No disparity in environmental impacts or benefits among any one socio-economic group was identified. The reinvestment of revenues from tolling on SR 520 shows a direct benefit since all toll revenues are being used to pay for a replacement bridge that will benefit not only current transportation users, but also pedestrians and bicyclists who cannot utilize the current bridge.

Table 5-18. Summary of Equity Impacts Across Hypotheses

Hypotheses/Questions	Result	Evidence
What are the direct social effects (tolls paid, travel times, adaptation costs) for various transportation system user groups from tolling the SR 520 bridge, transit, and other UPA strategies?	Mixed	Tolling caused shifts in traffic from SR 520 to I-90. Travel times decreases on SR 520 and increased slightly on I-90. Lower income groups eliminated a greater proportion of trips across Lake Washington than other income groups. Transit users experienced higher quality trips.
What is the spatial distribution of aggregate out-of-pocket and inconvenience costs, and travel time and mobility benefits?	Mixed results	Drivers on both SR 520 and I-90 experienced higher costs by the implementation of tolls. Drivers on SR 520 began paying $1.60-$3.59 per trip, although they experienced improved travel conditions. Drivers on I-90 experienced slightly increased travel times. Transit users on SR 520 experienced improved and faster service.
Are there any differential environmental impacts on certain socio-economic groups?	None identified	An examination of environmental impacts in each corridor by ZIP code area shows a distribution of positive and negative effects across all socio-economic groups, with no individual socio-economic group unfairly benefiting or adversely impacted.
How does reinvestment of revenues from tolling SR 520 impact various transportation system users?	Direct benefit	All toll revenues from the SR 520 bridge (after paying for operations and maintenance of the toll system) are being used to pay for a replacement bridge that will benefit all transportation users of SR 520, including drivers and transit users, as well as pedestrians and bicyclists who will be able to use the new bridge.

Source: Battelle.

Summary of Environmental Analysis

Table 5-19 presents a summary of the questions examined in the environmental analysis of the Seattle/LWC UPA projects, and further details of the analysis are presented in Appendix H. The projects had positive impacts on air quality, and energy consumption. The analysis indicated positive impacts on air quality overall. Over the combined effects on all four freeway facilities, reductions of between 2.5 percent to 5.8 percent in emissions, and a 2.9 percent reduction in fuel use were calculated. On SR 520, emissions decreased by 30-37.9 percent and fuel use declined by 32.2 percent. These decreases were offset somewhat by increases along I-90 and I-405 of 6-12 percent and enhanced somewhat by decreases in emissions and fuel use on I-5.

Table 5-19. Summary of Environmental Impacts Across Questions

Questions	Result	Evidence
What are the impacts of the Seattle UPA strategies on air quality?	Positive impacts.	Emission reductions of over 30 percent for all pollutants on SR 520. Emission reductions between 2.5-5.8 percent when considering the difference between pre- and post-deployment combined effects of SR 520, I-90, I-5, and I-405.
What are the impacts on energy consumption?	Positive impacts.	Fuel use reduction of 32.2 percent on SR 520. Combined fuel use reduction of 11.3 percent when considering the difference between pre- and post-deployment combined effects of SR 520, I-90, I-5, and I-405.

Source: Earth Matters, Inc.

Summary of Non-Technical Success Factors

As highlighted in Table 5-20, people, process, structures, the media, and competencies all played supporting roles in the successful implementation, deployment, and operation of the Seattle/LWC UPA projects. The multi-organizational structure, with its specific roles and responsibilities, supported the implementation, deployment, and operations of the UPA projects. A team of competent staff were able to lead the region through the implementation of a technologically complex project, albeit with some delays. The UPA was only a portion of a larger bridge replacement project, which had been in the works years before the UPA funding was introduced. Likewise, tolling was not new to the region; however, early tolling on an existing facility to partly fund the new facility was a new strategy for the region. An extensive outreach and communications plan aided the local partners' ability to inform the public and cultivate users. The successful deployment of electronic tolling on the SR 520 has opened the door to discussions on also tolling the other bridge across Lake Washington (the I-90 bridge), as well as in other critical corridors in the region. Additionally, the public tends to be more supportive of tolling and the UPA projects in the post-deployment period, although support is not overwhelming. Appendix I contains additional details on the analysis of non-technical success factors.

Table 5-20. Summary of Non-Technical Success Factors

Questions	Results	Evidence
What role did the following areas play in the success of the Seattle/LWC UPA projects? 1. People 2. Processes 3. Structures 4. Media 5. Competencies	1. Effective 2. Effective 3. Some project delays, but ultimately effective in delivering electronic tolling 4. Some coverage problematic, but media also provided outlet to education public about tolling portion of UPA projects 5. Effective	1./5. Agency staff held technical expertise and project management skills needed to successfully implement the projects. Staff held their colleagues in high regard. 1./5. Early tolling on the SR 520 was accepted publicly and politically through the deliberate outreach and communications of top agency leadership. 2. Delays to tolling were unfortunate, but necessary for the successful deployment of electronic tolling. 3. Clearly defined roles and responsibilities within the multi-agency organizational structure. 4. Media kept the projects in the public eye, although their contribution to public opinion sometimes leaned toward negative by focusing on delays and technical difficulties in implementing the electronic tolling.
Does the public support the UPA strategies as effective and appropriate ways to reduce congestion?	Partially Supported	Respondents tend to be more supportive of tolling and the UPA projects in the post-deployment period, although support is not overwhelming.

Source: University of Minnesota.

Summary of Benefit Cost Analysis

This analysis examined the net societal costs and benefits of the Seattle/LWC UPA projects. To summarize, the benefits of the Seattle/LWC UPA projects including travel time savings, vehicle operating costs, and reduced emissions total $203,240,696. The cost of the UPA projects, in 2012 dollars, was $115,250,100.

As presented in Table 5-21, the benefit-to-cost ratio for the Seattle/LWC UPA projects was 1.76 and the net societal benefit was $87,990,596. This BCA examined the net societal costs and benefits of the Seattle/LWC UPA projects. The analysis had several limitations and required numerous assumptions. One limitation was having only one year of crash data. This was too little data to include crash results in the BCA. Future travel time savings benefits, vehicle operating cost benefits and emissions benefits were all derived using the PSRC model. The model itself makes numerous assumptions in order to predict the future. In addition, the model was not able to accurately represent the current traffic volumes on the major routes around Lake Washington, possibly adding error to the estimates of benefits. The future year costs and benefits represent the best estimates available, but they are only estimates, and the actual costs and benefits may vary.

One other important item is that the toll revenue from this UPA project will be used to build a new bridge across the lake – replacing the aging floating bridge there now. This will enhance the safety and resiliency of the bridge and will benefit future travelers in this corridor. However, since the tolls collected as part of this UPA project are transfers of wealth from travelers to the DOT the tolls do not appear in this benefit cost analysis. Appendix J contains details on the BCA.

Table 5-21. Question for the BCA

Hypotheses/Questions	Result	Evidence
What are the overall benefits, costs, and net benefits from the Seattle/LWC UPA projects?	Positive societal benefits	Benefits: $203,240,696 Costs: $115,250,100 Net Benefits: $87,990,596 Benefit-to-cost ratio of 1.76

Source: Texas A&M Transportation Institute.

This page intentionally left blank

Chapter 6 Summary and Conclusions

This report has presented the results from the national evaluation of the Seattle/LWC UPA projects. The report included a summary of the UPA and CRD programs, the Seattle/LWC UPA partners and projects, and the evaluation process and data. The major findings from the evaluation were presented. Appendix A through K contain more detailed descriptions of the 11 analysis areas. This section summarizes the major findings from the evaluation and presents overall conclusions on the Seattle/LWC UPA project.

Summary of Major Findings

Table 6-1 highlights the key findings from the national evaluation of the Seattle/LWC UPA projects based on the U.S. DOT's four objective questions.

Table 6-1. U.S. DOT Objective Questions and Seattle/LWC UPA Impacts

U.S. DOT 4 Objective Questions Evaluation Analyses
How much was congestion reduced?
Congestion. The initiation of tolling on the SR 520 bridge resulted in increased peak period travel speeds, reduced trip times, and improved trip-time reliability for that corridor. However, these measures were slightly degraded for the adjacent I-90 corridor. Decreased throughput was observed in the LWC.
Tolling. Monthly transactions on the SR 520 bridge remained relatively constant in 2012, averaging between 1 million and 1.5 million. Use levels by day of the week and time-of-day also remained relatively constant through 2012. Quarterly revenues ranged from \$11.7 million to \$15.2 million during the post-deployment period.
Transit. Transit performance has improved with faster travel times and increased on-time performance, and ridership increased with the deployment of the UPA projects. Transit riders reported increased satisfaction with their commute.
TDM. Although VMT decreased on SR 520, very modest mode shifts to transit, bike, and walk were likely not contributing factors since these shifts were offset by small increases in SOV travel and decreases in carpooling. While vanpooling grew substantially in the study area, telecommuting does not seem to have increased during the evaluation period.
Technology. The technology components, including ATM systems and the real-time travel time signs were deployed successfully and contributed to the overall operation of the LWC. Findings were inconclusive as to the impact and users had mixed reactions to these components.
What are the associated impacts of the congestion reduction strategies?
Safety. The number of crashes was statistically significantly lower in the post-deployment period on SR 520, but statistically significantly higher on I-90, likely as a result of VMT shift from SR 520 to I-90 after the initiation of tolling. The ATM signs had no statistically significant effect on the number of crash rates. However, more extensive analysis over a longer period is needed. Generally positive reactions on improved safety were received from the SR 520 travelers, transit operators, and WSP officers, but IRT operators did not feel the ATM signs were effective.
Equity. Tolling caused shifts in traffic resulting in decreased travel times for SR 520 users and increased travel times for I-90 users. Lower income groups were particularly impacted, with significant decreases in trips across Lake Washington. Transit users experienced higher quality trips from the UPA projects. Drivers on SR 520 and I-90 experienced higher costs. No disparity in environmental impacts or benefits among socioeconomic group was identified. The reinvestment of revenues from tolling on SR 520 shows a direct benefit since all toll revenues are being used to pay for a replacement bridge that will benefit not only current transportation users, but also pedestrians and bicyclists who cannot utilize the current bridge.
Environmental. The environmental analysis indicated reductions of over 30 percent in both emissions and fuel use on SR 520, as well as decreases for other routes in the study area.
What are the non-technical success factors?
Non-Technical Success Factors. The local partners built on existing strong working relationships. Early tolling on the SR 520 was accepted publicly and politically through the deliberate outreach and communications of top agency leadership. The local media was objective and kept the tolling project visible, although reporting sometimes tended to be negative. The public tended to be more supportive of tolling and the UPA projects in the post-deployment period.
What is the overall cost and benefit of the strategies?
Benefit Cost Analysis (BCA). The Seattle/LWC UPA projects had a benefit-to-cost ratio of 1.76. The calculated net societal benefit was positive due to travel time savings and reduced emissions in the study area, which were assumed to be directly attributable to the UPA project.

Source: Battelle.

Conclusions

The Seattle/LWC UPA projects were designed to demonstrate the effectiveness of innovative strategies for addressing congestion and to provide better mobility options for residents. This report documents the evaluation of the projects by the national evaluation team sponsored by U.S. DOT. The following conclusions can be drawn from the experience in deploying the UPA projects and in the use of the different projects.

- The findings of this report are based on data ending in December 2012 and represented only one year of full operation of tolling on SR 520. Thus, some findings may have changed if examined over a longer period of time in which both the local partners would gain more experience with operations in the corridor and travelers would have more time to modify their travel behavior.
- Additionally, although a robust dataset was provided by the local partners, the evaluation is limited in that the post-deployment lasted only a year. Some data, such as crash data, can have such year to year variability that additional evaluation is recommended to validate these findings over a longer period.
- The Seattle UPA partners worked effectively within their own agencies but also as a team to plan and deliver the UPA projects in a coordinated fashion. They professionally addressed technical issues, delaying the initiation of tolling in order to have a successful deployment, and handled difficult public relations challenges that arose prior to the initiation of tolling on the existing SR 520 bridge.
- The initiation of tolling on an already-built structure with no major capacity improvement represents a major change in national transportation culture that could have posed a challenge under the best of circumstances. The local partners worked to meet the challenge through an effective outreach and marketing campaign prior to tolling to educate the public on the tolling project and ways to sign up for a *Good to Go!* account.
- A primary objective of this tolling project was to generate revenue directly from SR 520 users to fund a new replacement bridge. Additionally, variable tolling was deployed as a means to influence travel behavior and reduce congestion on the SR 520 corridor. Both of these objectives were achieved. Relatively minor impacts were identified on other routes in the LWC as a result of the tolling project, as was anticipated.
- The initiation of tolling on a corridor where alternate routes are available will almost inevitably impact those alternate routes from users who modify their travel behavior to avoid paying a toll. Tolling the SR 520 bridge improved mobility and safety on that corridor, while adjacent routes experienced degraded conditions, including increased VMT and crashes during the evaluation period. While this is not necessarily unexpected, additional mitigation measures should be investigated for those routes.
- Many of the UPA projects provide benefits that are difficult to quantify. Although the evaluation found little quantifiable benefit for the ATM signage, real-time travel time signs on the freeways, and real-time transit travel time signs at bus stops, surveys indicate that the provision of real-time information is valuable to users and provides an improved travel experience.

This page intentionally left blank

Appendix A. Congestion Analysis

Reducing traffic congestion on the SR 520 bridge represents a major focus of the Seattle/Lake Washington Corridor (LWC) Urban Partnership Agreement (UPA) projects. Tolling all traffic using the SR 520 bridge was the primary project for accomplishing this objective. At the same time, the UPA projects were not intended to increase traffic congestion on parallel and adjacent freeways in the area, including I-90, I-5, I-405, and SR 522.

Table A-1 presents the hypotheses for the Seattle/LWC UPA congestion analysis. Figure A-1 highlights the location of SR 520, I-90, and the other freeways addressed in the hypotheses. The first hypothesis is that deploying the UPA projects will reduce travel times and increase speeds on the SR 520 bridge. The second related hypothesis is that the UPA projects will not increase travel times or decrease speeds on other freeways in the area. These freeways include I-90, I-5, I-405, and SR 522. The third hypothesis is that deploying the UPA projects will improve travel time reliability on SR 520, while the fourth hypothesis is that travel time reliability will not decrease on the nearby facilities.

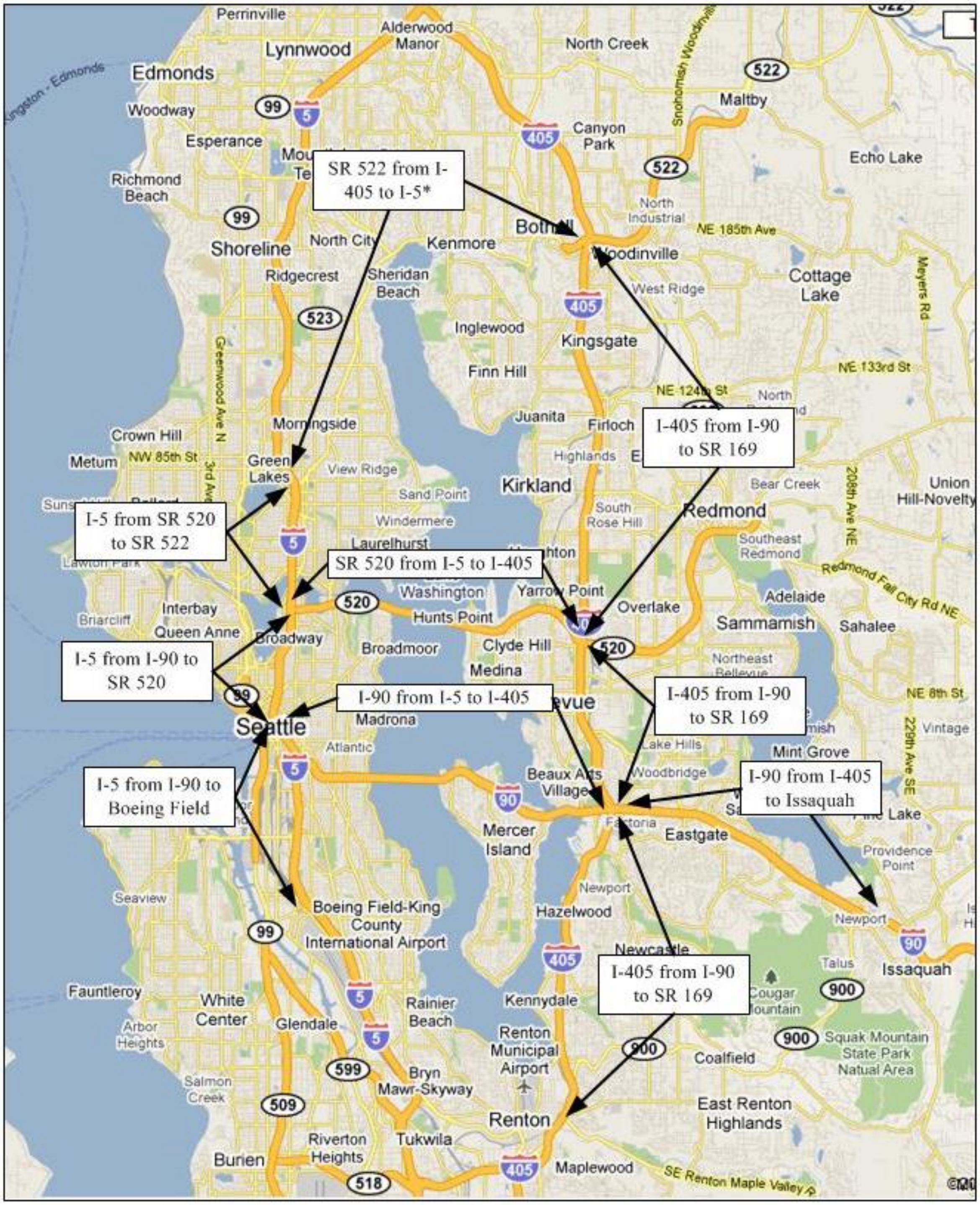
The fifth hypothesis is that the total corridor throughput of the roadways around and over Lake Washington will remain the same or will increase as a result of deploying the UPA projects. The sixth hypothesis is that vehicle and person throughput on the SR 520 bridge will remain the same or will increase as a result of the UPA projects, while the seventh hypothesis is that the UPA projects will not reduce vehicle and person throughput on the nearby facilities. The eighth hypothesis is that the UPA projects will improve average speeds on the SR 520 bridge. The ninth hypothesis is that that the UPA projects will not increase the temporal or the spatial extent of congestion on the nearby facilities. The tenth hypothesis is that travelers will perceive that congestion has been reduced on the SR 520 bridge. The final hypothesis is that travelers will not perceive that congestion has increased on the nearby facilities.

The remainder of this appendix is divided into eight sections. The data sources used in the analysis are described in Section A.1, followed by the traffic data analysis methods in Section A.2. Section A.3 presents the analysis of changes in travel times and travel speeds on SR 520, I-90, and other facilities in the area. Section A.4 discusses changes in travel-time reliability on SR 520, I-90, and other facilities, including the 95th percentile travel time and the Buffer Index. Section A.5 examines vehicle and person throughput on SR 520, I-90, and other facilities. Section A.6 analyzes changes in vehicle miles traveled (VMT) on SR 520, I-90, and other freeways. Section A.7 summarizes the results from surveys of area travelers and interviews with Washington State Patrol (WSP) troopers, Washington State Department of Transportation (WSDOT) Incident Response Team (IRT) operators, and King County Metro Transit bus operators related to congestion. The appendix concludes with a summary of the congestion analysis hypotheses in Section A.8.

Table A-1. Congestion Hypotheses

Hypotheses
Deploying the UPA projects will reduce travel times and increase speeds on SR 520 over Lake Washington between I-5 and I-405.
Deploying the UPA projects will not increase travel times or decrease speeds on the following nearby facilities: • I-90 general purpose lanes (between I-5 and I-405) • I-90 (between Issaquah/MP 19.41 and I-405) • I-5 (between SR 522 and I-405) • I-90 Express Lanes • SR 522 (between I-405 and I-5) • I-405 (between SR 169 and SR 522)
Deploying the UPA projects will improve travel time reliability on SR 520 over Lake Washington between I-5 and I-405.
Deploying the UPA projects will not decrease travel time reliability on the following nearby facilities: • I-90 general purpose lanes (between I-5 and I-405) • I-90 (between Issaquah/MP 19.41 and I-405) • I-5 (between SR 522 and I-405) • I-90 Express Lanes • SR 522 (between I-405 and I-5) • I-405 (between SR 169 and SR 522)
Total corridor throughput of the roadways around and over Lake Washington will remain the same or will increase as a result of deploying the UPA projects.
Vehicle and person throughput on SR 520 will remain the same or will increase as a result of the UPA projects.
The UPA projects will not reduce the vehicle and person throughput on the following nearby facilities: • I-90 general purpose lanes (between I-5 and I-405) • I-90 (between Issaquah/MP 19.41 and I-405) • I-5 (between SR 522 and I-405) • I-90 Express Lanes • SR 522 (between I-405 and I-5) • I-405 (between SR 169 and SR 522)
The UPA projects will improve average speeds on SR 520.
The UPA projects will not increase the temporal or spatial extent of congestion on the following facilities: • I-90 general purpose lanes (between I-5 and I-405) • I-90 (between Issaquah/MP 19.41 and I-405) • I-5 (between SR 522 and I-405) • I-90 Express Lanes • SR 522 (between I-405 and I-5) • I-405 (between SR 169 and SR 522)
Travelers will perceive that congestion has been reduced in the SR 520 corridor.
Travelers will not perceive that congestion has increased on the following nearby facilities: • I-90 general purpose lanes (between I-5 and I-405) • I-90 (between Issaquah/MP 19.41 and I-405) • I-5 (between SR 522 and I-405) • I-90 Express Lanes • SR 522 (between I-405 and I-5) • I-405 (between SR 169 and SR 522)

Source: Battelle.



* Not included in final analysis because limited data availability

Source: Google Maps, modified by Texas A&M Transportation Institute.

Figure A-1. Location of SR 520, I-90, and Other Freeways

A.1 Data Sources

The WSDOT traffic sensor system represents the primary data source for the congestion analysis. The WSDOT traffic sensor data is collected, processed, maintained, and distributed by the WSDOT Northwest Region Traffic Management Center (NRTMC). Data from the vehicle-occupancy counts conducted by the Washington State Transportation Center (TRAC) on a regular basis were also used in the analysis. Data on transit ridership on routes operating on the SR 520 bridge and other freeways in the area were obtained from Appendix C – Transit Analysis. Information on travelers' perceptions of changes in congestion levels, travel speeds, and trip-time reliability was obtained from the Seattle household travel survey sponsored by the John A. Volpe National Transportation Systems Center (Volpe) and the surveys of area residents sponsored by WSDOT. Information is also presented from the WSDOT-sponsored interviews with WSP troopers, WSDOT IRT operators, and King County Metro Transit bus operators.

A.2 Traffic Data Analysis Methods

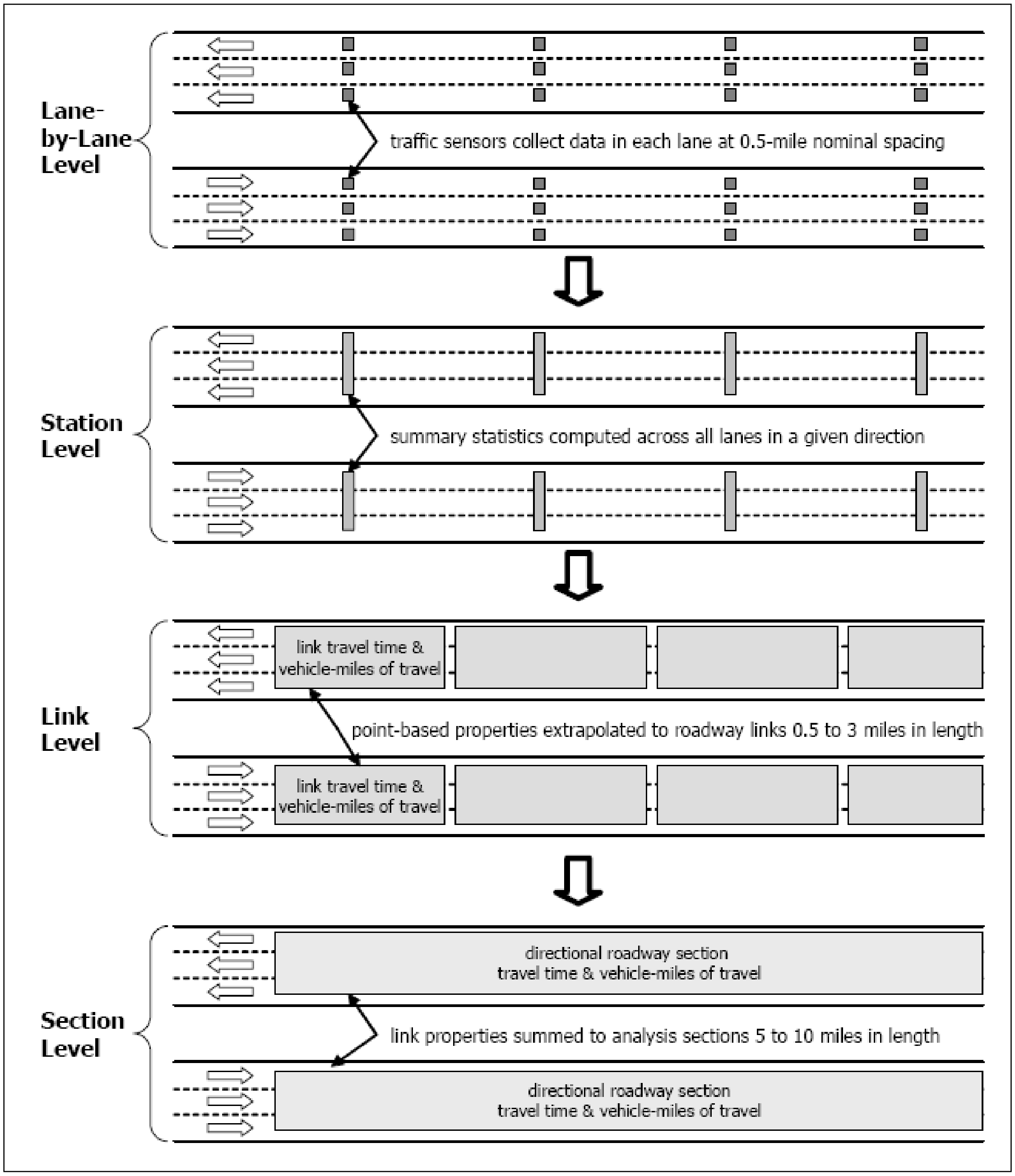
Data from the WSDOT traffic sensors, which is collected continuously, cover the freeway segments included in the congestion analysis. The sensors represent the primary source for the traffic volume and travel speed evaluation. Data from the traffic sensors is communicated to the WSDOT NRTMC where it is used to generate travel-time information that is disseminated to the public and used to support WSDOT traffic management activities.

WSDOT uses two freeway loop detector configurations: single-loop detectors and speed-trap detectors. Single-loop detectors allow volume and lane occupancy to be measured in each lane at each location. Speed-trap detectors also measure volume and lane occupancy, as well as the average speed of traffic and limited vehicle type classifications. At a minimum, these traffic sensors record volume, lane occupancy, and speed every 20 seconds on a lane-by-lane basis. The traffic sensors are generally located in each lane, including any HOV lanes, and entrance and exit ramps. WSDOT archives the traffic sensor data for research and evaluation purposes. The archives contain 5-minute aggregations of the raw traffic sensor data.

Figure A-2 illustrates the process that was used to aggregate the WSDOT traffic sensor data spatially. The national evaluation team used the 5-minute data collected on a lane-by-lane basis. Speed and volume data from each detector were aggregated across all lanes in each direction to yield detector station values. Volume data from the lane detectors were summed to provide a detector station volume, while speed data were averaged across all lanes to provide an average detector station speed. Speed data from the slower moving auxiliary lanes on the freeway were excluded from the aggregation.

Detector station data were converted to link-level data at the next level of aggregation, which focused on assigning a "zone of influence" for each detector station. The zone of influence was equivalent to one-half the distance to the nearest upstream and downstream sensors. Link-travel times were computed by applying the average detector station speed over the zone of influence for each detector station. Vehicle volumes were subtotaled and multiplied by link length to estimate VMT for each link.

For the congestion analysis, traffic sensor data were analyzed on a peak period basis. For the purposes of this analysis, the a.m. peak period was defined to from 6:00 a.m. to 10 a.m. while the p.m. peak period was defined to be from 3:30 p.m. to 7:00 p.m. Data from the pre-deployment period was from January 2010 to December 2010. Data used to represent corridor performance in the post-deployment period was from January 2012 through December 2012. Tolling on SR 520 was initiated in December 2011.



Source: Texas A&M Transportation Institute.

Figure A-2. Roadway Data Spatial Aggregation Scheme

A.3 Travel Time and Travel Speeds

Travel time is a key measure for assessing traffic congestion. Travel time is easily understood by the public and is used by agency staff for planning and operations. Travel time-based measures form the framework for quantifying the extent to which the UPA improvements impacted congestion on the SR 520 bridge and other facilities in the area. The three measures discussed in this section are travel times, mean travel speeds, and the Travel Time Index.

A.3.1 Travel Times

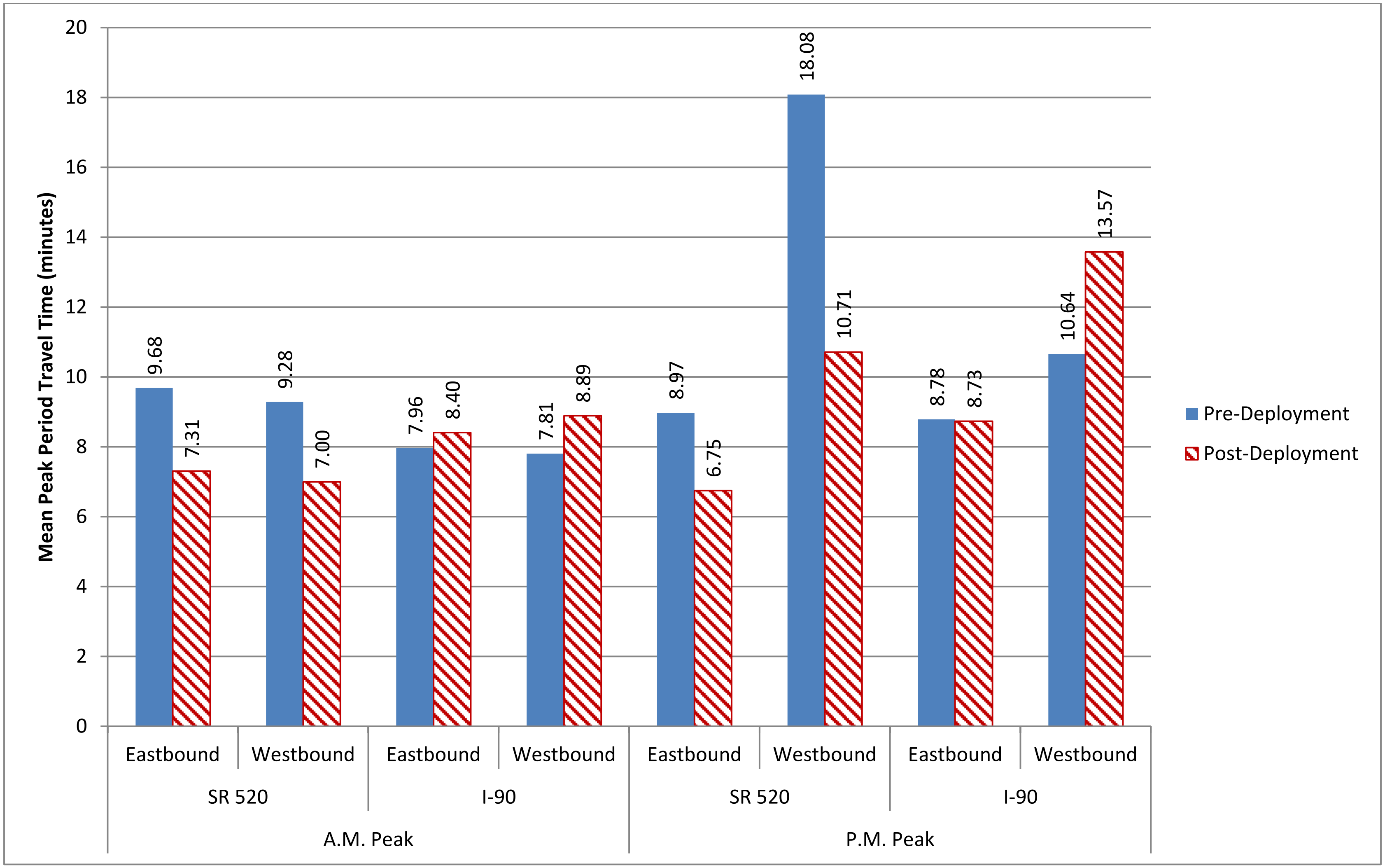
Figure A-3 highlights the mean travel times on SR 520 and I-90 between I-405 and I-5 crossing Lake Washington, in the morning and afternoon peak periods in both directions of travel. The mean morning peak-period travel time on SR 520 was reduced by approximately 2 minutes in both the eastbound and westbound direction from the pre-deployment to the post-deployment evaluation periods. This equates to a 25 percent reduction in mean travel times over Lake Washington and resulted in significant increases in travel speeds on SR 520 (see Section A.3.2). The mean travel time on I-90 increased by only approximately 1 minute in both directions in the morning peak period. The mean afternoon peak-period travel time on SR 520 in the eastbound direction decreased by approximately 2 minutes in the pre-deployment period to the post-deployment period, while the mean afternoon travel time in the westbound direction decreased by approximately 8 minutes. In contrast, the mean peak-period travel times on I-90 remained approximately the same in the pre- and post-deployment periods in the eastbound direction and increased by approximately 3 minutes in the westbound direction. These changes in mean travel times suggest a shift in traffic from SR 520 to I-90 after tolling on the SR 520 bridge was implemented.

Figure A-4 presents the mean peak-period travel times on the sections of I-5 and I-405 between I-90 and SR 520. This changes suggest that implementing tolling on SR 520 had little to no impact on travel using these facilities. In the post-deployment period, mean travel times in the northbound direction on I-5 declined by approximately 30 seconds in both the morning and the afternoon peak periods and increased by approximately 30 seconds in the southbound direction in the morning peak period and approximately 2.5 minutes in the afternoon peak period.

A similar trend was observed on I-405. Travel times in the northbound direction during the morning and afternoon peak periods decreased slightly. Traffic traveling on I-405 in the southbound direction from SR 520 toward I-90 experienced little change in peak-period travel times during the morning peak period, but increased by approximately 3 minutes in both the general-purpose freeway lanes and the HOV lanes during the afternoon peak period.

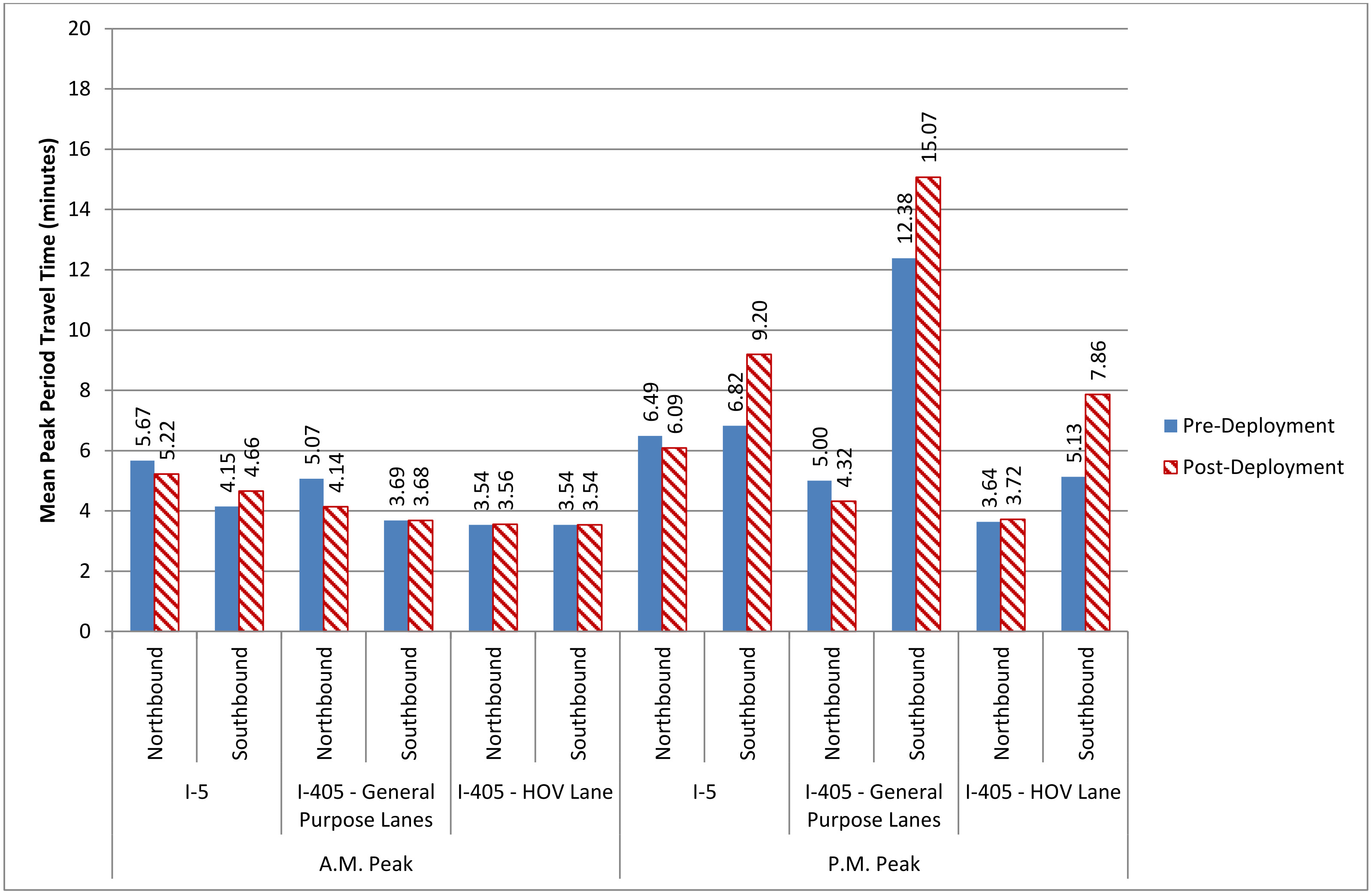
Figure A-5 presents the mean peak-period travel times on I-5 from Boeing Field to I-90 and I-5 from SR 520 to SR 522. The mean morning peak-period travel times on I-5 in this segment increased in the northbound direction by approximately 4 minutes in the general purpose freeway lanes and 1 minute in the HOV lane. Travel times in the southbound direction in the morning peak period remained relatively constant. In the afternoon peak period, the mean travel times increased by a few seconds in both directions of travel. Morning peak period mean travel times on I-5 from SR 520 to SR 522 remained generally the same in the northbound direction and declined by approximately one minute in the southbound direction. In the afternoon peak period, the mean travel times increased slightly in the northbound direction and increased by approximately 4 minutes in the southbound direction.

Figure A-6 illustrates the changes in mean travel times on I-90, from I-405 to Issaquah, and I-405, from SR 169 to I-90. The mean travel times on I-90 in the general purpose freeway lanes and the HOV lane remained approximately the same in the pre- and post-deployment periods for the morning and afternoon peak periods in both the eastbound and westbound direction of travel. The mean travel times on I-405 increased by approximately 3 minutes in the general-purpose freeway lanes and by approximately 50 seconds in the HOV lanes in the morning peak period in the northbound direction. The mean travel times in the southbound direction decreased by approximately 1 minute in the general purpose freeway lanes and remained the same in the HOV lanes. In the afternoon peak period, the mean travel time in the general purpose freeway lanes increased by approximately 1.4 minutes in the northbound direction and by approximately 1 minute in the southbound direction. Mean travel times in the HOV lanes remained the same in the northbound direction and increased by a little less than a minute in the southbound direction.



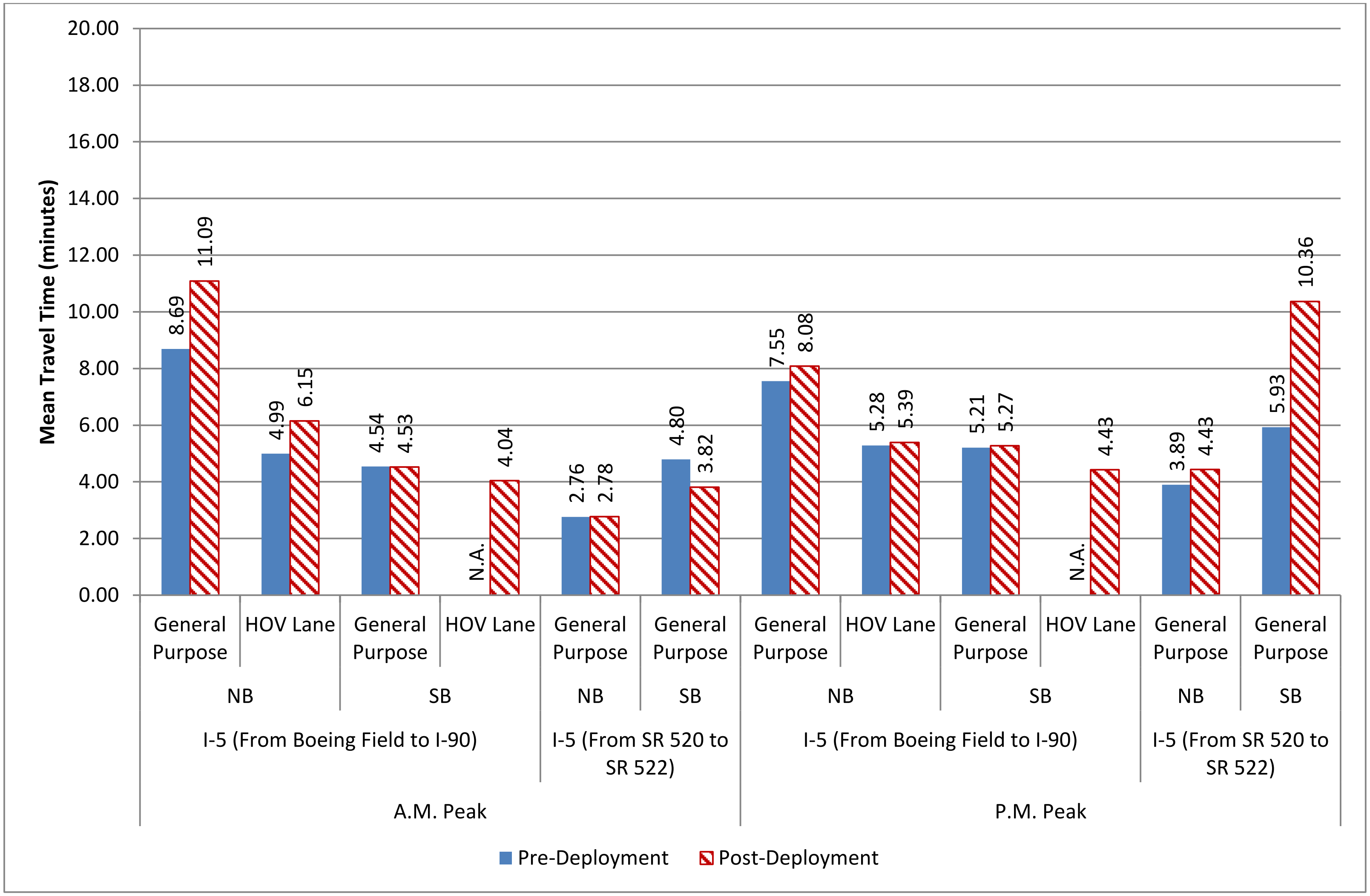
Source: Texas A&M Transportation Institute.

Figure A-3. Mean Peak Period Travel Times (in Minutes) on SR-520 and I-90



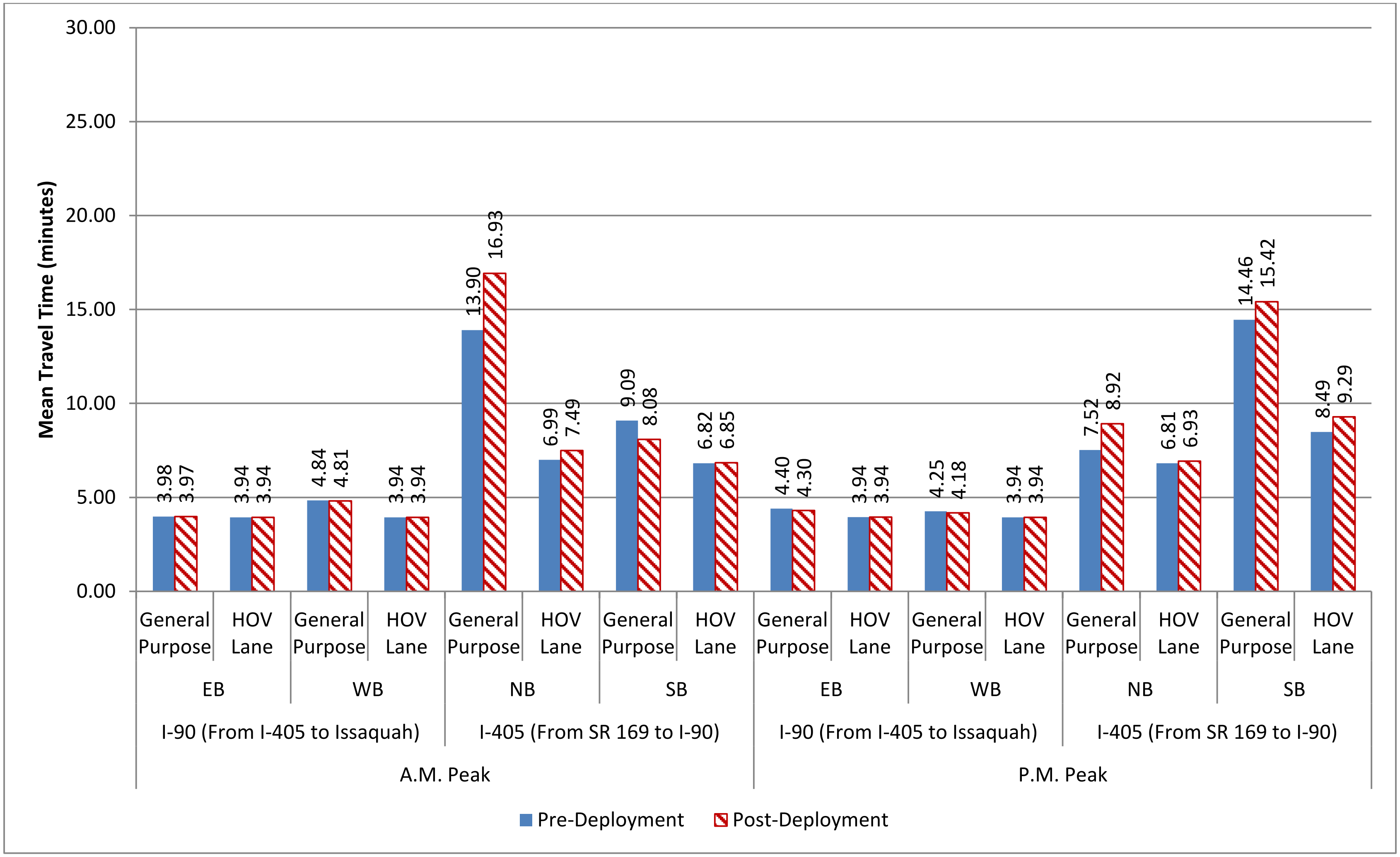
Source: Texas A&M Transportation Institute.

Figure A-4. Mean Peak Period Travel Times (in Minutes) on I-5 and I-405 between SR 520 and I-90



Source: Texas A&M Transportation Institute.

Figure A-5. Mean Peak Period Travel Times (in minutes) on I-5 Approaching the LWC During the A.M. and P.M. Peak Periods



Source: Texas A&M Transportation Institute.

Figure A-6. Mean Peak Period Travel Time (in minutes) on I-90 and I-405 Approaching the LWC During the A.M. and P.M. Peak Periods

Figure A-7 presents the pre- and post-deployment mean travel times in 30-minute increments on SR 520 in the morning and afternoon peak periods. Figure A-8 presents the same information for I-90. The mean travel times for SR 520 are shorter in the post-deployment period for both directions of travel in both the morning and afternoon peak periods. The mean travel times throughout the morning and the afternoon peak periods follow similar patterns, however. The mean travel times on I-90 are slightly longer in the morning peak period in both directions of travel in the post-deployment period. The mean travel times in both directions of I-90 are slightly longer throughout the peak period, in the post-deployment period until approximately 5:30 p.m., when they drop to the same level or slightly below the pre-deployment mean travel times. The post-deployment mean travel times on I-90 are also longer earlier in the afternoon peak period. These changes also support that some travelers are switching from SR 520 to I-90 since tolling on the SR 520 bridge was implemented.

A statistical comparison of changes in the mean travel times within each peak period was conducted using a linear mixed-effect modeling technique. Table A-2 and Table A-3 present the results of this analysis. The time-of-day and deployment period were considered fixed effects. Monthly and day-of-week traffic patterns, as well as other factors, were treated as random effects. The models were calibrated separately by direction and by lane type. The factors that are known to potentially influence the traffic patterns are appropriately accounted for in the models, while the fixed-effect results indicate the magnitude and statistical significance of UPA deployment impacts.

The mean travel times for eastbound traffic on SR 520 were statistically different in every interval during both the morning and afternoon peak periods except between 6:00 a.m. to 6:30 a.m. In the morning peak period, reductions in travel times ranged from 1 to 3.5 minutes in the eastbound direction, and up to 5 minutes in the westbound direction. In the afternoon peak period, reductions in mean travel times were between 2 and 3 minutes in the eastbound direction and as high as 9.5 minutes in the westbound direction.

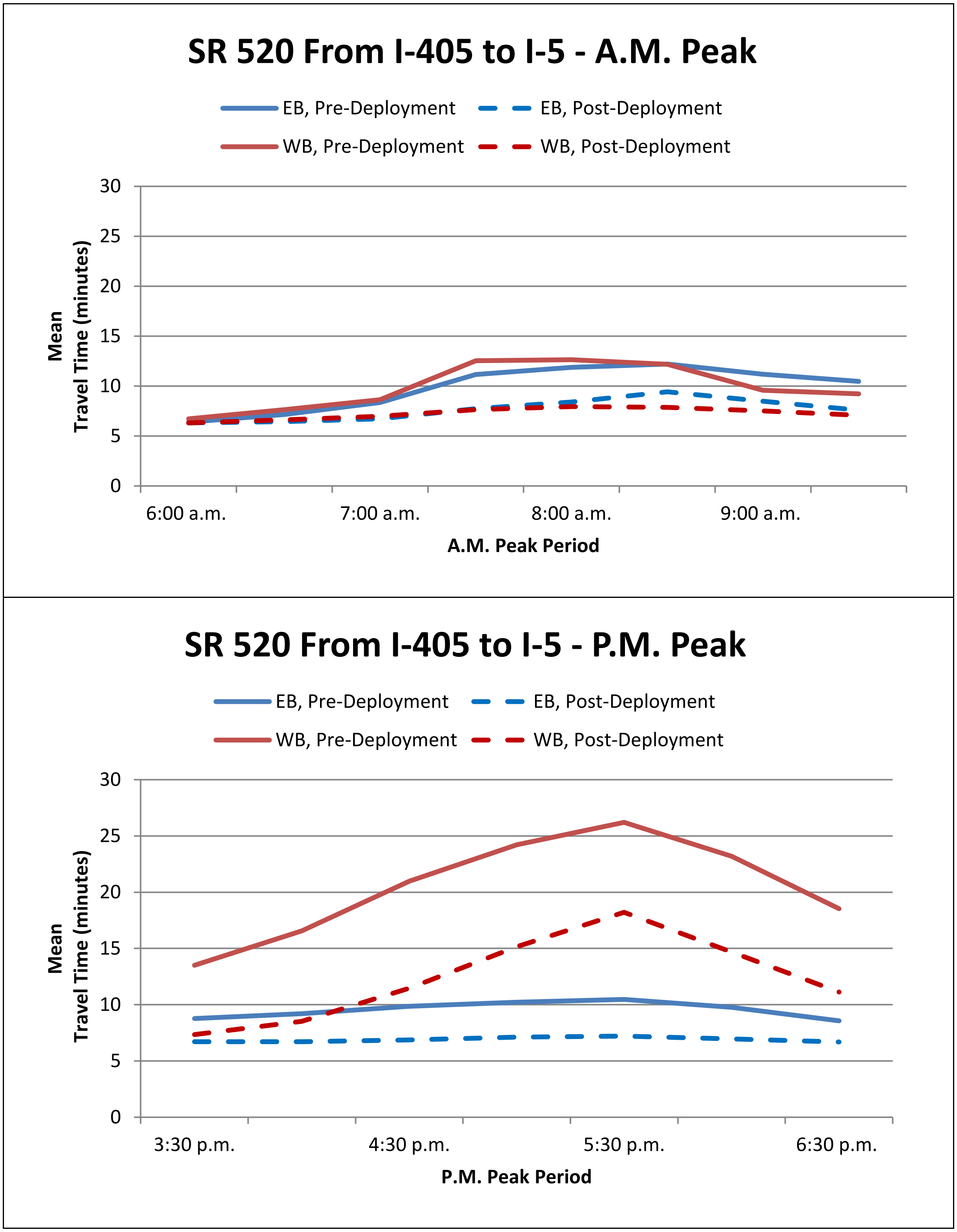
Travel times in both directions of I-90 in the morning peak were statistically higher in the post-deployment period except between 6:00 a.m. and 7:00 a.m. The largest increase occurred between 7:30 a.m. and 8:30 a.m. in both directions of travel with the mean travel times increasing approximately 2 minutes in the eastbound direction and almost 3 minutes in the westbound direction. In the afternoon peak period, the mean travel times on I-90 were also statistically higher in both directions of travel during the post-deployment period. The most significant increase in travel times occurred between 4:30 p.m. and 5:30 p.m., with travel times increasing by up to 1.5 minutes in the eastbound direction and by approximately 6 minutes in the westbound direction.

Traffic traveling northbound on I-5 between I-90 and SR 520 experienced a slight reduction of approximately 1 minute in travel times between 8:00 a.m. and 10:00 a.m. and again between 5:00 p.m. and 7:00 p.m. Traffic traveling in the southbound direction leading to I-90 experienced slight increases in average travel time between 7:00 a.m. and 9:00 a.m. During the afternoon peak period, southbound travel times were statistically higher throughout the entire peak period. These increases were as high as 3 minutes from 5:00 p.m. to 6:30 p.m.

Mean travel times for northbound traffic using the general purpose lanes of I-405 between I-90 and SR 520 were statistically lower in the post-deployment period from 7:30 a.m. and 10:00 a.m. The largest reduction, approximately 2 minutes, occurred in the 8:30 to 10:00 a.m. intervals. While the mean travel times for southbound traffic using this section of I-405 were not statistically different during the morning peak period, the average travel times for southbound traffic in the afternoon peak period increased by approximately 2 minutes during most intervals. Post-deployment travel times in the northbound direction in the afternoon peak period were statistically lower by approximately 1 minute from 3:30 p.m. to 5:00 p.m. This reduction did not continue for the remainder of the afternoon peak period, however. Mean travel times in the HOV lanes on I-405 between SR 520 and I-90 did not change significantly during any interval in either direction during either peak period.

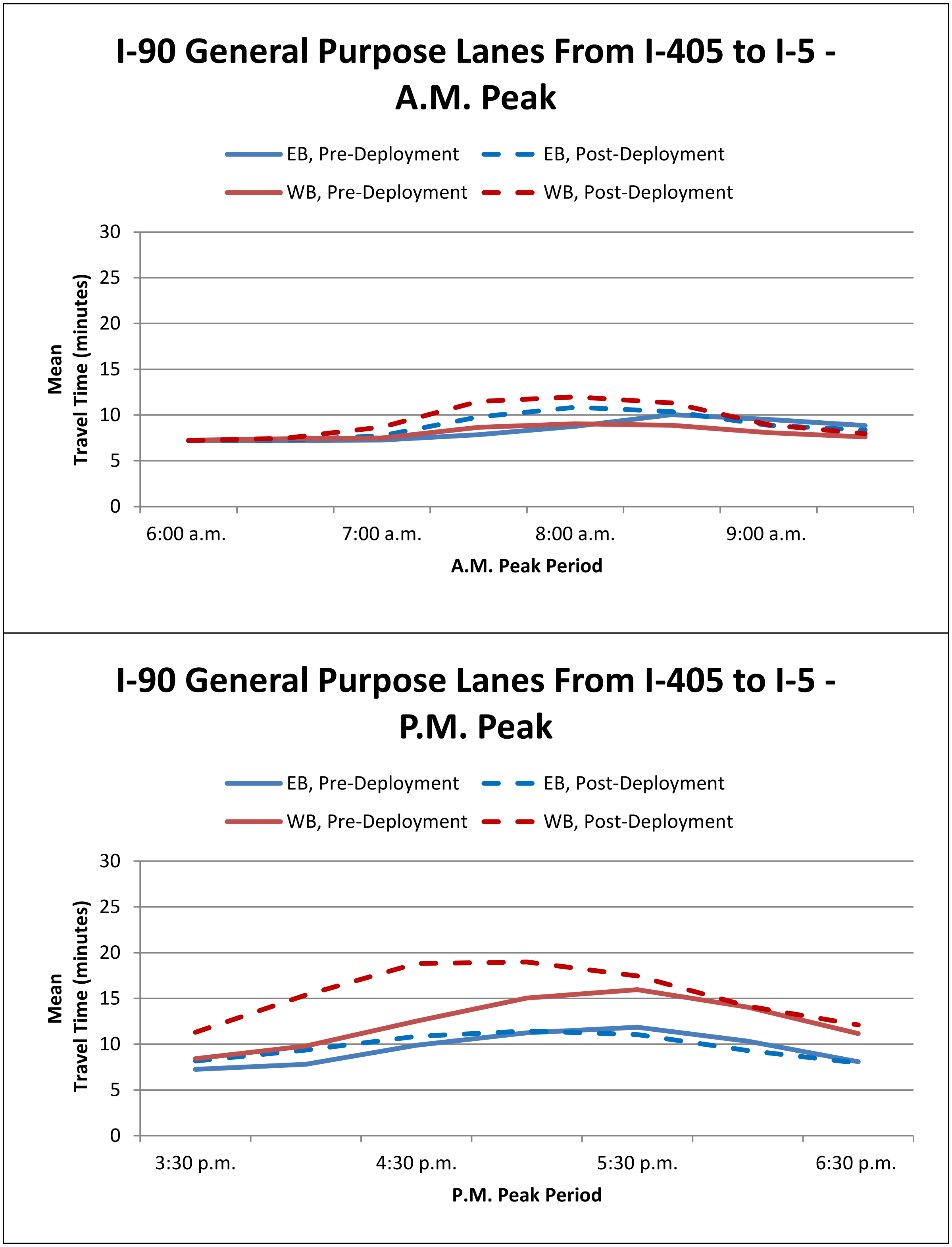
For the section of I-405 between SR 520 and SR 522, travel times were statically higher in the post-deployment period during every interval in the morning peak period in the southbound direction and in every interval during the afternoon peak period in the northbound direction. The increases in southbound travel times were between 1 to 2.5 minutes, with the largest increase occurring between 8:30 a.m. and 9:00 a.m. The mean travel times in the northbound direction during the afternoon peak period increased by approximately 5 to 6 minutes in every interval.

Travel times in the HOV lanes in the section of I-405 between SR 520 and SR 522 were statistically higher in the southbound direction during the morning peak period and in the northbound direction in the afternoon peak period. The increases were generally less than 2 minutes, however. Travel times in the northbound direction were slightly lower in the all intervals in the morning peak period. These reductions were less than 1 minutes in all intervals. Travel times in the southbound HOV lane in this section were approximately 1 minute longer in the post-deployment period.



Source: Texas A&M Transportation Institute.

Figure A-7. Pre- and Post-Deployment Mean Travel Times for SR 520 from I-405 to I-5



Source: Texas A&M Transportation Institute.

Figure A-8. Pre- and Post-Deployment Mean Travel Times for I-90 General Purpose Lanes from I-405 to I-5

Table A-2. Differences in Mean Travel Times in the LWC by Time Intervals within the Peak Period

Time Interval	Difference in Pre- and Post-Deployment Mean Travel Times (minutes)									
	SR 520		I-90		I-5		I-405 GP		I-405 HOV	
	From I-405 to I-5				From SR 520 and I-90					
Beginning	EB	WB	EB	WB	NB	SB	NB	SB	NB	SB
A.M. Peak										
6:00 – 6:30 a.m.	-0.08	-0.40	0.00	-0.04	0.04	-0.09	-0.06	-0.03	-0.01	0.00
6:30 – 7:00 a.m.	-0.71	-1.00	0.05	0.07	0.06	-0.11	-0.08	-0.01	-0.01	0.00
7:00 – 7:30 a.m.	-1.63	-1.67	0.45	1.17	0.26	0.17	-0.02	-0.01	0.01	0.00
7:30 – 8:00 a.m.	-3.40	-4.90	1.96	2.83	0.02	1.19	-0.62	0.16	0.03	0.00
8:00 – 8:30 a.m.	-3.45	-4.69	2.07	2.94	-0.65	1.08	-1.09	0.11	0.01	0.00
8:30 – 9:00 a.m.	-2.76	-4.31	0.34	2.43	-1.75	1.00	-1.81	0.06	0.02	0.00
9:00 – 9:30 a.m.	-2.69	-2.07	-0.64	0.86	-1.40	0.50	-2.26	0.08	0.01	0.01
9:30 – 10:00 a.m.	-2.88	-2.13	-0.52	0.36	-1.05	0.49	-1.92	-0.01	0.07	-0.01
P.M. Peak										
3:30 – 4:00 p.m.	-2.06	-6.15	0.93	2.89	0.63	1.30	-1.46	2.94	-0.01	0.00
4:00 – 4:30 p.m.	-2.51	-8.03	1.53	5.57	0.59	1.72	-1.20	2.49	0.01	0.00
4:30 – 5:00 p.m.	-2.99	-9.51	0.98	6.29	-0.10	1.88	-0.53	2.17	0.03	0.00
5:00 – 5:30 p.m.	-3.11	-9.05	0.21	3.95	-0.57	3.14	-0.17	1.58	0.01	0.00
5:30 – 6:00 p. m.	-3.26	-8.00	-0.79	1.48	-1.18	3.12	0.29	1.39	0.02	0.00
6:00 – 6:30 p.m.	-2.79	-8.51	-1.04	0.11	-1.07	3.26	0.05	2.81	0.01	0.01
6:30 – 7:00 p.m.	-1.89	-7.39	-0.12	0.93	-0.50	2.18	-0.30	2.72	0.07	-0.01

Note: Shaded cells represent statistically significant differences at a 95 percent confidence level.

Note: Negative values represent reductions in travel time and positive values represent increases in travel times.

Source: Texas A&M Transportation Institute.

Table A-3. Differences in Mean Travel Times Approaching the LWC by Time Intervals within the Peak Period

Time Interval	Difference in Pre- and Post-Deployment Mean Travel Times (minutes)													
	I-405 GP		I-405 HOV		I-405 GP		I-405 HOV		I-5		I-5		I-90	
	SR 522 to SR 520				I-90 to SR 169				SR 522 to SR 520*		I-90 and Boeing Field*		I-405 and Issaquah*	
	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	EB	WB
A.M. Peak														
6:00 - 6:30 a.m.	0.01	0.82	-0.72	0.11	1.48	-0.05	0.03	0	0	0.07	0.56	-0.01	0	-0.1
6:30 - 7:00 a.m.	0.01	1.24	-0.55	0.29	2.34	-1.26	0.34	0.01	-0.01	-0.01	2.22	-0.03	0	-0.1
7:00 - 7:30 a.m.	0.04	1.57	-0.37	0.64	3.54	-1.31	0.65	0.05	-0.01	-0.52	2.99	-0.02	-0.01	0.14
7:30 - 8:00 a.m.	0.14	2.37	-0.36	1.53	4.31	-1.77	1.43	0.02	0.04	-1.83	2.8	-0.05	-0.01	0.24
8:00 - 8:30 a.m.	0.19	2.48	-0.41	1.69	4.31	-1.34	0.93	0.12	0.03	-1.62	3.43	0	-0.01	-0.12
8:30 - 9:00 a.m.	0.08	2.77	-0.22	1.40	3.88	-1.54	0.39	0.01	0.02	-1.82	3.29	0.02	-0.01	-0.11
9:00 - 9:30 a.m.	-0.05	2.36	-0.31	0.69	2.52	-0.44	0.12	0	0.01	-1.28	2.4	-0.02	-0.01	-0.08
9:30 - 10:00 a.m.	0.00	1.38	-0.31	0.44	1.87	-0.33	0.08	0	0.02	-0.83	1.46	-0.01	-0.02	-0.13
P.M. Peak														
3:30 - 4:00 p.m.	6.32	0.33	1.10	0.50	1.8	-0.09	0.14	0.44	0.28	3.69	0.11	-0.14	0	-0.1
4:00 - 4:30 p.m.	5.27	0.38	1.44	0.74	1.7	0.33	0.14	0.65	0.35	5.15	0.3	-0.1	-0.08	-0.02
4:30 - 5:00 p.m.	4.72	0.56	1.99	1.07	2.05	1.18	0.15	0.99	0.76	5.94	1.28	0.12	-0.12	0.02
5:00 - 5:30 p.m.	4.50	0.60	1.91	1.21	1.75	1.27	0.18	1	1	5.59	1.61	0.14	-0.19	-0.04
5:30 - 6:00 p.m.	4.91	0.50	1.65	1.17	1.55	1.18	0.15	0.98	0.72	4.77	0.96	0.11	-0.23	-0.13
6:00 - 6:30 p.m.	6.15	0.23	1.62	0.53	0.93	1.22	0.06	0.85	0.5	3.82	-0.09	0.11	-0.12	-0.13
6:30 - 7:00 p.m.	5.42	-0.08	0.74	0.05	0.06	1.62	0	0.69	0.17	2.09	-0.47	0.21	0	-0.14

Note: Shaded cells represent statistically significant differences at a 95 percent confidence level.

Note: Negative values represent reductions in travel times and positive values represent increases in travel times.

Source: Texas A&M Transportation Institute

***General Purpose Lanes Only**

A.3.2 Mean Travel Speeds

The mean peak-period travel speeds on the various facilities were also analyzed for the pre- and post-deployment periods. The results of this analysis are presented in Figure A-9 through Figure A-12 and highlighted in this section. The results reflect similar trends as the mean travel times, with conditions on SR 520 improving through faster travel speeds in the post-deployment period, and conditions worsening on many of the other facilities due to slower travel speeds.

As illustrated in Figure A-9, the mean travel speeds on SR 520 increased from approximately 45 mph to 56 mph in eastbound direction in the morning peak period and from approximately 47 mph to 58 mph in the westbound direction. During the afternoon peak period, the mean travel speeds increased from approximately 47 mph to 60 mph in the eastbound direction and from 27 mph to approximately 45 mph in the westbound direction.

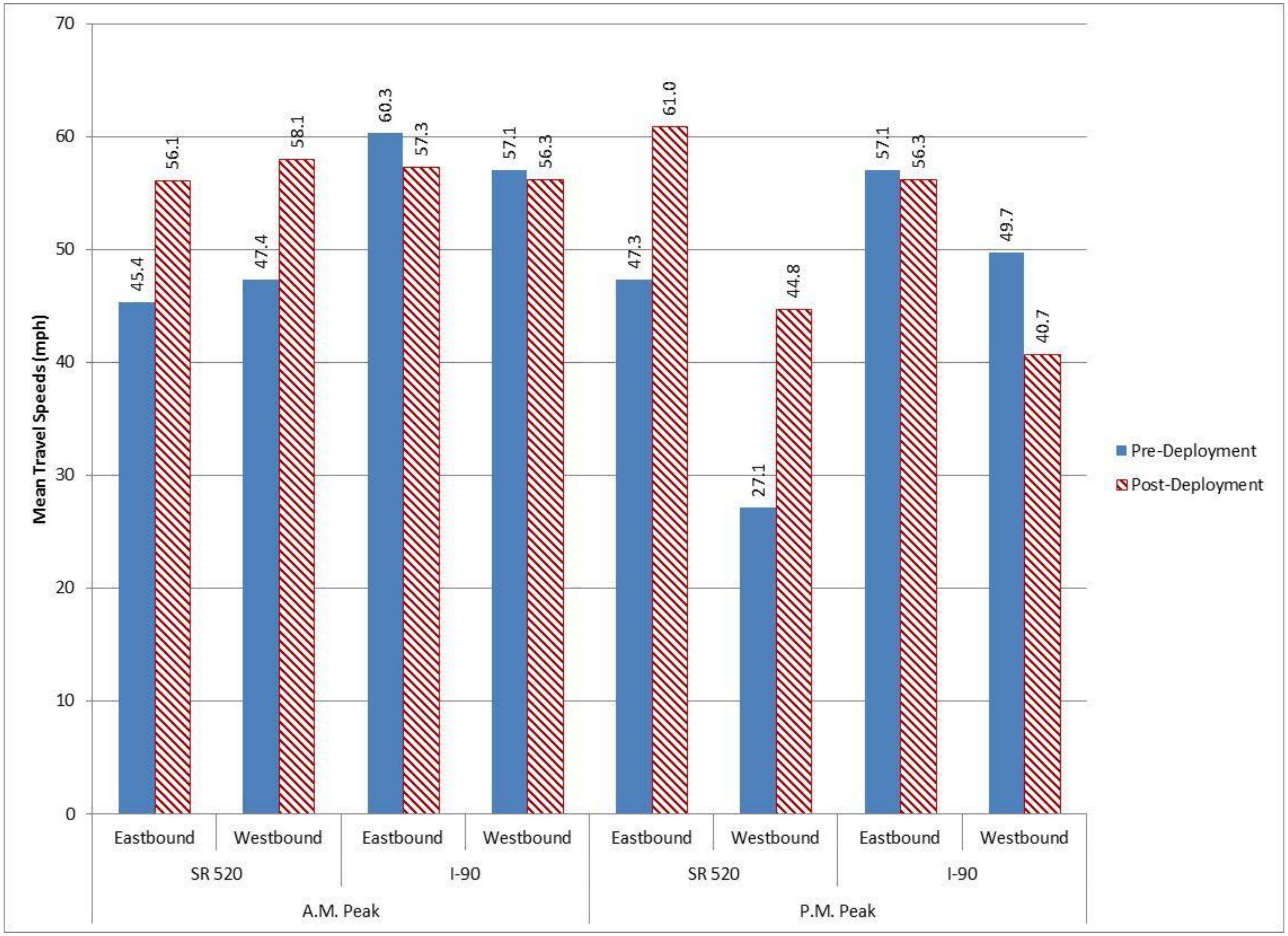
While travel speeds on SR 520 increased, peak-period travel speeds on I-90 declined in both directions of travel in the post-deployment period. In the morning peak period, travel speeds declined from approximately 60 mph to 57 mph in the eastbound direction and from 57 mph to 56 mph in the westbound direction. In the afternoon peak period, the mean travel speeds declined from approximately 57 mph to 56 mph in the eastbound direction and from almost 50 mph to almost 41 mph in the westbound direction. The faster travel speeds on SR 520 and the lower travel speeds on I-90 indicate a shift in use patterns in the post-deployment period. The lower travel speeds suggest that congestion increased on I-90 during the post-deployment period.

As illustrated in Figure A-10, mean travel speeds on I-5 between I-405 and SR 522 increased by approximately 1 mph in the morning peak period in the northbound direction of travel, but decreased by almost 5 mph in the southbound direction. The afternoon mean peak-period travel speeds on I-5 increased by almost 3 mph in the northbound direction, but decreased by 10 mph in the southbound direction. Morning mean peak-period travel speeds in the I-405 general purpose freeway lanes between SR 169 and SR 522 increased by 7 mph in the northbound direction and remained constant in the southbound direction. In the afternoon peak period, the mean travel speeds in the I-405 general purpose freeway lanes increased from approximately 49 mph to 57 mph in the northbound direction and decreased from 25 mph to approximately 18 mph in the southbound direction. Mean travel speeds in the I-405 HOV lanes remained relatively constant at approximately 65 mph in both directions of travel in the morning peak period. In the afternoon peak period, mean travel speeds in the HOV lanes remained relatively constant at approximately 63 mph in the southbound direction and decreased from approximately 51 mph to 39 mph in the southbound direction.

As illustrated in Figure A-11, the morning mean peak-period travel speeds on I-5 from Boeing Field to I-90 decreased by 7 mph in the general purpose freeway lanes and by almost 9 mph in the HOV lane in the northbound direction. The mean travel speeds in the general purpose freeway lanes remained constant in the southbound direction. Mean travel speeds in the afternoon peak period remained approximately the same for the general purpose freeway lanes in both the northbound and southbound direction and in the HOV lanes in the northbound direction. Pre-deployment data were not available for the southbound HOV lanes in either the morning or afternoon peak periods.

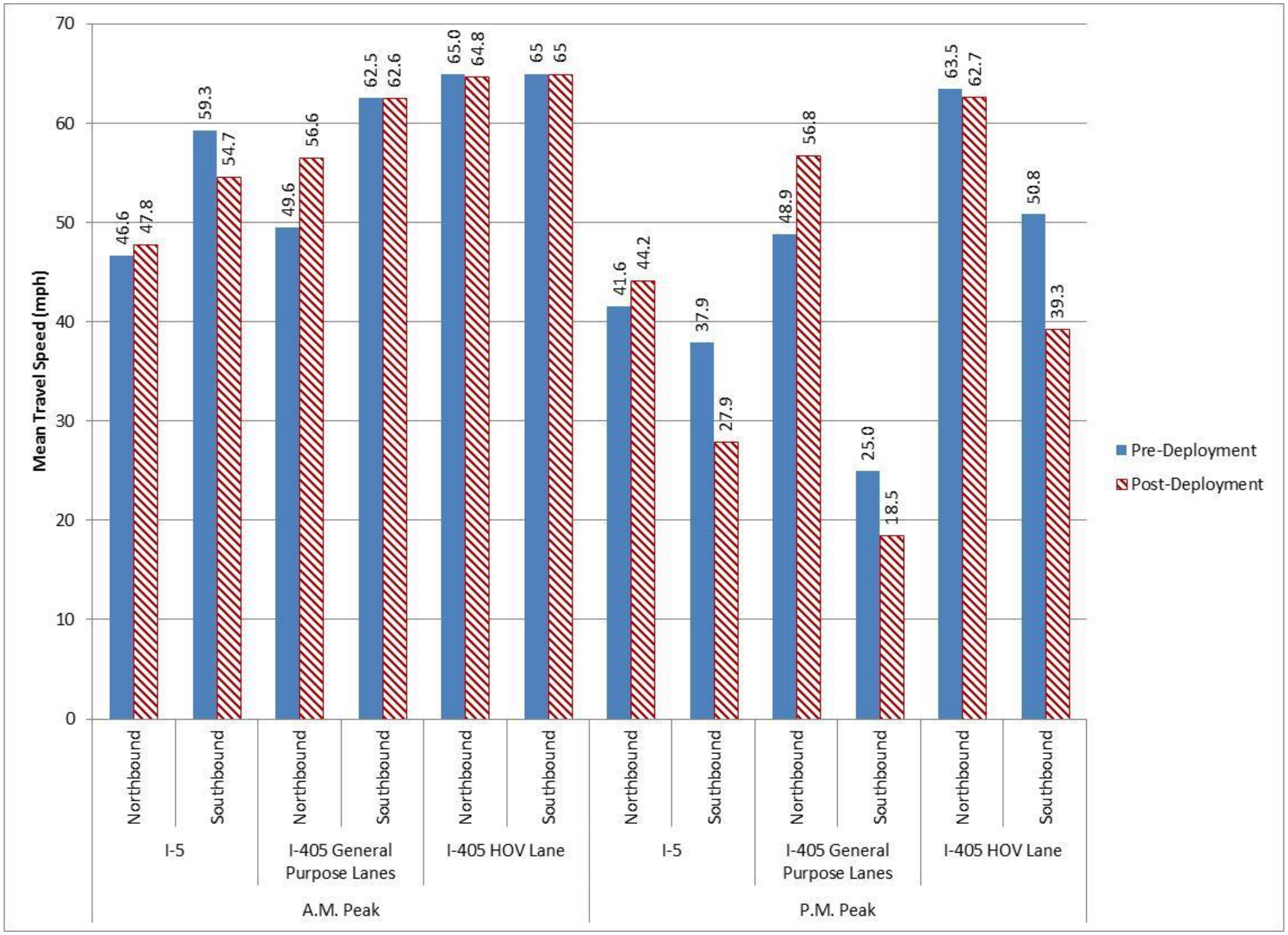
As shown in Figure A-11, the morning mean peak-period travel speeds on I-5 from SR 520 to SR 522 remained the same in the northbound direction and increased by approximately 5 mph in the southbound direction. The afternoon mean peak-period travel speeds decreased by approximately 5 mph in the northbound direction and by approximately 14 mph in the southbound direction.

Figure A-12 presents the changes in mean peak-period travel speeds on I-90 from I-405 to Issaquah and I-405 from SR 169 to I-90. The mean travel speeds for the I-90 general purpose freeway lanes and HOV lanes remained relatively constant in both directions of travel in both peak periods. The morning mean peak-period travel speeds in the I-405 general purpose freeway lanes decreased by 6 mph in the northbound direction and increased by 5 mph in the southbound direction. The morning mean travel speeds in the HOV lanes decreased by approximately 4 mph in the northbound direction and remained constant in the southbound direction. In the afternoon peak period, mean travel speeds in the general purpose freeway lanes decreased by approximately 8 mph in the northbound direction and 2 mph in the southbound direction. The morning mean travel speeds in the HOV lanes decreased by 1 mph in the northbound direction and approximately 4 mph in the southbound direction.



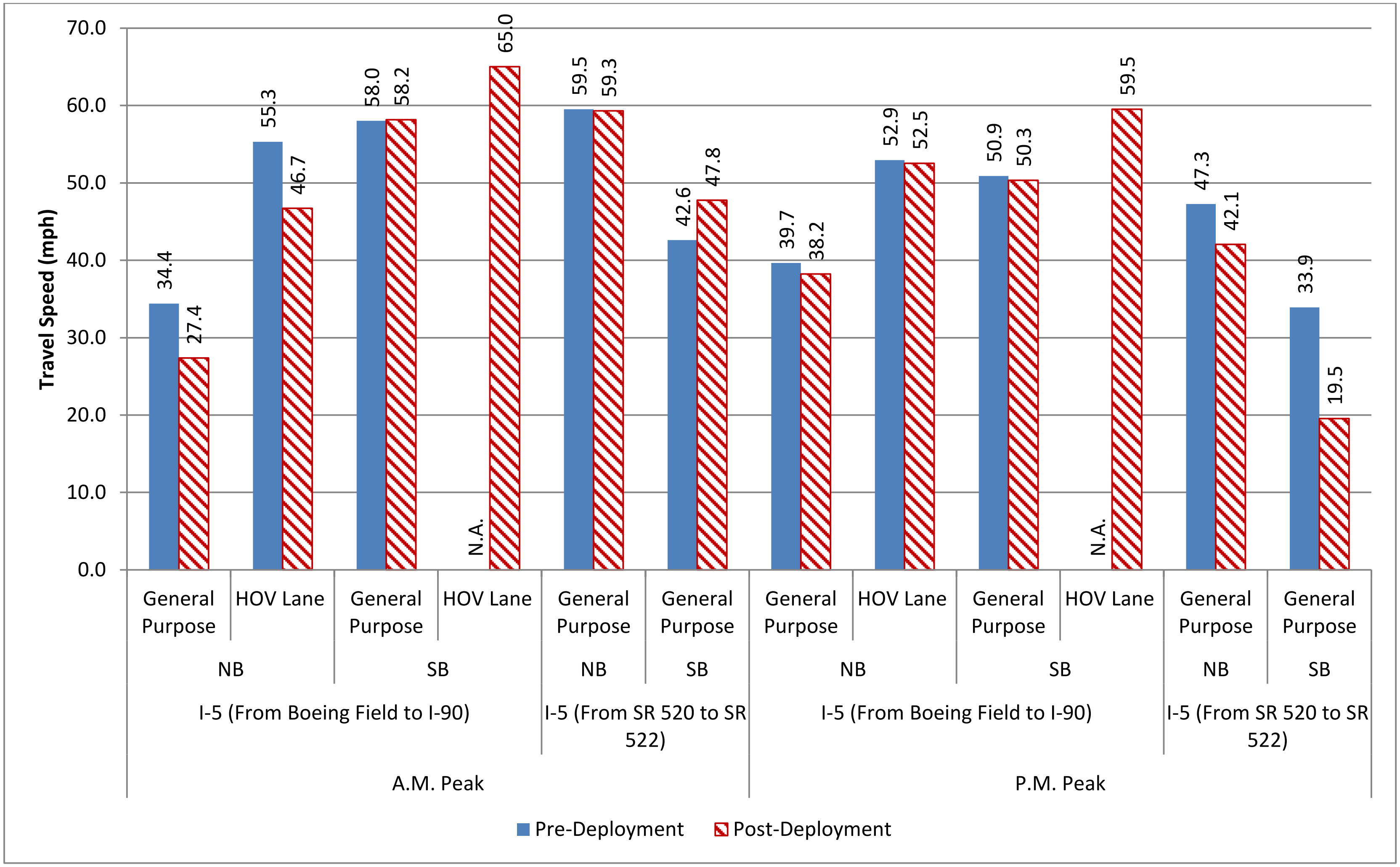
Source: Texas A&M Transportation Institute.

Figure A-9. Mean Peak Period Travel Speeds (in mph) on SR 520 and I-90 for the A.M. and P.M. Peak Periods



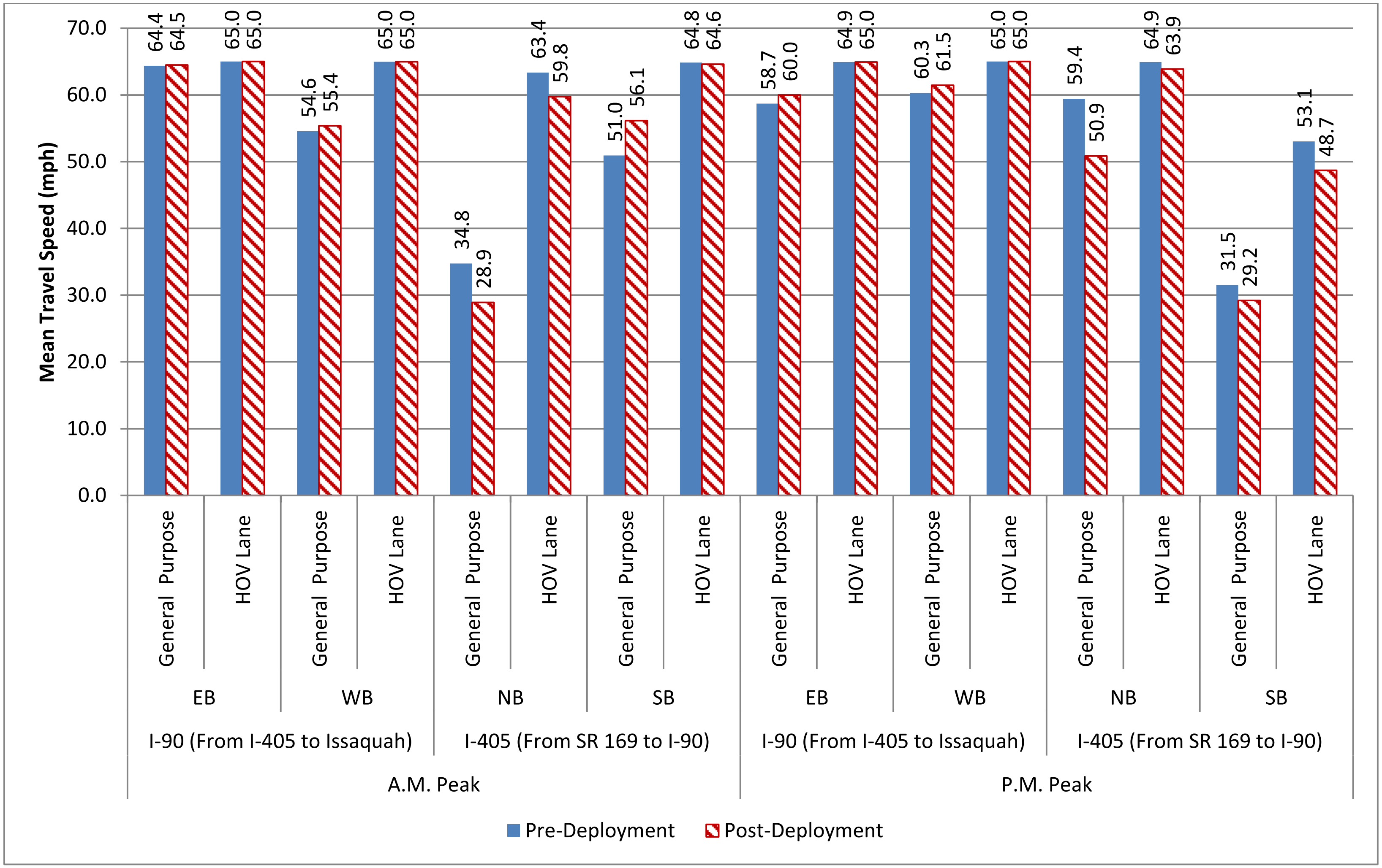
Source: Texas A&M Transportation Institute.

Figure A-10. Mean Peak Period Travel Speeds (in mph) on I-5 and I-405 between SR 520 and I-90 for the A.M. and P.M. Peak Periods



Source: Texas A&M Transportation Institute.

Figure A-11. Mean Peak Period Travel Speeds (in mph) on I-5 Approaching the LWC for the A.M. and P.M. Peak Periods



Source: Texas A&M Transportation Institute.

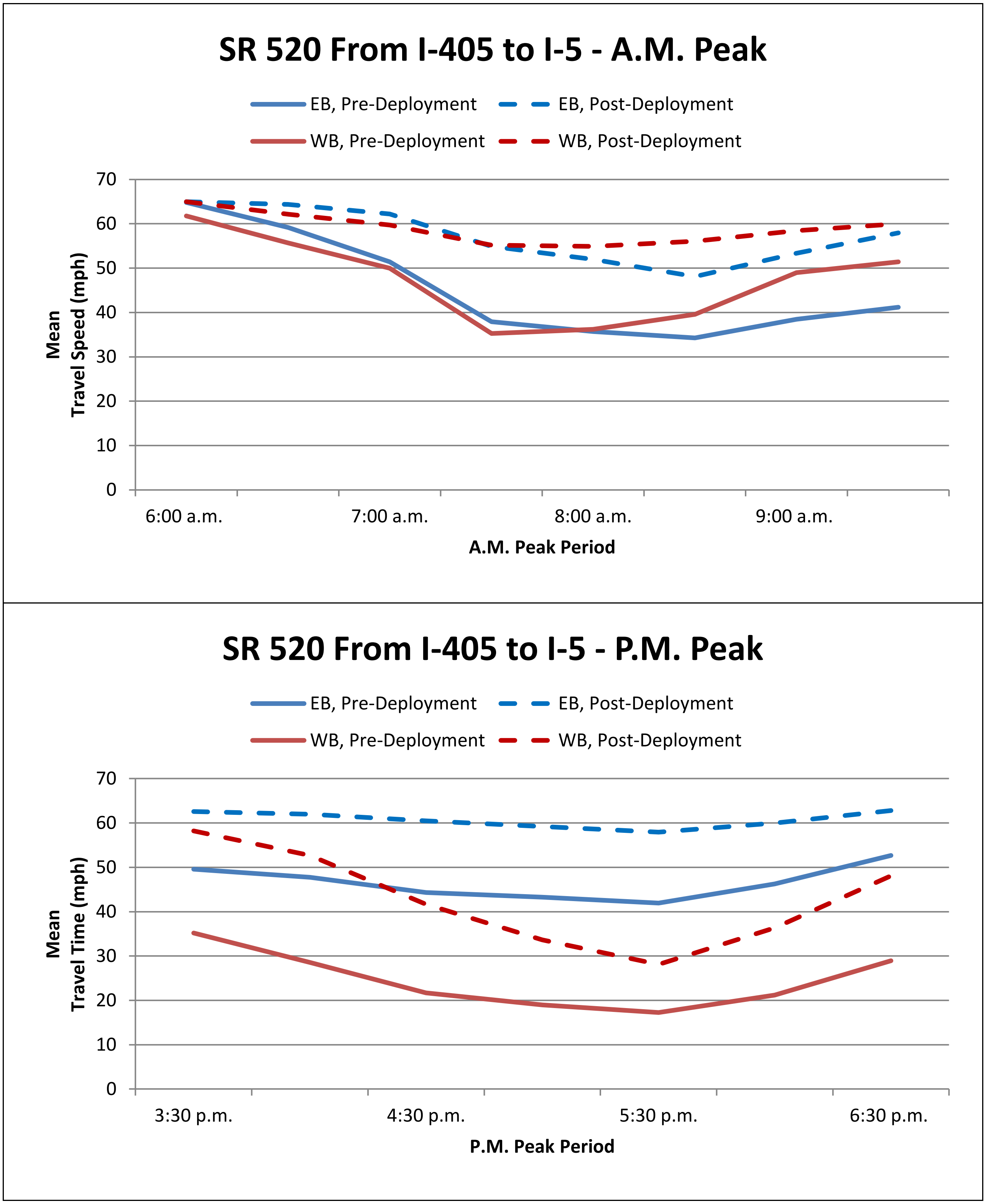
Figure A-12. Mean Peak Period Travel Speeds (in mph) on I-5 Approaching the LWC during the A.M. and P.M. Peak Periods

The national evaluation team also examined changes in travels speed throughout the duration of the peak period as a result of implementing the UPA improvements. Figure A-13 shows how mean travel speeds on SR 520 changed in both the a.m. and p.m. peak periods and Figure A-14 illustrates a similar comparison for travel speeds on I-90.

The mean travel speeds on SR 520 remained above 45 mph in both directions of travel throughout the entire morning peak period in the post-deployment period. In the pre-deployment period, the mean travel speeds dropped below 45 mph for a major portion of the morning peak period. Travel speeds in both directions of travel on SR 520 were substantially higher throughout the entire duration of the afternoon peak period, compared to the pre-deployment period, although speeds are not as high as the morning peak period.

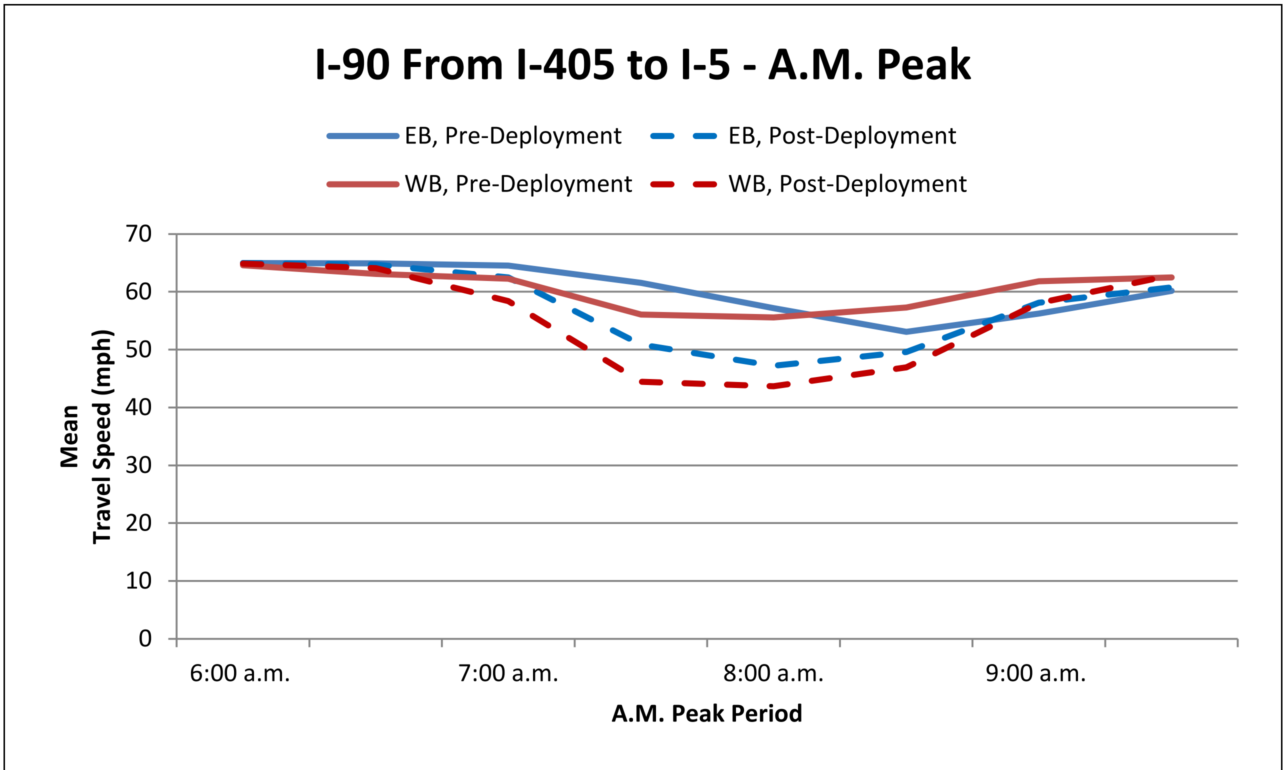
Figure A-13 illustrates a reduction mean travel speeds in both directions of travel on I-90 beginning around 7:00 a.m. and lasting until 9:00 a.m. in the post-deployment period. In the afternoon peak period, travel speeds are lower and dropped substantially much earlier in the post-deployment period – around 4:30 p.m. – compared to the speed profile for the pre-deployment period.

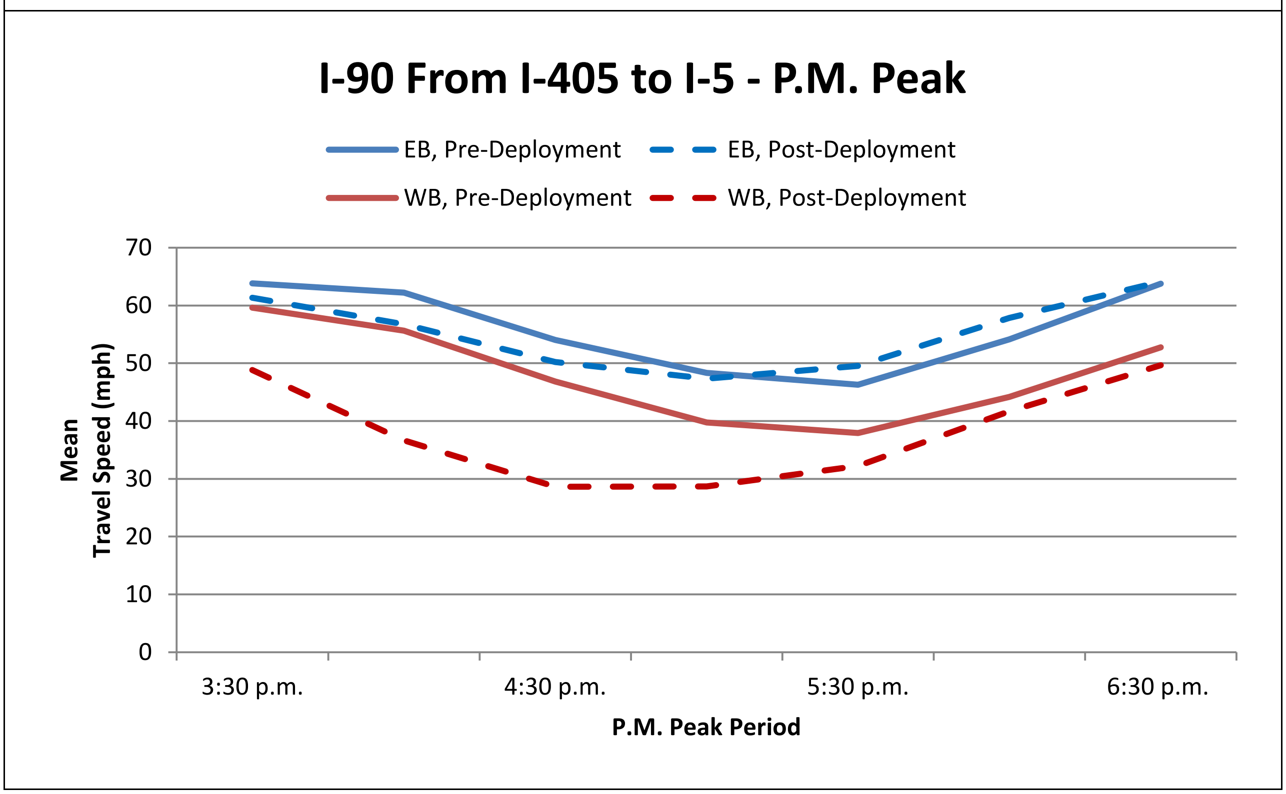
As with travel times, the national evaluation team performed a statistical comparison of difference in mean travel speeds on all of the evaluation corridors. The results of these statistical analyses are summarized in Table A-4 and Table A-5.



Source: Texas A&M Transportation Institute.

Figure A-13. Pre-and Post-Deployment Average Travel Speeds for SR 520 General Purpose Lanes from I-405 to I-5





Source: Texas A&M Transportation Institute.

Figure A-14. Pre-and Post-Deployment Average Travel Speeds for I-90 General Purpose Lanes from I-405 to I-5

Table A-4. Difference in Pre- and Post-Deployment on Travel Speeds in the SR 520/I-90 Corridor by Time Intervals within the Peak Period

Time Interval	Difference in Pre- and Post-Deployment Travel Speed (mph)									
	SR 520		I-90		I-5		I-405 GP		I-405 HOV	
	From I-405 to I-5				From SR 520 and I-90					
	EB	WB	EB	WB	NB	SB	NB	SB	NB	SB
A.M. Peak										
6:00 - 6:30 a.m.	0.7	3.5	-0.0	0.3	-0.6	0.7	1.0	0.6	0.0	0.
6:30 - 7:00 a.m.	5.5	6.6	-0.4	0.0	-0.6	0.9	1.4	0.3	0.1	0.0
7:00 - 7:30 a.m.	10.7	9.6	-3.1	-5.4	-2.6	-1.7	0.9	-0.1	-0.13	0.0
7:30 - 8:00 a.m.	15.3	18.1	-10.4	-10.9	-1.1	-9.8	4.8	-1.5	-0.5	0.0
8:00 - 8:30 a.m.	13.9	16.5	-9.3	-10.7	1.9	-9.6	7.8	-1.0	-0.4	0.0
8:30 - 9:00 a.m.	10.9	15.2	-3.0	-8.9	5.2	-8.5	10.8	-0.6	-0.8	0.0
9:00 - 9:30 a.m.	12.2	10.0	2.1	-4.2	3.2	-3.4	13.5	-0.5	-0.8	-0.0
9:30 - 10:00 a.m.	14.8	9.9	1.4	-1.2	2.7	-2.5	11.7	0.1	-1.1	0.0
P.M. Peak										
3:30 - 4:00 p.m.	13.0	22.0	-4.9	-2.7	-2.5	-6.4	13.7	-11.3	2.0	-8.9
4:00 - 4:30 p.m.	14.3	21.8	-6.5	-10.0	-1.7	-7.0	11.2	-8.7	1.0	-11.0
4:30 - 5:00 p.m.	15.8	18.6	-4.3	-15.6	0.9	-7.5	6.3	-5.2	-1.6	-11.8
5:00 - 5:30 p.m.	15.2	13.8	-2.0	-14.8	2.0	-10.4	4.3	-3.0	-3.4	-13.1
5:30 - 6:00 p.m.	15.3	10.6	1.6	-8.8	2.6	-10.7	0.3	-1.5	-4.8	-12.1
6:00 - 6:30 p.m.	13.4	13.6	3.0	-4.4	3.6	-14.2	0.9	-1.0	-1.6	-10.4
6:30 - 7:00 p.m.	10.2	16.6	0.4	-1.4	2.8	-14.6	4.1	-5.5	-0.12	-7.4

Note: Shaded cells represent statistically significant differences at a 95 percent confidence level.

Note: Negative values represent reductions in travel times and positive values represent increases in travel times.

Source: Texas A&M Transportation Institute.

Table A-5. Differences in Average Travel Speeds Approaching the LWC by Time Intervals within the Peak Period

Time Interval	Difference in Pre- and Post-Deployment Mean Travel Speeds (mph)													
	I-405 GP		I-405 HOV		I-405 GP		I-405 HOV		I-5		I-5		I-90	
	SR 522 to SR 520				I-90 to SR 169				SR 522 to SR 520		I-90 and Boeing Field		I-405 and Issaquah	
	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	EB	WB
A.M. Peak														
6:00 - 6:30 a.m.	-0.04	-3.43	2.25	-0.45	-7.55	0.52	-0.25	0	0	-1.69	-5.41	0.09	0	1.43
6:30 - 7:00 a.m.	0.02	-3.59	1.54	-1.84	-5.89	7.9	-2.91	-0.05	0.29	0.12	-9.34	0.47	0.02	1.45
7:00 - 7:30 a.m.	-0.14	-3.50	1.17	-3.68	-5.72	6.52	-5.04	-0.48	0.18	5.9	-10.06	0.23	0.08	-1.19
7:30 - 8:00 a.m.	-0.87	-3.25	1.03	-5.56	-4.75	6.17	-8.82	-0.2	-0.77	9.88	-5.62	0.48	0.19	-1.19
8:00 - 8:30 a.m.	-0.91	-3.19	1.27	-6.25	-5.76	6.69	-6.7	-0.98	-0.63	5.73	-6.34	-0.04	0.16	1.68
8:30 - 9:00 a.m.	-0.51	-3.73	0.95	-5.68	-5.92	8.67	-3.25	-0.09	-0.45	6.16	-6.56	-0.26	0.1	1.25
9:00 - 9:30 a.m.	0.14	-4.28	1.33	-3.36	-5.84	2.92	-1.07	0	-0.09	8.16	-7.46	0.21	0.11	1.18
9:30 - 10:00 a.m.	0.00	-2.58	1.08	-2.18	-5.31	2.19	-0.76	0	-0.24	6.89	-5.37	0.13	0.33	1.89
P.M. Peak														
3:30 - 4:00 p.m.	-12.95	-1.39	-4.38	-2.49	-10.92	-0.13	-1.24	-2.54	-1.98	-10.08	0.39	1.32	0.11	1.51
4:00 - 4:30 p.m.	-8.38	-1.75	-4.19	-3.29	-10.43	-0.85	-1.22	-3.22	-2.65	-12.92	-0.31	0.92	1.05	0.45
4:30 - 5:00 p.m.	-6.48	-2.22	-5.05	-4.00	-12.23	-2.39	-1.43	-5.12	-6.15	-14.73	-3.14	-1.1	1.56	-0.22
5:00 - 5:30 p.m.	-6.27	-2.18	-4.77	-4.26	-10.3	-2.53	-1.63	-5.18	-8.69	-16.56	-5.04	-1.33	2.33	0.62
5:30 - 6:00 p.m.	-7.34	-1.94	-3.71	-4.29	-9.53	-2.39	-1.38	-5.1	-7.78	-16.55	-3.53	-0.81	2.61	1.82
6:00 - 6:30 p.m.	-13.16	-1.03	-5.81	-2.27	-6.14	-2.76	-0.49	-4.86	-6.47	-17.32	-0.56	-0.87	1.35	1.96
6:30 - 7:00 p.m.	-16.07	0.10	-3.70	-0.52	-0.4	-5.37	0	-4.41	-2.76	-12.38	3.38	-2.18	-0.05	2.08

Note: Shaded cells represent statistically significant differences at a 95 percent confidence level.

Note: Negative values represent reductions in travel times and positive values represent increases in travel times.

Source: Texas A&M Transportation Institute.

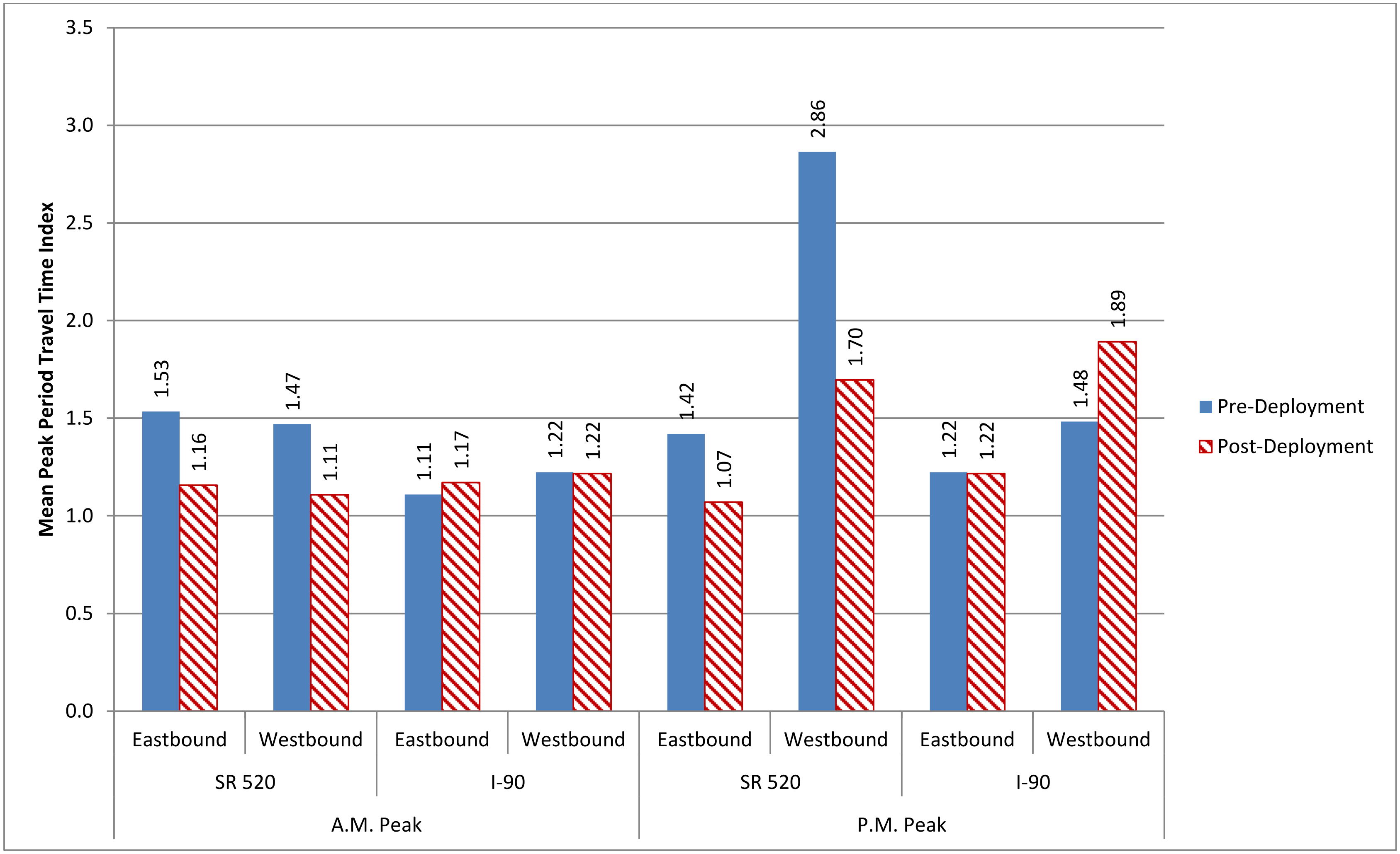
A.3.3 Travel Time Index

The Travel Time Index is another measure that is frequently used to assess the extent to which changes in a corridor impact travel time. The Travel Time Index is the ratio of the median travel time during peak periods to the free-flow travel time (i.e., the time it would take to traverse the same distance traveling at the speed limit). The Travel Time Index is used to assess how much more time a trip takes during the peak periods as opposed to the same trip if it occurred during non-peak travel periods. As an example, a Travel Time Index of 1.20 means that a trip during the peak period takes 20 percent longer than the same trip if it was made during free-flow periods.

Figure A-15 through Figure A-18 presents a comparison of the pre- and post-deployment Travel Time Indices for SR 520, I-90, and other facilities for both the morning and afternoon peak periods. The Travel Time Indices for SR 520 were reduced substantially during both the morning and afternoon peak periods in both directions of travel. The Travel Times Indices on SR 520 in the eastbound direction in the a.m. peak were only 1.16 and 1.11 times longer than free-flow travel times after tolling of the SR 520 bridge, compared to being almost 1.5 times longer prior to deploying the UPA improvements – a 37 percent reduction. In the afternoon peak, the Travel Time Index for eastbound traffic on SR 520 improved from 1.42 to 1.07 – a 35 percent improvement. For westbound traffic, the change was much more substantial. Travel in the westbound direction on SR 520 took nearly 3 times as long during the p.m. peak compared to the same trip occurring during free-flow conditions, in the pre-deployment period. In the post-deployment period, traveling on SR 520 took 1.7 times longer – a 116 percent degradation in performance.

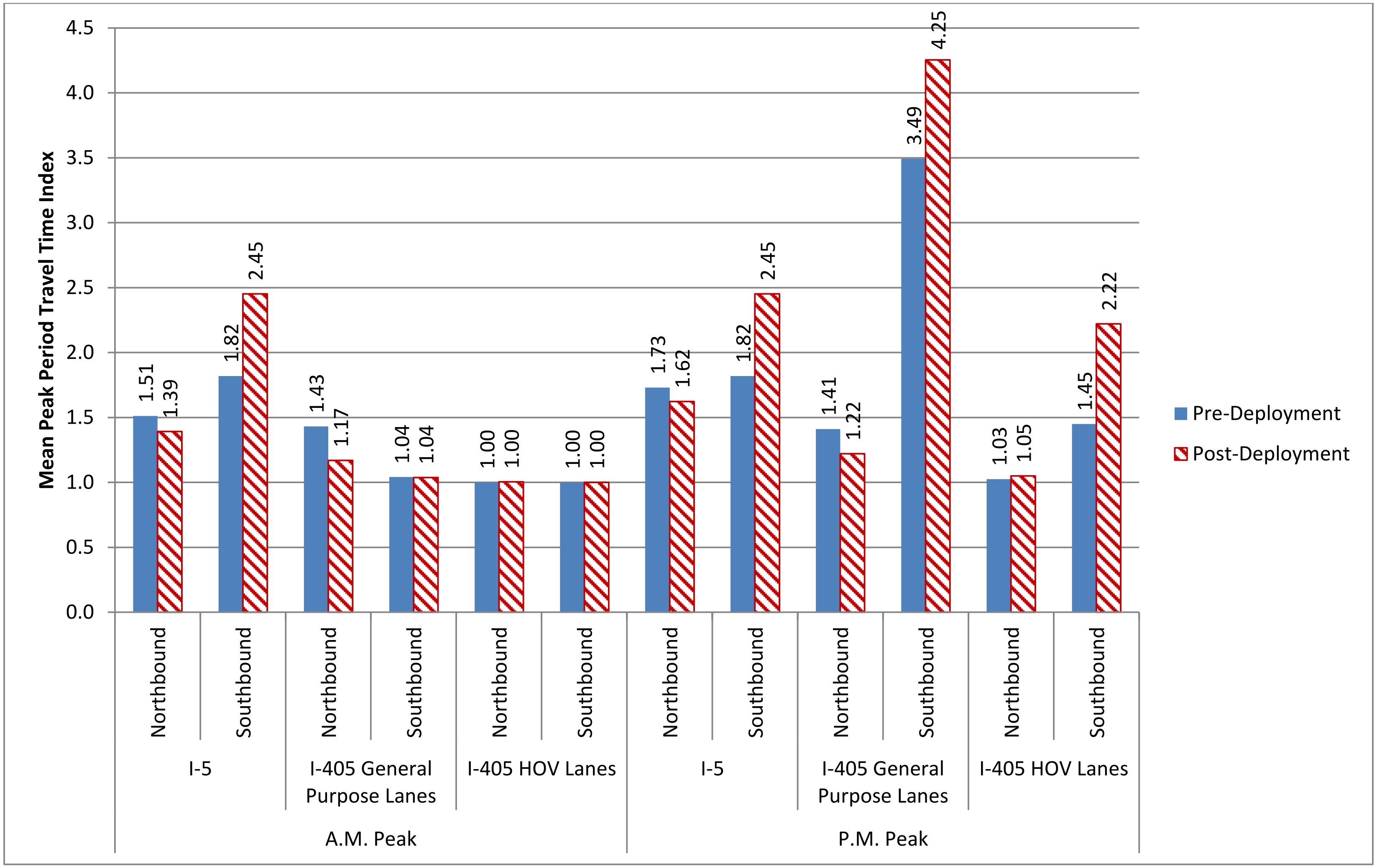
While the Travel Time Index improved substantially on SR 520, it increased or remained the same on other roadways. The Travel Time Index for eastbound traffic on I-90 in the morning peak increased from 1.11 to 1.17 – a 6 percent increase. In the afternoon peak period, the Travel Time Index increased from 1.47 to 1.89 in the post-deployment period – indicating that travel times were nearly two times longer.

As presented in Figure A-16 through Figure A-18, the Travel Time Index also increased on some facilities and remained relatively constant on others. Freeway segments experiencing the largest increases in the Travel Time Index included I-5 from SR 520 to SR 522 in the afternoon peak period in the southbound direction – an increase from 2.34 to 4.10 – and the I-405 general purpose freeway lanes – 3.49 to 4.25 – and HOV lane – 1.45 to 2.22 – in the southbound direction in the afternoon peak period. Other facilities experienced slight increases or no changes, with a few experiencing slight decreases.



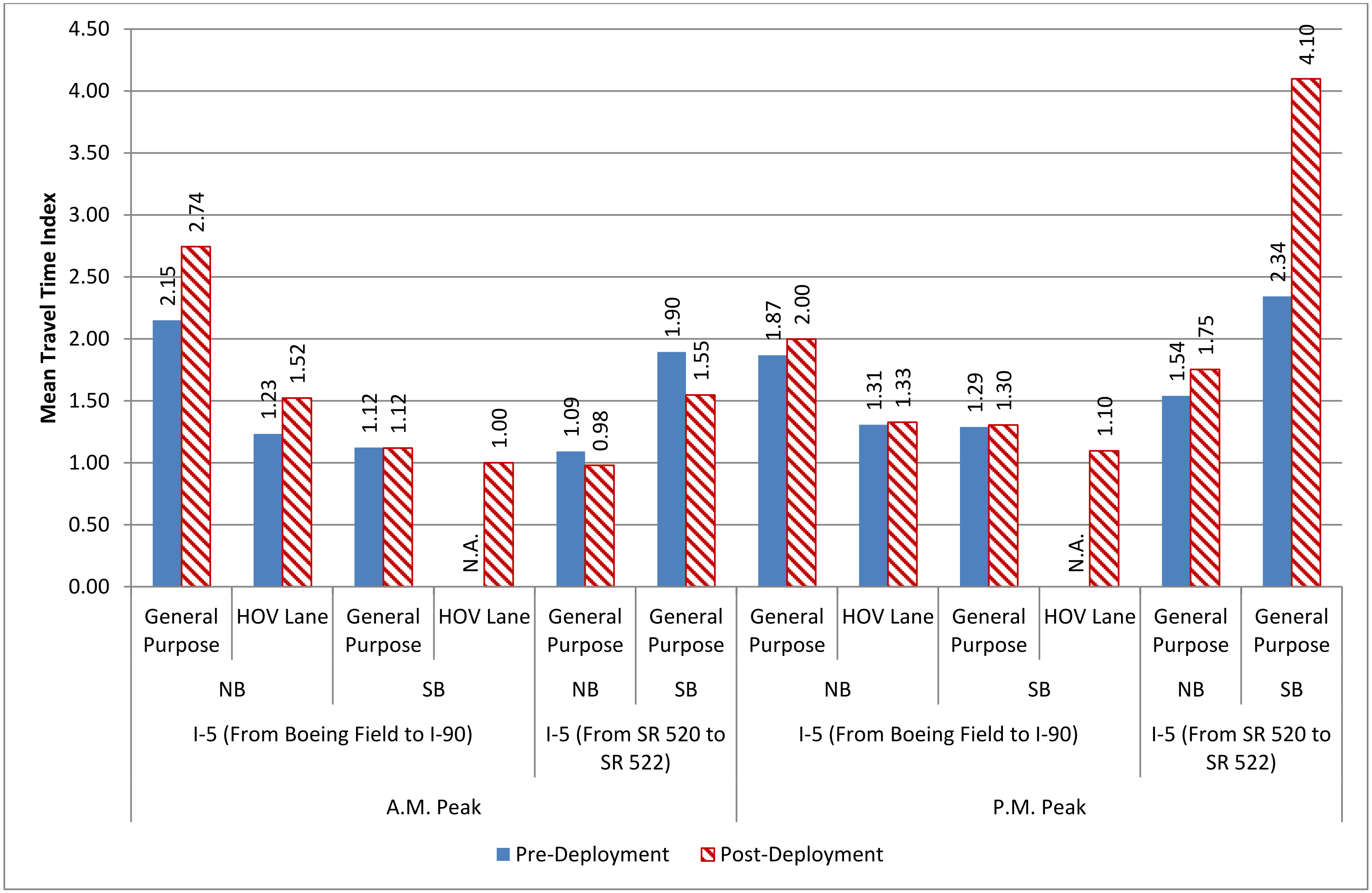
Source: Texas A&M Transportation Institute.

Figure A-15. Travel Time Indices on SR 520 and I-90 for the A.M. and P.M. Peak Periods



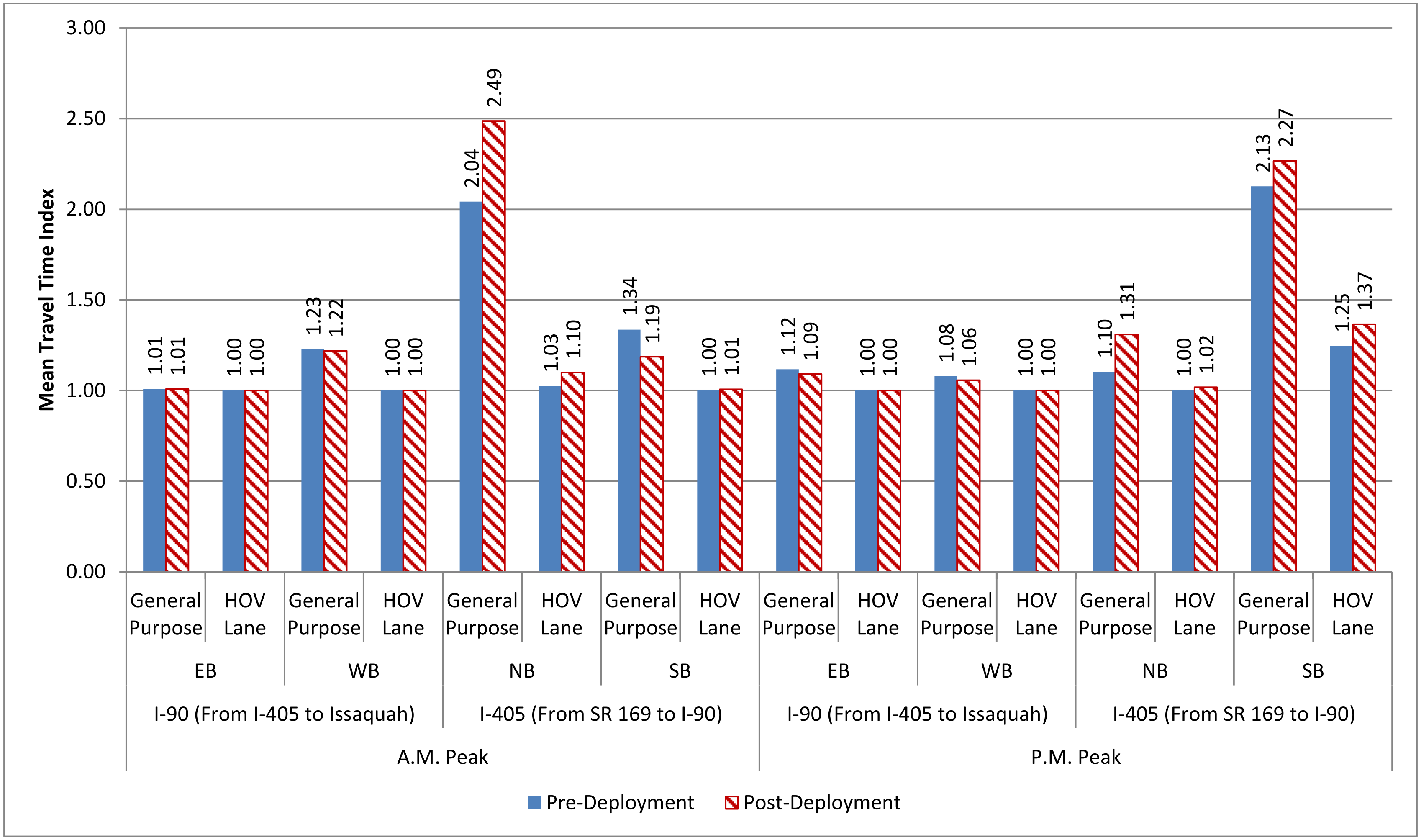
Source: Texas A&M Transportation Institute.

Figure A-16. Travel Time Indices on I-5 and I-405 between SR 520 and I-90 for the A.M. and P.M. Peak Periods



Source: Texas A&M Transportation Institute.

Figure A-17. Travel Time Indices on I-5 Approaching the LWC for the A.M. and P.M. Peak Periods



Source: Texas A&M Transportation Institute.

Figure A-18. Travel Time Indices on I-90 and I-405 Approaching the LWC for the A.M. and P.M. Peak Periods

A.4 Travel Time Reliability

Travel-time reliability is a measure of the level of consistency in travel conditions over time. It is often used to assess how travel conditions and congestion vary over a substantial period of time. Travel-time reliability is often synonymous with travel-time predictability. Travelers often adjust their travel behaviors and expectations to accommodate expected levels of congestions.

The 95th percentile travel time and the Buffer Index are often used as measures of travel reliability. The 95th percentile travel time represents the worst travel time that a traveler would expect to experience during the “heaviest” traffic day. The Buffer Index represents the extra time, or time cushion, travelers need to add to their average trip time to ensure an on time arrival. An increase in the 95th percentile travel time or the Buffer Index indicates that travel time in a corridor has become less reliable, while a decrease in these values signify an improvement in travel time reliability.

A.4.1 95th Percentile Travel Times

Figure A-19 through Figure A-22 illustrate the changes in the 95th percentile travel times for SR 520, I-90, and the other freeways in the area for the morning and afternoon peak periods in both directions of travel. Table A-6 and Table A-7 present similar information, along with the change and the percent change from the pre- to the post-deployment periods.

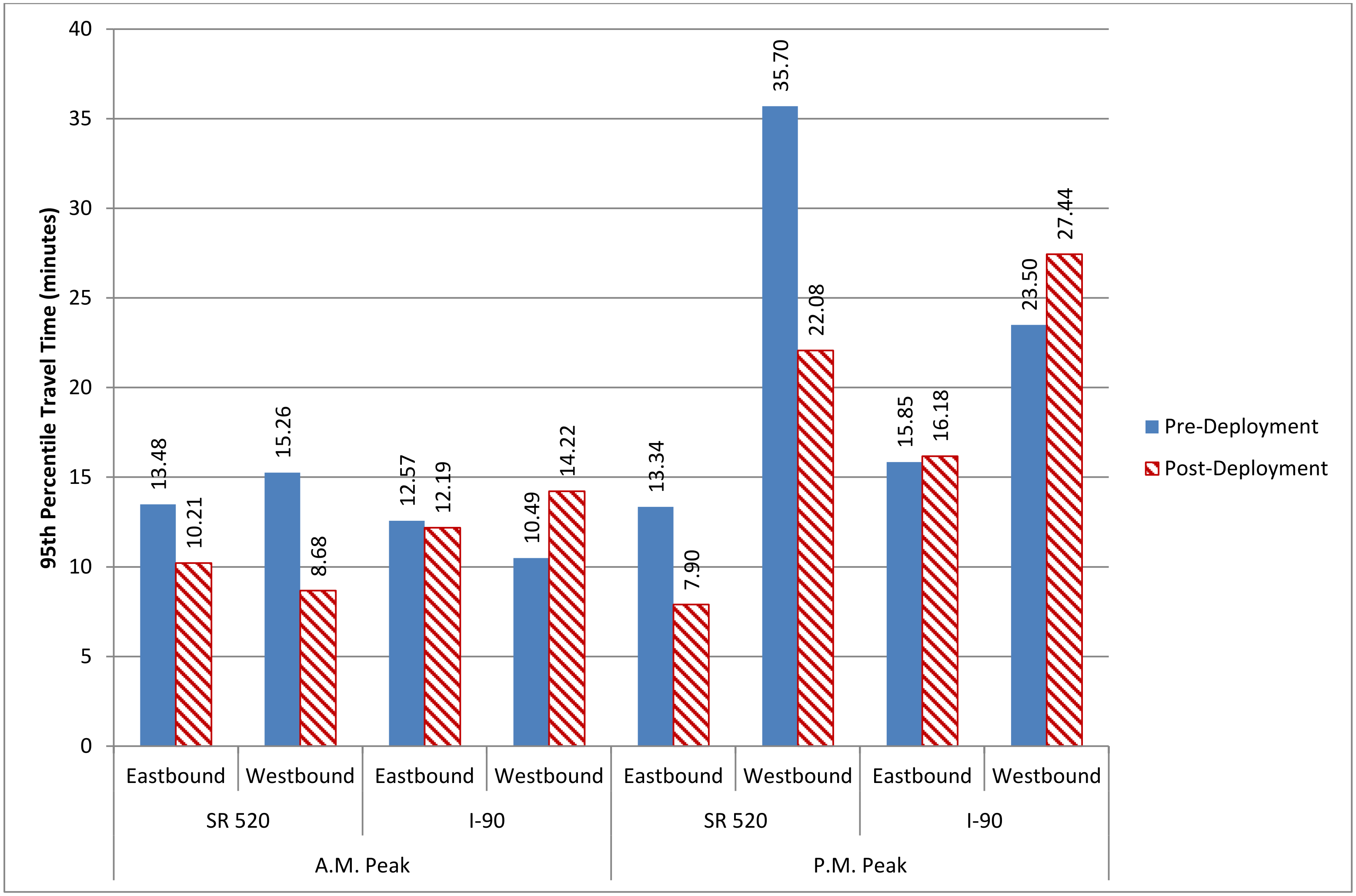
Figure A-19 illustrates the 95th percentile travel times for both directions of travel during the morning and afternoon peak periods for SR 520 and I-90 crossing Lake Washington. The morning peak period percentile travel time for the eastbound and westbound directions of travel on SR 520 declined by approximately 3 and 6 minutes, respectively. This change represents a 24 and 43 percent reduction in the 95th percentile travel time in the post-deployment period. In the afternoon peak period, the 95th percentile travel time changes were more dramatic for SR 520. The 95th percentile travel times on SR 520 declined by approximately 6 minutes in the eastbound direction and by over 13 minutes in the westbound direction, equating to declines of 40 and 38 percent, respectively.

In comparison, the 95th percentile travel times on I-90 during the morning peak period remained at approximately 12 minutes in the eastbound direction and increased from approximately 7 minutes to 15 minutes in the westbound direction. In the afternoon peak period, the 95th percentile on I-90 in the eastbound direction remained relatively unchanged at approximately 16 minutes in both the pre- and post-deployment periods. The largest change in 95th percentile travel time occurred for westbound traffic in the afternoon peak. During for this interval, the 95th percentile travel time increased from 23.5 minutes to 27.4 minutes, representing an approximate 17 percent increase.

Figure A-20 shows the 95th percentile travel times for both I-5 and I-405 between SR 520 and I-90. The 95th percentile travel time in general purpose lanes in the northbound direction remained the same or declined slightly in the post-deployment period on both I-5 and I-405 during both the morning and afternoon peak periods. During the morning peak period, the 95th percentile travel time in the general purpose lanes declined from almost 10 minutes to approximately 7 minutes on I-5. During the same time period, the 95th percentile travel times declined from almost 8 minutes to approximately 6 minutes for general purpose lanes on I-405. In the p.m. peak period, the 95th percentile travel times declined from approximately 13 minutes to 11.5 minutes on I-5. The 95th percentile travel time did not change substantially in the post-deployment period for either the general purpose lanes or the HOV lane during the afternoon peak.

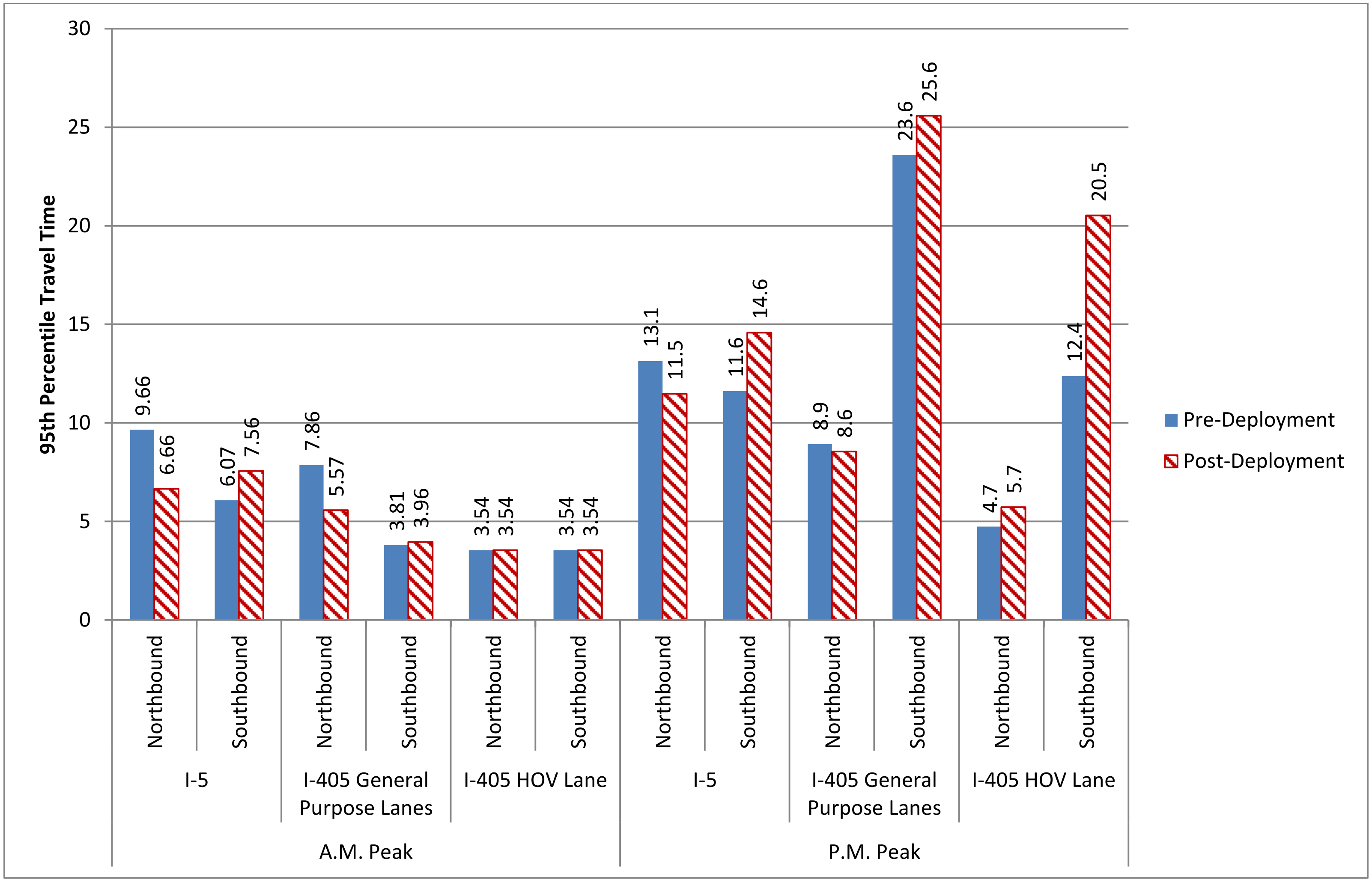
Figure A-21 presents the 95th percentile travel times for I-5 from Boeing Field to I-90 and from SR 520 to SR 522. Figure A-22 presents the same information for I-90 from I-405 to Issaquah and I-405 from SR 169 to I-90. On I-5 from Boeing Field to I-90, the morning peak-period 95th percentile travel time decreased slightly in the general purpose freeway lanes and increased slighted in the HOV lanes in the northbound direction. The 95th percentile travel time in the general purpose freeway lanes in the southbound direction remained approximately the same. In the afternoon peak-period, the 95th percentile travel time increased slightly in the general purpose freeway lanes in the southbound direction and decreased slightly in the HOV lane. The 95th percentile travel time in the northbound direction remained approximately the same.

On I-5 from SR 520 to SR 522, the 95th percentile travel times in the morning peak period remained the same in the northbound direction and decreased slightly in the southbound direction. In the afternoon peak period, the 95th percentile travel times increased in both the northbound and southbound directions, with the southbound direction increasing from 12.44 minutes to 17.47 minutes. As highlighted in Figure A-22, the 95th percentile travel times remained relatively constant on the I-90 general purpose freeway lanes and HOV lanes from I-405 to Issaquah in the morning and afternoon peak periods in both directions of travel. The 95th percentile travel times on I-405 from SR 169 to I-90 increased in both the general-purpose freeway lanes and the HOV lanes in the morning and afternoon peak periods in the northbound direction, but declined in the southbound direction.



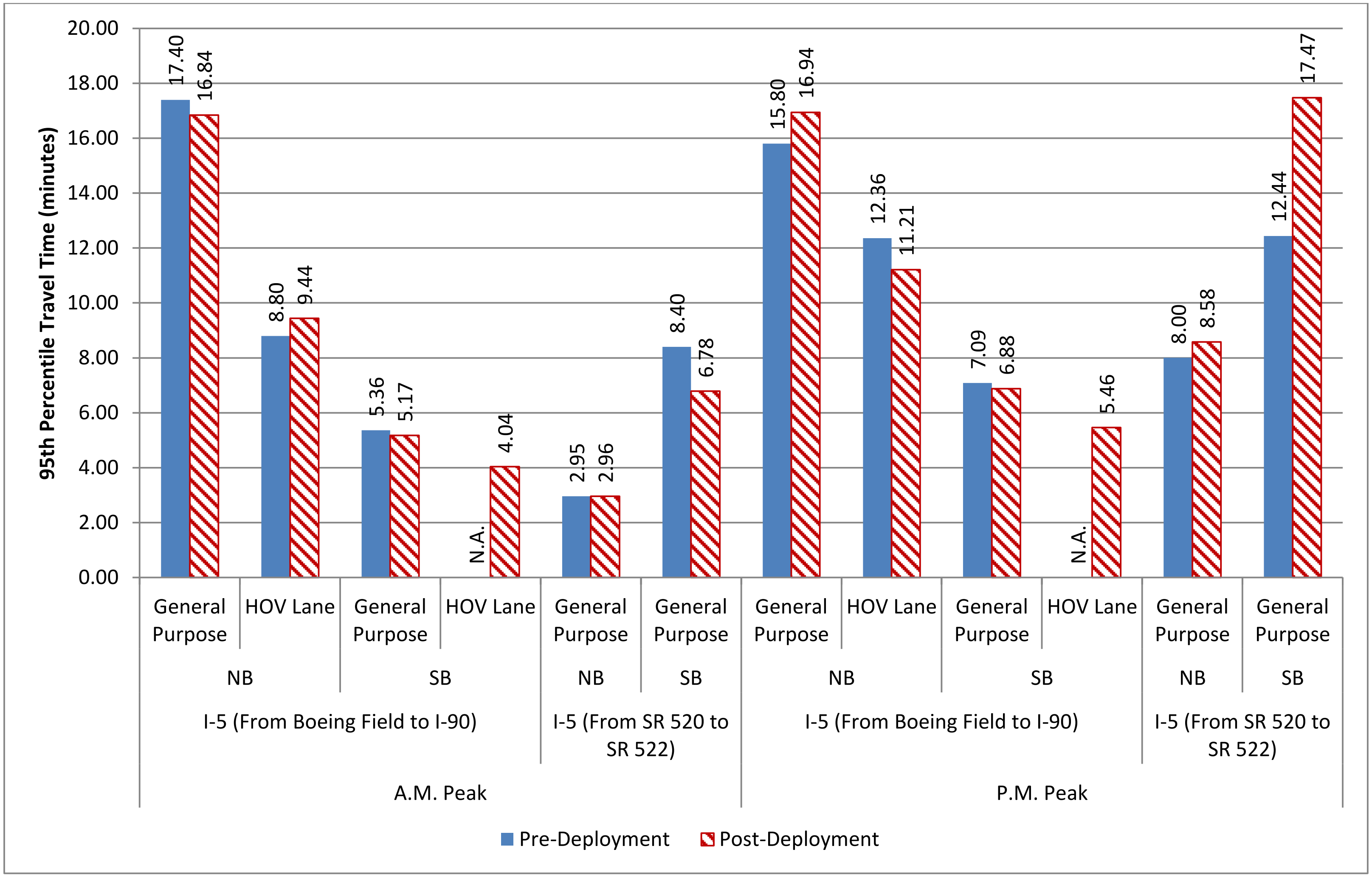
Source: Texas A&M Transportation Institute.

Figure A-19. 95th Percentile Travel Time (in Minutes) on SR 520 and I-90 for the A.M. and P.M. Peak Periods



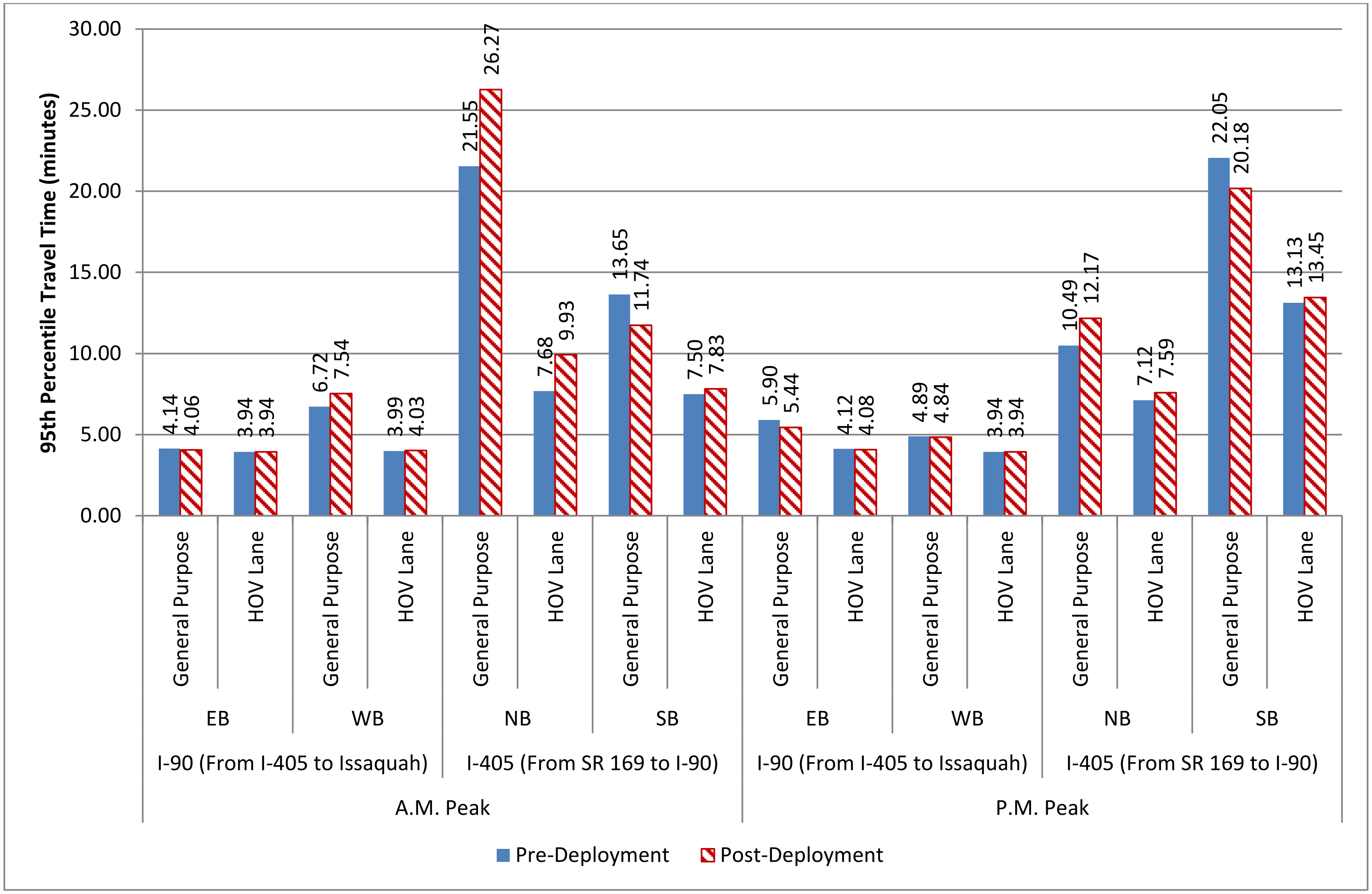
Source: Texas A&M Transportation Institute.

Figure A-20. 95th Percentile Travel Times on I-5 and I-405 between SR 520 and I-90 for the A.M. and P.M. Peak Periods



Source: Texas A&M Transportation Institute.

Figure A-21. 95th Percentile Travel Times on I-5 Approaching the LWC during the A.M. and P.M. Peak Periods



Source: Texas A&M Transportation Institute.

Figure A-22. 95th Percentile Travel Times on I-90 and I-405 Approaching the LWC during the A.M. and P.M. Peak Periods

Table A-6. Pre- and Post-Deployment 95th Percentile Travel Time (in Minutes) – A.M. Peak Period

Roadway	Limits	Direction	95th Percentile Travel Time – a.m. peak			
			Pre-Deployment	Post-Deployment	Change	Percent Change
SR 520	I-405 to I-5	EB	13.5	10.2	-3.3	-24.3%
		WB	15.3	8.7	-6.6	-43.2%
I-90	I-405 to I-5	EB	12.6	12.2	-0.4	-3.1%
		WB	15.8	16.2	0.3	2.1%
	I-405 and Issaquah (GP)	EB	4.14	4.06	-0.08	-1.9%
		WB	6.72	7.54	0.81	12.1%
	I-405 and Issaquah (HOV)	EB	3.94	3.94	0.00	0.0%
		WB	3.99	4.03	0.04	0.9%
I-5	SR 522 to SR 520	NB	2.95	2.96	0.01	0.1%
		SB	8.40	6.78	-1.61	-19.2%
	SR 520 to I-90	NB	9.7	6.7	-3.0	-31.0%
		SB	11.6	14.6	3.0	25.5%
	I-90 and Boeing Field	NB	17.40	16.84	-0.56	-3.2%
		SB	5.36	5.17	-0.19	-3.5%
	I-90 and Boeing Field (HOV)	NB	8.80	9.44	0.64	7.2%
		SB	N.A.	4.04	N.A.	N.A.
I-405	I-90 to SR 169 (GP)	NB	21.55	26.27	4.72	21.9%
		SB	13.65	11.74	-1.91	-14.0%
	I-90 to SR 169 (HOV)	NB	7.68	9.93	2.25	29.2%
		SB	7.50	7.83	0.33	4.4%
	I-90 to SR 520 (GP)	NB	7.9	5.6	-2.3	-29.2%
		SB	3.8	4.0	0.2	4.0%
	I-90 to SR 520 (HOV)	NB	3.6	3.8	0.2	5.9%
		SB	3.5	3.5	0.0	0.0%
	SR 520 to SR 522 (GP)	NB	8.9	9.1	0.2	2.0%
		SB	22.3	25.9	3.6	16.1%
	SR 520 to SR 522 (HOV)	NB	14.6	9.5	-5.1	-35.2%
		SB	10.8	13.4	2.6	23.9%

Source: Texas A&M Transportation Institute.

Table A-7. Pre- and Post-Deployment 95th Percentile Travel Time (in Minutes) – P.M. Peak Period

Roadway	Limits	Direction	95th Percentile Travel Time – p.m. peak			
			Pre-Deployment	Post-Deployment	Change	Percent Change
SR 520	I-405 to I-5	EB	13.3	7.9	-5.4	-40.8%
		WB	35.7	22.1	-13.6	-38.2%
I-90	I-405 to I-5	EB	15.8	16.2	0.3	2.1%
		WB	23.5	27.4	3.9	16.8%
	I-405 to Issaquah (GP)	EB	5.90	5.44	-0.47	-7.9%
		WB	4.89	4.84	-0.05	-1.0%
	I-405 to Issaquah (GP)	EB	3.94	3.94	0.00	0.0%
		WB	3.99	4.03	0.04	0.9%
I-5	SR 522 to SR 520	NB	8.00	8.58	0.58	7.2%
		SB	12.44	17.47	5.03	40.5%
	SR 520 to I-90	NB	13.1	11.5	-1.7	-12.6%
		SB	11.6	14.6	3.0	25.5%
	I-90 to Boeing Field (GP)	NB	15.80	16.94	1.14	7.2%
		SB	7.09	6.88	-0.21	-2.9%
	I-90 to Boeing Field (HOV)	NB	12.36	11.21	-1.15	-9.3%
		SB	N.A.	5.46	N.A.	N.A.
I-405	I-90 to SR 169 (GP)	NB	10.49	12.17	1.68	16.0%
		SB	22.05	20.18	-1.87	-8.5%
	I-90 to SR 169 (HOV)	NB	7.12	7.59	0.47	6.6%
		SB	13.13	13.45	0.32	2.4%
	I-90 to SR 520 (GP)	NB	8.9	8.6	-0.4	-4.2%
		SB	23.6	25.6	2.0	8.5%
	I-90 to SR 520 (HOV)	NB	4.7	5.7	1.0	21.0%
		SB	12.4	20.5	8.1	65.8%
	SR 520 to SR 522 (GP)	NB	23.4	27.1	3.8	16.1%
		SB	9.3	12.0	2.6	28.1%
	SR 520 to SR 522 (HOV)	NB	15.7	19.2	3.5	22.1%
		SB	8.5	13.8	5.3	63.0%

Source: Texas A&M Transportation Institute.

A.4.2 Buffer Index

The Buffer Index is a measure of the amount of extra time that travelers in a corridor need to allot to ensure that they arrive at their destination on time. It is computed as the difference between the 95th percentile travel time and the average travel time during a particular period of travel, expressed as a percentage of the normal travel time. For example, a buffer time of 40 percent in the morning peak period means that to guarantee an on-time arrival during their morning commute, a traveler would have to allow an additional 40 percent more time for the trip than it would take on average. It would be equivalent to allocating an extra 8 minutes in buffer time for a peak period trip that typically takes 20 minutes. A small buffer time implies that there is little variability in the average trip time and that, on average, little extra time must be allotted to the normal travel time to guarantee on time arrival. A high buffer time implies that travel times are highly variable and that a traveler needs to allot more time to account for this variability to guarantee on time arrival.

Figure A-23 through Figure A-26 present the Buffer Indices on SR 520, I-90, and other freeways in the area for the morning and afternoon peak periods in both directions of travel. Table A-8 and Table A-9 present the same information, along with the actual change and the percent change from the pre- to post-deployment periods.

Figure A-23 illustrates the Buffer Index for SR 520 and I-90 for the morning and afternoon peak periods in the pre- and post-deployment periods. The Buffer Index increased slightly from 0.37 to 0.41 in the eastbound direction on SR 520 during the morning peak period, representing an 11 percent decline in travel time reliability on this section of SR 520 in the post-deployment period. The Buffer Index for westbound traffic on SR 520 during the morning peak period declined from 0.68 in the pre-deployment period to 0.24 in the post-deployment period, representing a 65 percent increase in the travel time reliability for the westbound traffic in the post-deployment period. The Buffer Index increased very slightly from .98 to 1.0 in the eastbound direction on I-90.

This trend was reversed in the afternoon peak period on SR 520. There was a slight increase in the Buffer Index for westbound traffic from 1.01 to 1.08 and a substantial reduction from 0.57 to 0.18 for eastbound traffic. These results indicate that travel on SR 520 during the afternoon peak period was slightly less reliable in westbound direction, but was substantially more reliable in the eastbound direction. The Buffer Index for westbound traffic during the afternoon peak period remained above 1.0, however. A Buffer Index greater than 1.0 suggests that a traveler using SR 520 in the westbound direction needs to provide a buffer of nearly twice the average travel time to ensure an on-time arrival on any given day.

The trend on I-90 was the reverse of SR 520. In the morning peak period, the Buffer Index declined from 0.69 to 0.46 for traffic traveling eastbound on I-90, suggesting that travel time reliability for the eastbound traffic improved. The Buffer Index for westbound traffic in the afternoon peak period declined from 1.45 in the pre-deployment period to 1.19 in the post-deployment period, also suggesting an improvement in travel time reliability. The Buffer Index still exceeds 1.0 however, suggesting that congestion still exists. The Buffer Index for westbound traffic in the morning peak period and in the eastbound direction in the afternoon peak period on I-90 did not change substantially remaining at approximately 1.0.

Figure A-24 illustrates the changes in the Buffer Index for the segments of I-5 and I-405 between SR 520 and I-90. The Buffer Index for northbound traffic on both I-5 and I-405 was lower during the morning peak period in the post-deployment period. The Buffer Index for southbound traffic increased slightly on both facilities during the morning peak period, suggesting that using I-5 and I-405 to access I-90 became slightly less reliable in the post-deployment period, while using I-5 and I-405 to access SR 520 became slightly more reliable during the post-deployment period.

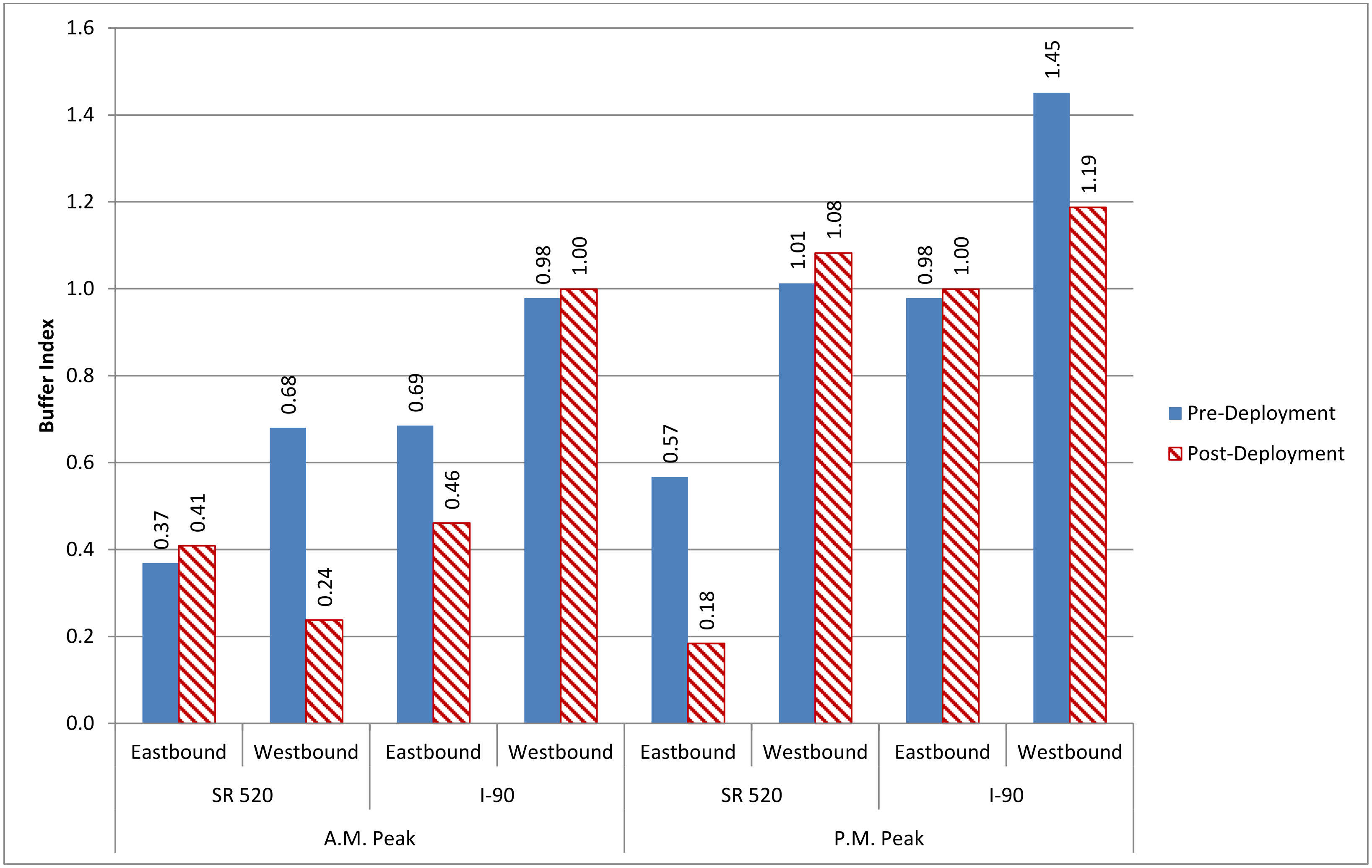
In the afternoon peak period, the reverse trend is evident. The Buffer Index was lower in morning peak period the post-deployment period for southbound travel on both I-5 and I-405 compared to the pre-deployment period. In the afternoon peak period, the Buffer Index for southbound traffic using I-5 declined from 0.73 in the pre-deployment period to 0.63 in the post-deployment period, representing a 14 percent reduction. For traffic using I-405, the Buffer Index declined from 1.17 to 0.76, representing a significant improvement in travel time reliability for southbound traffic using the I-405 general purpose lanes to access I-90.

For northbound travel between SR 520 and I-90, travel time reliability was worse for traffic using I-405 in the post-deployment period compared to the pre-deployment period. On I-405, the Buffer Index for northbound traffic using the general purpose lanes increased from 0.90 in the pre-deployment period to 1.20 in the post-deployment period. For traffic using I-5, the Buffer Index in the afternoon peak period for northbound travel decreased from 1.17 to 1.01, representing a slight improvement in reliability.

Travel-time reliability in the I-405 HOV lanes was not impacted during the morning peak period in either direction, as the Buffer Index remained the same or increased very slightly. Travel-time reliability in the I-405 HOV lanes in the afternoon peak period declined significantly between the pre- and post-deployment evaluation periods, however. During the afternoon peak period, the Buffer Index for the I-405 HOV lane in increased from 0.33 to 0.59 for the northbound direction and increased from 1.73 to 2.13 in the southbound direction.

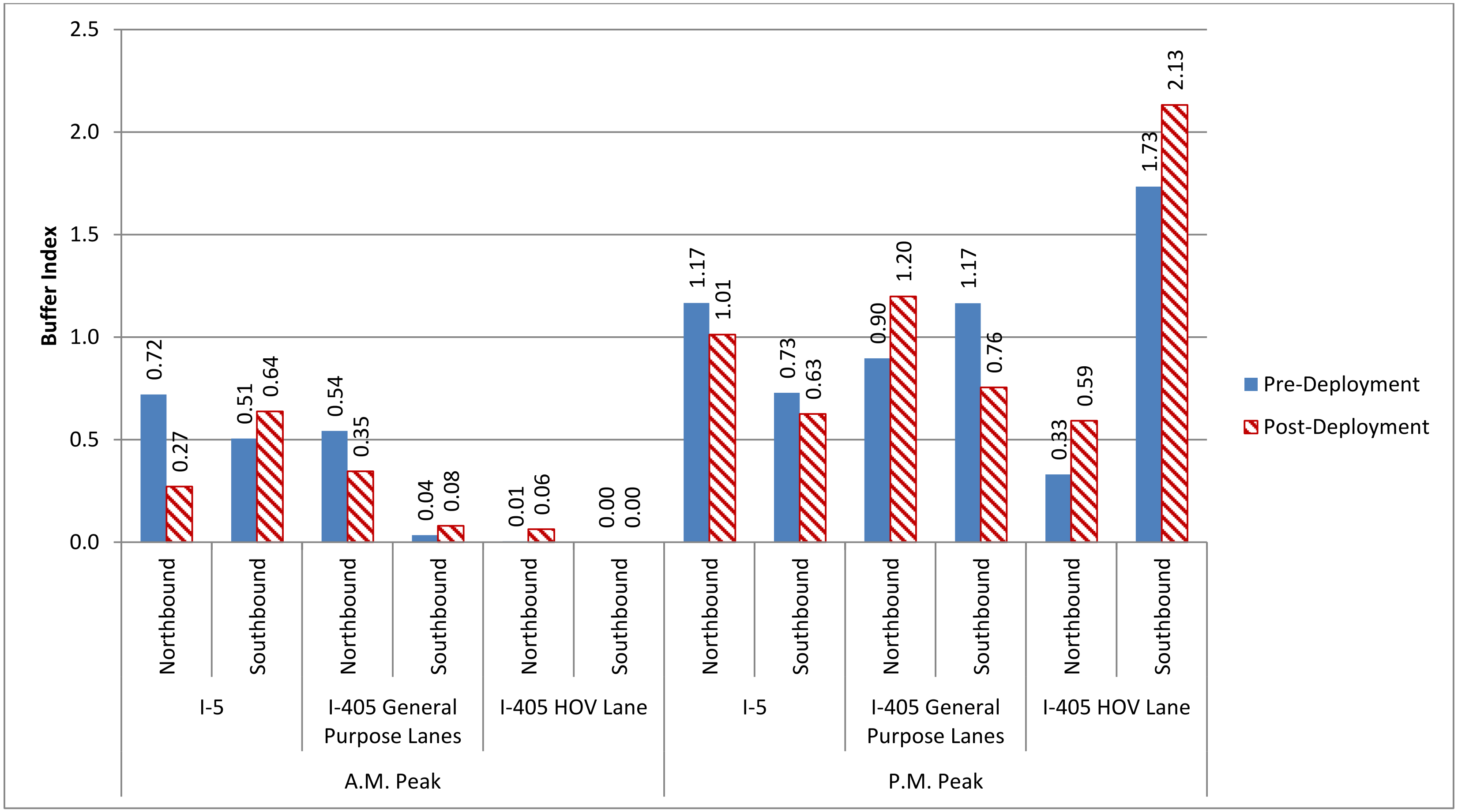
Figure A-25 presents the Buffer Index on I-5 from Boeing Field to I-90 and from SR 520 to SR 522. The Buffer Index was reduced in both the general purpose freeway lanes and the HOV lane in the morning peak period in the northbound and southbound direction on I-5 from Boeing Field to I-90. In the afternoon peak period, the Buffer Index declined slightly in the general purpose freeway lanes and the HOV lane in the northbound direction and the general purpose freeway lanes in the southbound direction. The Buffer Index on I-5 from SR 520 to SR 522 remained the same in the morning peak period in the northbound direction, but increased in the southbound direction. In the afternoon peak period, the Buffer Index increased slightly in the northbound direction, but decreased from 1.14 to 0.71 in the southbound direction.

Figure A-26 presents the Buffer Index from I-90 from I-405 to Issaquah and I-405 from SR 169 to I-90. The major increases in the Buffer Index were for the general purpose freeway lanes on I-90, which increased from 0.41 to 0.60 and the I-405 HOV lane in the morning peak period northbound direction, which increased from 0.11 to 0.33.



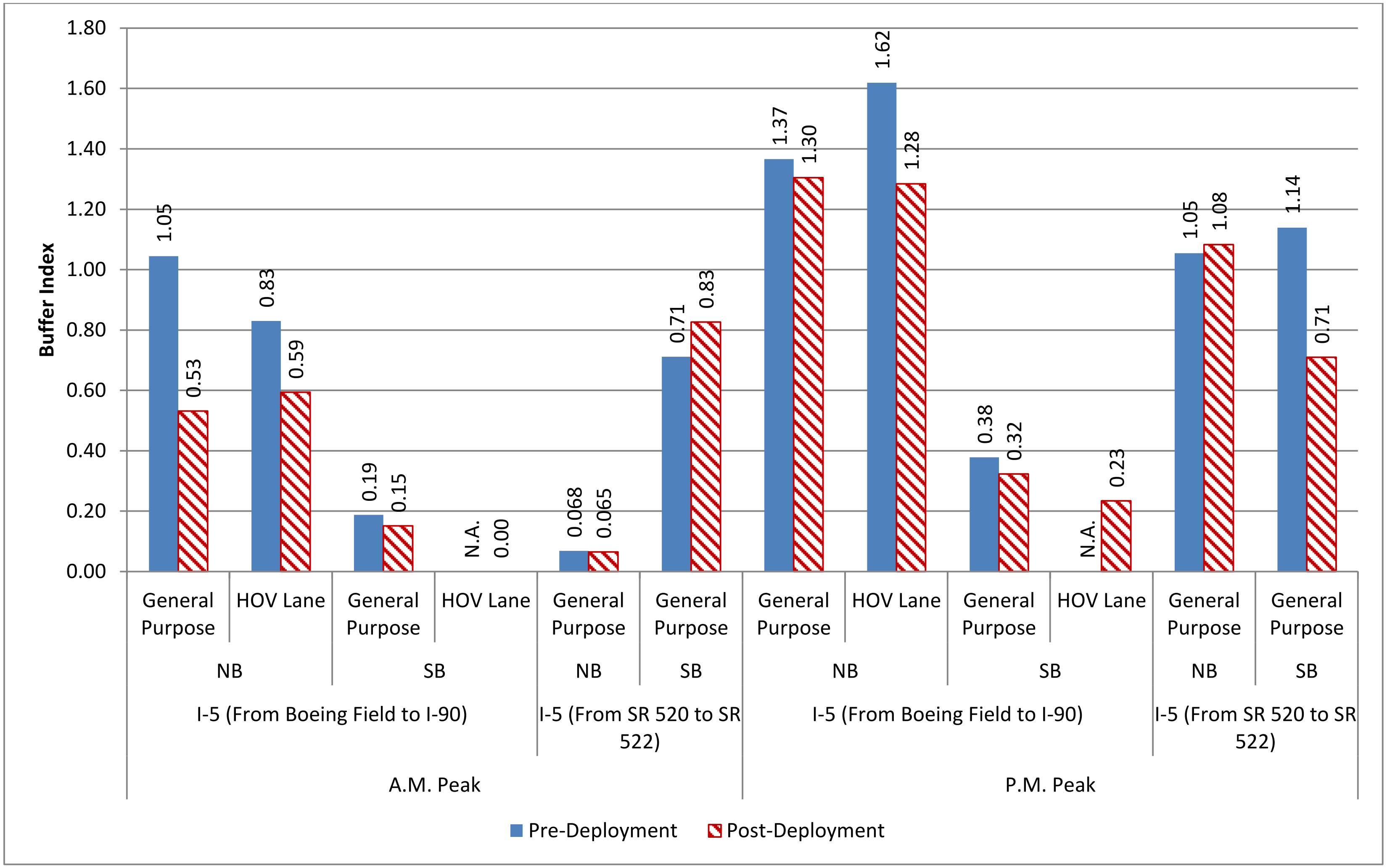
Source: Texas A&M Transportation Institute.

Figure A-23. Buffer Indices on SR 520 and I-90 for the A.M. and P.M. Peak Periods



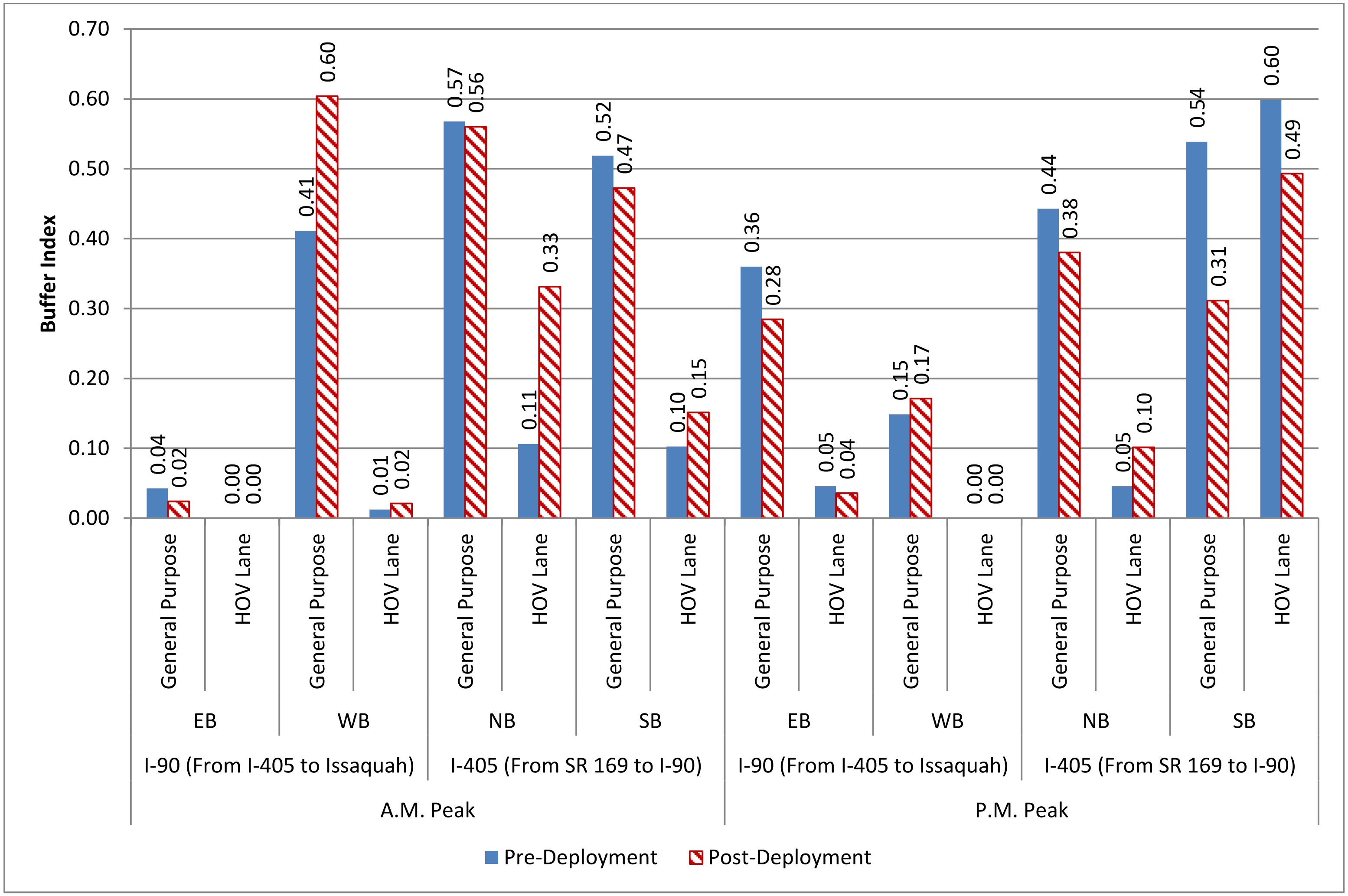
Source: Texas A&M Transportation Institute.

Figure A-24. Buffer Indices on I-5 and I-405 between SR 520 and I-90 for the A.M. and P.M. Peak Periods



Source: Texas A&M Transportation Institute.

Figure A-25. Buffer Indices on I-5 Approaching the LWC for the A.M. and P.M. Peak Periods



Source: Texas A&M Transportation Institute.

Figure A-26. Buffer Indices on I-90 and I-405 Approaching the LWC for the A.M. and P.M. Peak Periods

Table A-8. Pre- and Post-Deployment Buffer Indices – A.M. Peak Period

Roadway	Limits	Direction	Buffer Index – a.m. peak			
			Pre-Deployment	Post-Deployment	Change	Percent Change
SR 520	I-405 to I-5	EB	0.37	0.41	0.04	10.8%
		WB	0.68	0.24	-0.44	-65.1%
I-90	I-405 to I-5	EB	0.69	0.46	-0.22	-32.7%
		WB	0.98	1.00	0.02	2.0%
	I-405 to Issaquah (GP)	EB	0.04	0.02	-0.02	-44.1%
		WB	0.41	0.6	0.19	16.8%
	I-405 to Issaquah (HOV)	EB	0.00	0.00	0.00	-
		WB	0.01	0.02	0.01	70.0%
I-5	SR 522 to SR 520	NB	0.07	0.06	-0.01	-4.9%
		SB	0.71	0.83	0.11	16.1%
	SR 520 to I-90	NB	0.72	0.27	-0.45	-62.2%
		SB	0.73	0.63	-0.10	-14.1%
	I-90 and Boeing Field (GP)	NB	1.05	0.53	-0.51	-49.2%
		SB	0.19	0.15	-0.04	-19.3%
	I-90 and Boeing Field (HOV)	NB	0.83	0.59	-0.24	-28.5%
		SB	N.A.	N.A.	N.A.	N.A.
I-405	I-90 to SR 169 (GP)	NB	0.57	0.56	-0.01	-1.3%
		SB	0.52	0.47	-0.05	-8.9%
	I-90 to SR 169 (HOV)	NB	0.05	0.04	-0.01	-21.9%
		SB	0.00	0.00	0.00	-
	I-90 to SR 520 (GP)	NB	0.54	0.35	-0.20	-36.2%
		SB	0.04	0.08	0.05	128.6%
	I-90 to SR 520 (HOV)	NB	0.01	0.06	0.06	1175.0%
		SB	0.00	0.00	0.00	-
	SR 520 to SR 522 (GP)	NB	0.03	0.05	0.02	64.0%
		SB	0.58	0.64	0.06	10.3%
	SR 520 to SR 522 (HOV)	NB	0.69	0.07	-0.62	-89.5%
		SB	0.22	0.42	0.20	88.1%

Source: Texas A&M Transportation Institute.

Table A-9. Pre- and Post-Deployment Buffer Indices – P.M. Peak Period

Roadway	Limits	Direction	Buffer Index – p.m. peak			
			Pre-Deployment	Post-Deployment	Change	Percent Change
SR 520	I-405 to I-5	EB	0.57	0.18	-0.38	-67.6%
		WB	1.01	1.08	0.07	6.9%
I-90	I-405 to I-5	EB	0.98	1.00	0.02	2.0%
		WB	1.45	1.19	-0.26	-18.2%
	I-405 and Issaquah (GP)	EB	0.36	0.28	-0.08	-21.0%
		WB	0.41	0.60	0.19	46.8%
	I-405 and Issaquah (HOV)	EB	0.00	0.00	0.00	-
		WB	0.01	0.02	0.01	70.0%
I-5	SR 522 to SR 520	NB	1.05	1.08	0.03	2.7%
		SB	1.14	0.71	-0.43	-37.7%
	SR 520 to I-90	NB	1.17	1.01	-0.16	-13.3%
		SB	0.73	0.63	-0.10	-14.1%
	I-90 and Boeing Field (GP)	NB	1.37	1.30	-0.06	-4.5%
		SB	.38	.32	-0.06	-14.7%
	I-90 and Boeing Field (HOV)	NB	1.62	1.28	-0.33	-20.7%
		SB	0.00	0.23	0.23	-
I-405	I-90 to SR 169 (GP)	NB	0.44	0.38	-0.06	-14.2%
		SB	0.54	0.31	-0.23	-4.2%
	I-90 to SR 169 (HOV)	NB	0.05	0.10	0.06	121.9%
		SB	0.6	0.49	-0.11	-17.7%
	I-90 to SR 520 (GP)	NB	0.90	1.20	0.30	33.6%
		SB	1.17	0.76	-0.41	-35.2%
	I-90 to SR 520 (HOV)	NB	0.33	0.59	0.26	78.9%
		SB	1.73	2.13	0.40	23.0%
	SR 520 to SR 522 (GP)	NB	0.69	0.29	-0.40	-58.1%
		SB	0.07	0.36	0.30	445.3%
	SR 520 to SR 522 (HOV)	NB	0.49	0.63	0.14	28.5%
		SB	0.01	0.65	0.64	6387.5%

Source: Texas A&M Transportation Institute.

A.5 Vehicle and Person Throughput

Changes in vehicular and person throughput were examined to assess the extent to which congestion was reduced on SR 520 and I-90 by deploying the UPA improvements. According to the NCHRP's *Guide to Effective Freeway Performance Measurement,*[1] throughput is a fundamental measure of freeway performance. Throughput is a measure of the number of users "served" by the transportation system. Throughput indicates if more vehicles and/or more persons are "served" as a result of the UPA projects, even though travel times or travel-time reliability has not changed.

Two types of throughput were used in this assessment – vehicle throughput and person throughput. Vehicle throughput was determined by measuring the number of vehicles using both the general purpose freeway lanes and the HOV lanes on SR 520 and I-90. Person throughput was calculated as the total number of persons "served" by different transportation modes utilizing the corridor.

A.5.1 Vehicle Throughput

Vehicle throughput is a measure of the number of vehicles that are serviced in one direction of a facility during the analysis period. The WSDOT freeway detectors were used to measure vehicle throughput at the evaluation screenlines. Figure A-27 illustrates the approximate location of the screenlines used in this analysis, which were selected to correspond to the detector stations used in the travel time and travel speed analysis. The location of these detector stations were as follows:

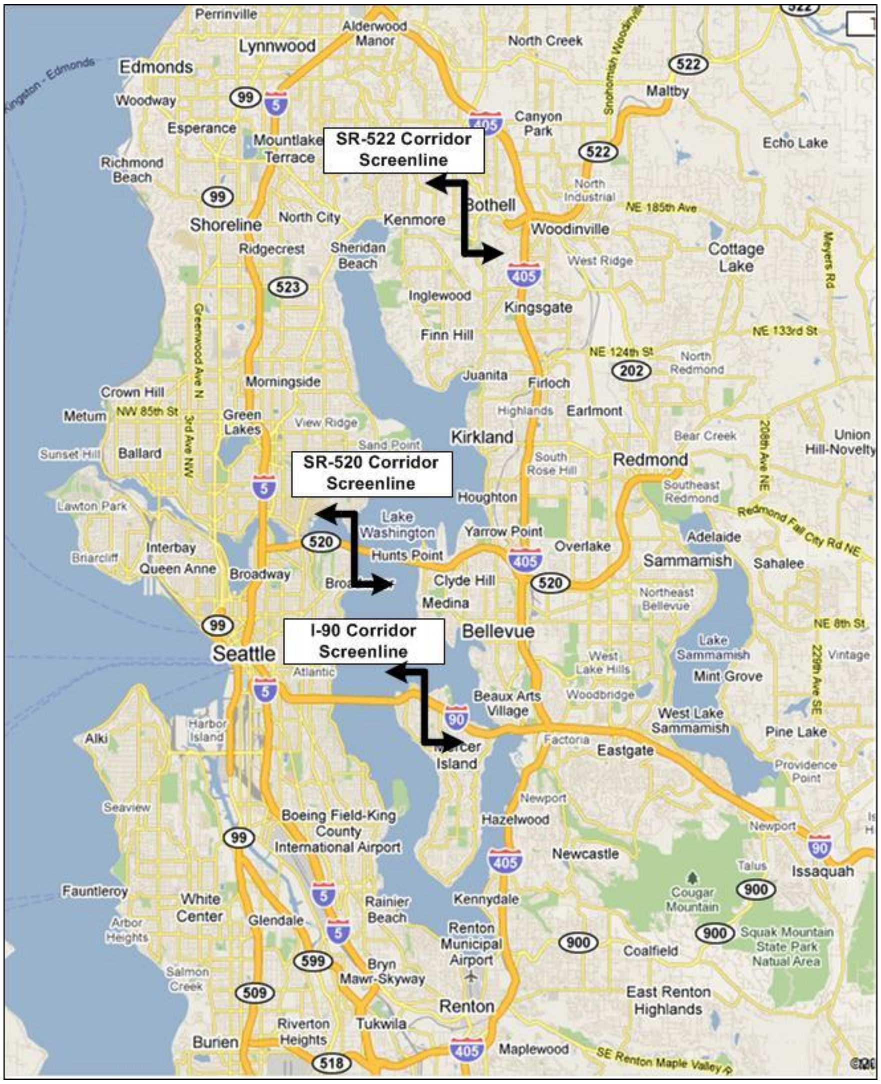
- SR 520 @ West Side of Bridge (Milepoint 3.06);
- I-90 @ Island Crest Way E (Milepoint 7.20); and
- SR 522 @ 77th Ct NE (Milepoint 7.82).

Total vehicle throughput is the sum of all types of vehicle traversing the roadway during the analysis period. With the exception of SR 522, the data used in analyzing throughput was from 2010 the pre-deployment period and 2012 for the post-deployment period. Only two months of pre-deployment data for October and November, 2011, was available for SR 522.

Figure A-28 presents the average total peak period throughput in the pre- and post-deployment periods. The average morning peak period vehicle throughput in both directions on SR 520 declined in the post-deployment period. In the eastbound direction, the average peak-period throughput declined by 25 percent in the morning peak period, while in the westbound direction the average vehicle throughput declined by 12 percent. In the afternoon peak period, the average vehicle throughput in the eastbound direction declined by 33 percent and remained relatively constant in the westbound direction.

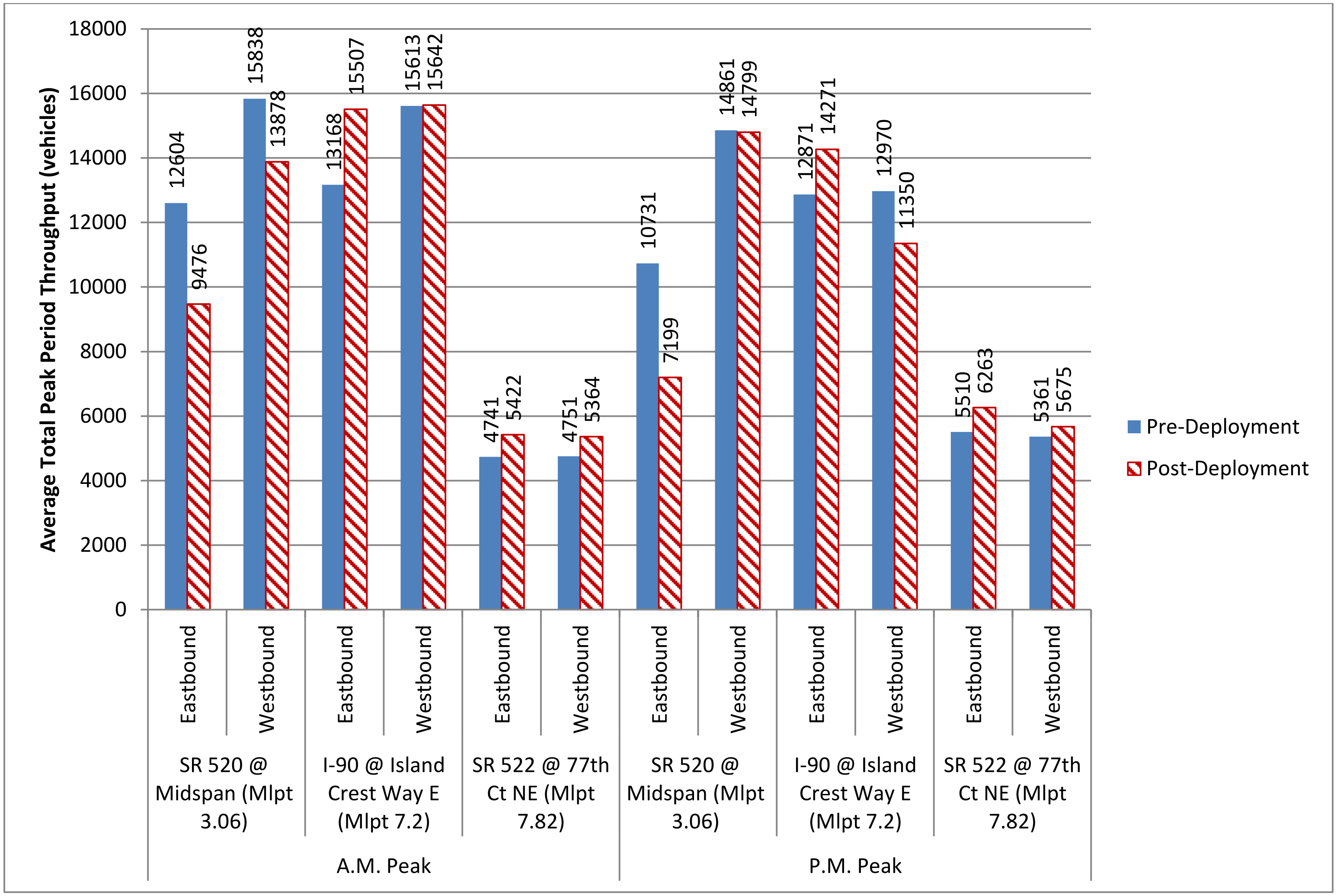
[1] Marigiotta, R, et al. *Guide to Effective Freeway Performance Measurement*. NCHRP Web-Only Document 97. National Academy of Science, Transportation Research Board. Available at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w97.pdf. Accessed August 2013.

On I-90, the average morning and afternoon peak-period vehicle throughput in the eastbound direction increased by 18 percent in the morning peak period and by 11 percent in the afternoon peak period. In the westbound direction the average peak-period throughput remained unchanged for the morning peak period, and declined by 12 percent in the afternoon peak period.



Source: Google Maps; modified by Texas A&M Transportation Institute.

Figure A-27. Approximate Locations of Screenlines for Throughput Comparisons for SR 520, I-90, and SR 522



Source: Texas A&M Transportation Institute.

Figure A-28. Pre-and Post-Deployment Average Peak Period Vehicle Throughput for SR 520, I-90, and SR 522

On SR 522, the average morning peak-period vehicle throughput increased by approximately 14 percent in both directions of travel in the post-deployment period. In the afternoon peak period, the average vehicle throughput increased by 14 percent in the eastbound direction and by 6 percent in the westbound direction.

The national evaluation team also examined throughput changes within the morning and afternoon peak periods. Vehicle throughput was averaged over 30-minute intervals within the peak periods in this analysis. Vehicle throughput was modeled on freeway sections with consistent cross-sections. The result of this analysis, which examined SR 520, I-90, and SR 522, is presented Figure A-29 through Figure A-31.

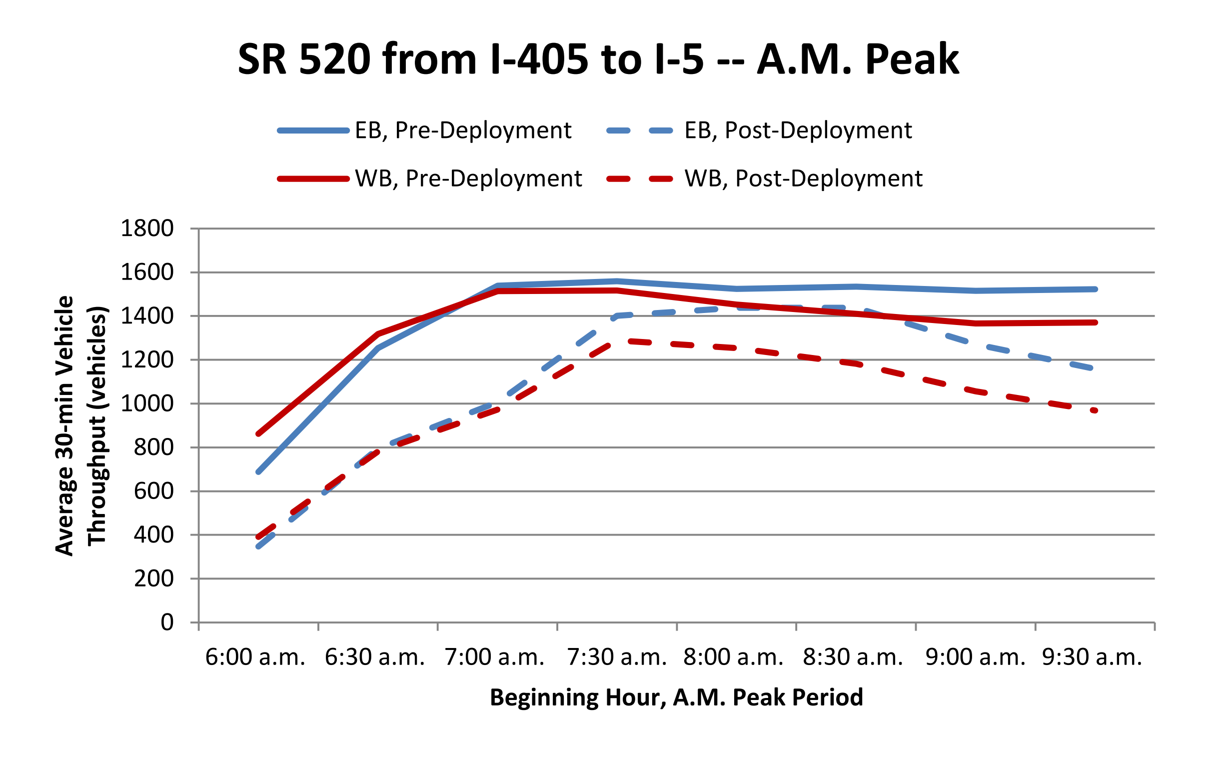
Figure A-29 shows that average vehicle throughput on SR 520 declined in the post-deployment period in the morning and the afternoon peak periods in eastbound direction of travel and for the westbound direction of travel in the morning peak period. The lines representing the post-deployment period – the dashed lines – are lower than the pre-deployment lines – the solid lines. Vehicle throughput appears to build a little later as indicated by a shifting of the dashed lines to the right, in the morning period peak for both directions on SR 520 in the post-deployment period compared the pre-deployment period. This same shift does not occur in the p.m. peak, where the pre- and post-deployment lines generally are parallel to each other. Similar trends are also reflected in the slight shift in toll volumes to later in the morning peak period discussed in Appendix B – Tolling Analysis.

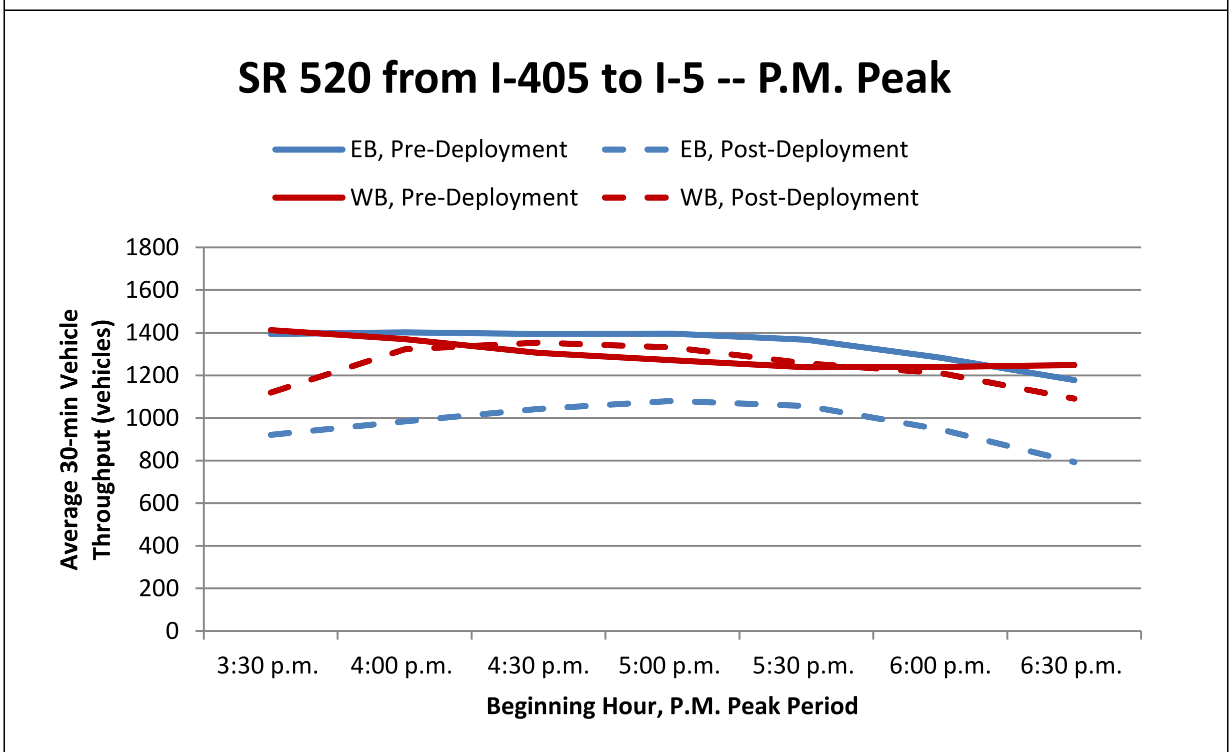
Figure A-30 presents a similar comparison of average 30-minute vehicle throughput for I-90. The results show a reverse trend from SR 520. The average 30-minute vehicle throughput on I-90 is higher in the post-deployment period for the morning and afternoon peak periods. The highest average vehicle throughput has shifted to the left, suggesting that more vehicles are using I-90 earlier in the morning peak period regardless of direction of travel. Beginning at around 7:30 a.m., the pre- and post-deployment average vehicle throughput tends to reflect similar trends, suggesting that congestion levels have stabilized and the facility is operating in a congestion regime. In the afternoon peak period, the average vehicle throughput in the eastbound direction on I-90 in the post-deployment period remains consistent compared to pre-deployment conditions. For westbound traffic, the average 30-minute throughput on I-90 is lower in the post-deployment period suggesting that the freeway is more congested in the post-deployment period.

Figure A-31 presents a comparison of the average 30-minute vehicle throughput for a limited section of SR 522 from 68th Ave. NE to 83rd Place NE. Both directions of travel in this section of SR 522 experienced a general increase in average vehicle throughput throughout both the morning and afternoon peak periods. The limited amount of pre-deployment data on SR 522 raises caution in trying to identify changing trends and use patterns, which might have a tendency to mask any true trends in the data.

A statistical analysis using a linear mixed-effect model was conducted to determine the level of difference between pre- and post-deployment vehicle throughput on SR 520 and I-90. Due to the limited duration of pre-deployment data, SR 522 was not included in the statistical analysis. The time-of-day and deployment were considered fixed effects, while monthly and day-of-week traffic patterns and other factors were treated as random effects. The models were calibrated separately by direction and by lane type. Using this approach, the factors that are known to potentially influence the traffic patterns are still appropriately accounted for in the models, while the fixed-effect results indicate the magnitude and statistical significance of the UPA deployment impacts. Differences were evaluated at a 95 percent confidence level.

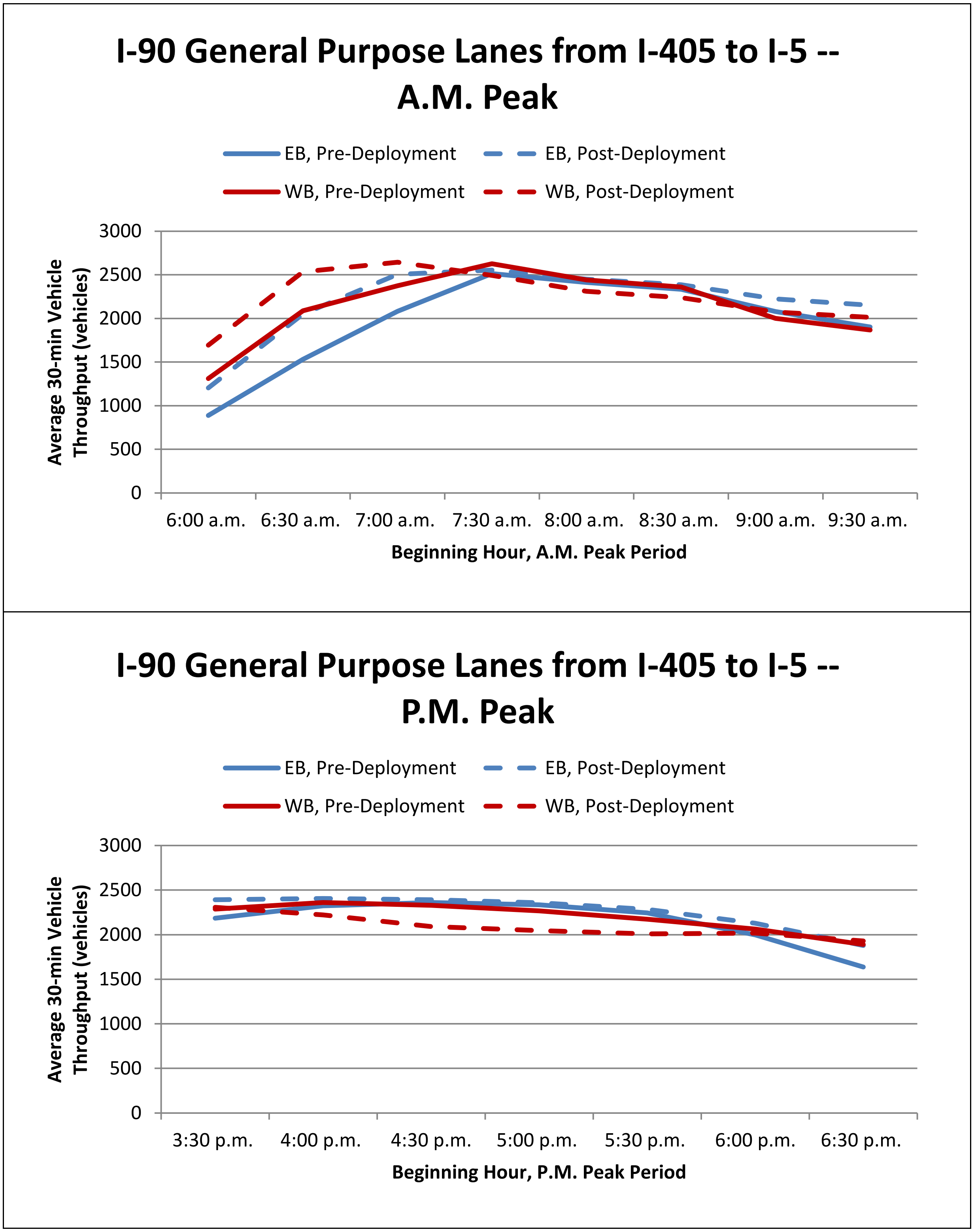
The results, which are represented in Table A-10, indicate that the difference in the 30-minute average vehicle throughput in each direction of travel on SR 520 is statically significant across all intervals in the morning and morning peak periods. The average 30-minute vehicle throughputs for each direction of travel on I-90 during each peak were also statistically significant at a 95th percentile confidence level.





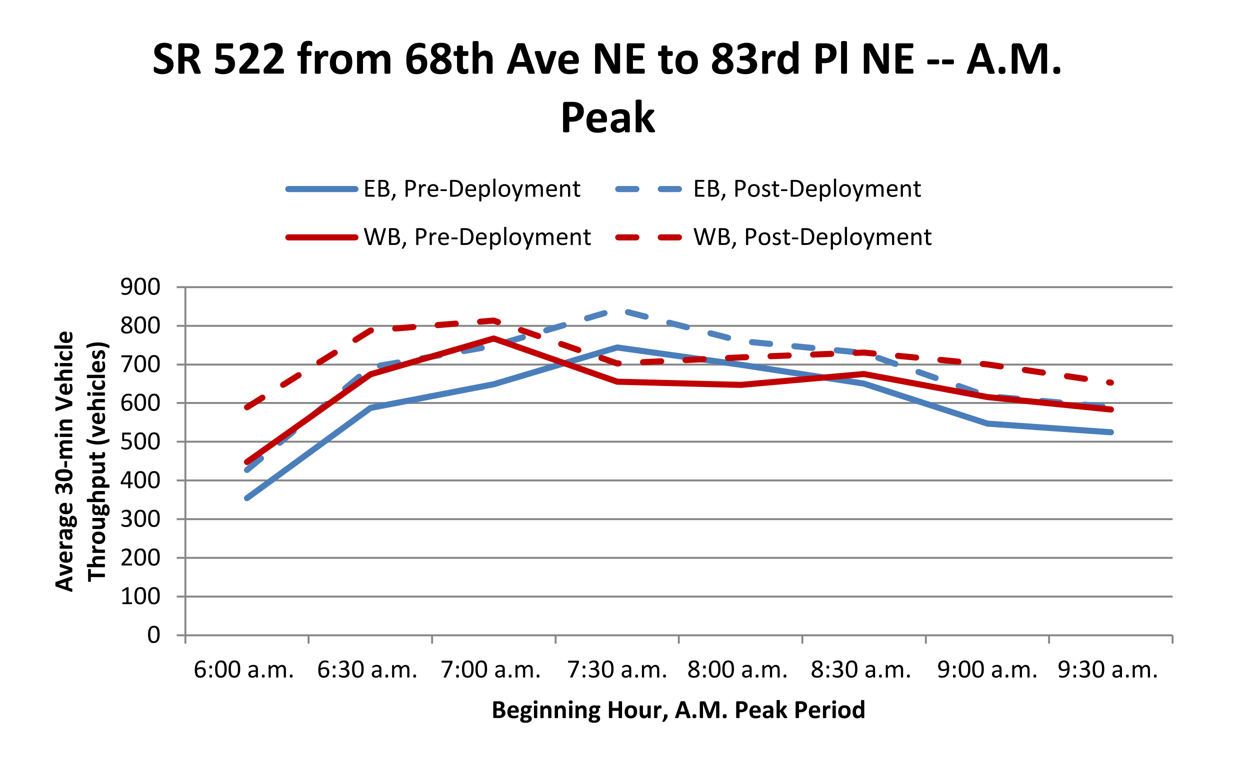
Source: Texas A&M Transportation Institute.

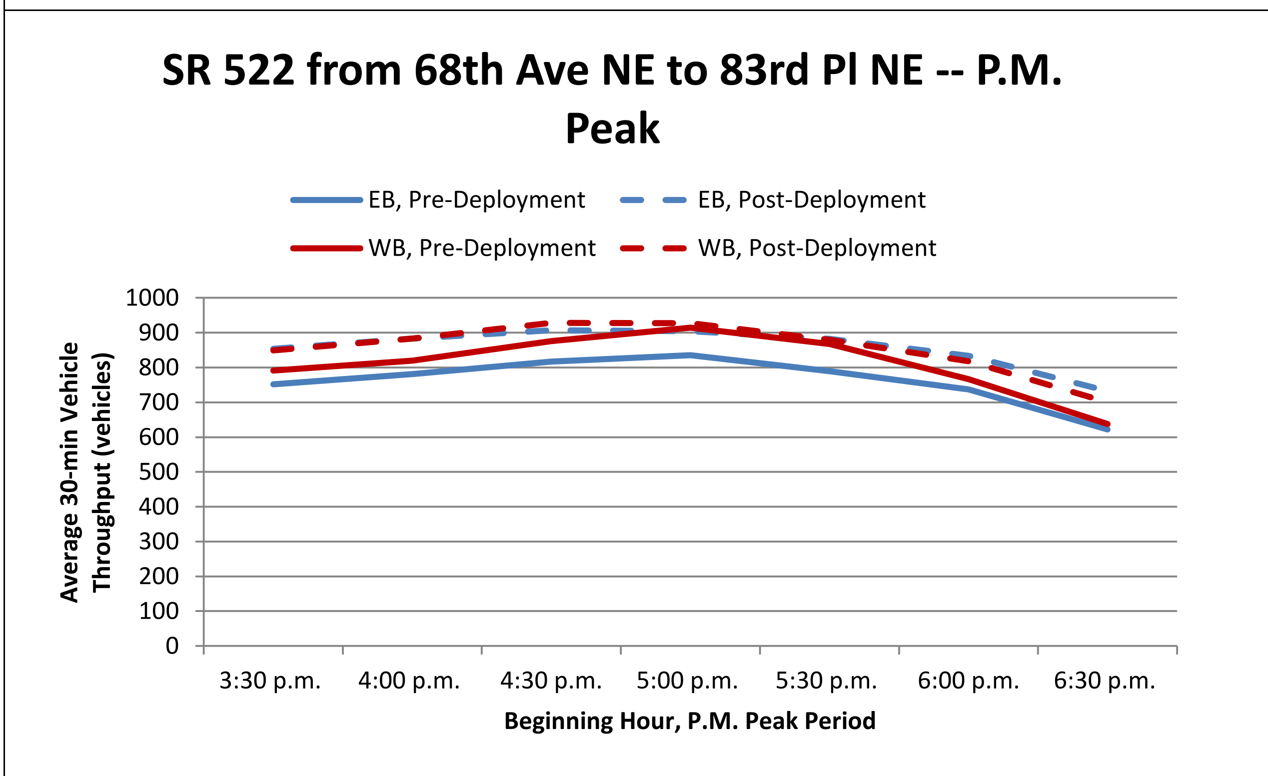
Figure A-29. Pre- and Post-Deployment Average 30-Minute Throughput for SR 520 from I-405 to I-5



Source: Texas A&M Transportation Institute.

Figure A-30. Pre- and Post-Deployment Average 30-Minute Throughput for I-90 General Purpose Lanes from I-405 to I-5





Source: Texas A&M Transportation Institute.

Figure A-31. Pre- and Post-Deployment Average 30-Minute Throughput for SR 522 from I-405 to I-5

Table A-10. Statistical Comparison of Pre- and Post-Deployment Average 30-minute Vehicle Throughput on SR 520 and I-90

Time Interval	Difference in Pre- and Post-Deployment Average 30-minute Vehicle Throughput (vehicles)			
	SR 520		I-90	
	From I-405 to I-5			
	Eastbound	Westbound	Eastbound	Westbound
A.M. Peak				
6:00 - 6:30 a.m.	-341	-471	313	380
6:30 - 7:00 a.m.	-459	-536	519	445
7:00 - 7:30 a.m.	-532	-541	424	270
7:30 - 8:00 a.m.	-158	-228	41	-133
8:00 - 8:30 a.m.	-85	-198	36	-129
8:30 - 9:00 a.m.	-97	-228	53	-123
9:00 - 9:30 a.m.	-244	-311	145	71
9:30 - 10:00 a.m.	-365	-402	248	145
P.M. Peak				
3:30 - 4:00 p.m.	-474	-293	209	18
4:00 - 4:30 p.m.	-418	-47	83	-141
4:30 - 5:00 p.m.	-352	48	30	-238
5:00 - 5:30 p.m.	-316	59	24	-222
5:30 - 6:00 p.m.	-311	17	39	-162
6:00 - 6:30 p.m.	-336	-29	129	-46
6:30 - 7:00 p.m.	-385	-158	240	40

Note: Shaded cells represent statistically significant differences at a 95 percent confidence level.

Note: Negative values represent reductions in throughput and positive values represent increases in throughput.

Source: Texas A&M Transportation Institute.

Table A-11 shows the percent change in peak period vehicle throughput for those facility crossing Lake Washington, including SR 520, I-90, and SR 522. The table shows that with the exception of the westbound direction during the p.m. peak, average peak period vehicle throughput declined dramatically on SR 520 after implementing the UPA improvements. For these periods, average peak period throughput on SR 520 declined between 25 and 33 percent in the eastbound direction and by 12 percent in the westbound direction during the a.m. The table shows that most of this demand was eastbound demand was absorbed by I-90 and SR 520, which both showed increases in average vehicle throughput. The table also shows that average peak period vehicle throughput in the westbound direction on I-90 did not change substantially in the a.m. peak and declined in the p.m. peak. This suggests that I-90 may have been able to absorb the shifting diverted demand from SR 520 in the a.m. peak but not during the p.m. peak.

Table A-11. Percent Change in Peak Period Vehicle Throughput Across and Around Lake Washington.

Peak Period	Direction	Average Peak Period Vehicle Throughput (vehicles)			
		Pre-Deployment	Post-Deployment	Change	Percent Change
SR 520					
A.M. Peak	EB	12604	9476	-3128	-24.8%
	WB	15838	13878	-1960	-12.4%
P.M. Peak	EB	10731	7199	-3532	-32.9%
	WB	14861	14799	-62	-0.4%
I-90					
A.M. Peak	EB	13168	15507	2339	17.8%
	WB	15613	15642	29	0.2%
P.M. Peak	EB	12871	14271	1400	10.9%
	WB	12970	11350	-1620	-12.5%
SR 522					
A.M. Peak	EB	4741	5422	681	14.4%
	WB	4751	5364	613	12.9%
P.M. Peak	EB	5510	6263	753	13.7%
	WB	5361	5675	314	5.9%
Combined Total					
A.M. Peak	EB	30513	30405	-108	-0.4%
	WB	36202	34884	-1318	-3.6%
P.M. Peak	EB	29112	27733	-1379	-4.7%
	WB	33192	31824	-1368	-4.1%

Source: Texas A&M Transportation Institute.

A.5.2 Person Throughput

Person throughput is similar in concept to vehicle throughput. The emphasis is on the number of people served, however, rather than the number of vehicles served. Person throughput is defined as the number of persons, including vehicle occupants, pedestrians, and bicyclist, traversing a roadway section in one direction per unit of time. Person throughput is estimated by multiplying vehicle throughput for different vehicle classes by the average number of occupants per vehicles in each vehicle class.

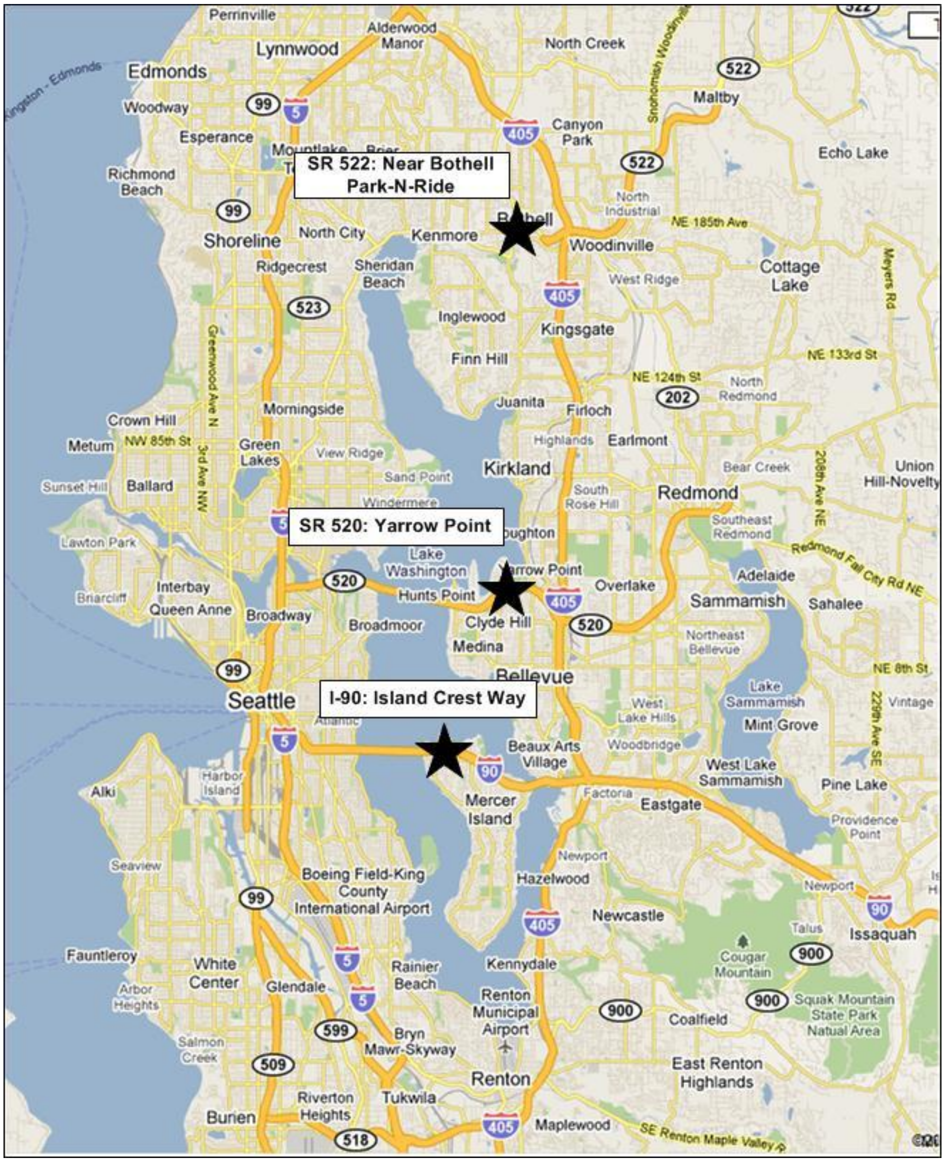
TRAC collects vehicle occupancy information at numerous locations throughout the Seattle region area on a regular basis. TRAC samples average vehicle occupancy on select facilities and stores the information in a database. This database provides a historical archive of all the vehicle occupancy studies performed by TRAC in the Seattle area. The national evaluation team selected three sites, one each on SR 520, I-90, and SR 522 for the analysis of vehicle occupancy. These sites, which are shown in Figure A-32, provide a representative sample of vehicle occupancy for through traffic across Lake Washington.

Using the TRAC database,[2] the national evaluation team extracted all the vehicle occupancy counts performed by TRAC during the pre- and post-deployment evaluation periods. Vehicle occupancy studies occurring between the hours of 6:00 a.m. to 9:00 a.m. and from 3:00 p.m. to 7:00 p.m. were used to compute the average vehicle occupancy for the morning peak and afternoon peak periods. The data from multiple counts were combined to generate average vehicle occupancies for the peak periods. It should be noted that data were not collected throughout the entire pre- and post-deployment periods, but were sampled during the time period. For the purpose of this comparison, the average vehicle occupants have been aggregated based on data on the number of occupants in vehicles traveling in both the general purpose lanes and in the HOV lanes at the three locations in the corridor.

Table A-12 presents the average vehicle occupancy for non-transit vehicles at the three sites. The non-transit vehicle occupancy remained approximately the same or declined slightly between the pre- and post-deployment period at all three sites. The largest change in non-transit vehicle occupancy levels occurred for traffic traveling westbound on SR 520. The average vehicle occupancy for non-transit vehicles decreased from 1.22 to 1.11, or a 9 percent reduction, in the morning peak period westbound direction and from 1.40 to 1.21 in the afternoon peak period westbound direction, or a 14 percent reduction. The average vehicle occupancy level of non-transit vehicles also declined by 5 percent, from 1.23 to 1.17, for traffic traveling eastbound on SR 520 during the afternoon peak period.

The average vehicle occupancy of non-transit vehicles also declined slightly on I-90 in the post-deployment period. A decline of 2 percent or less was recorded for the morning and afternoon peak periods in both directions of travel. The average vehicle occupancy in the morning peak period declined below 1.1 for both direction of travel on I-90 in the post-deployment period, and to less than 1.2 in afternoon peak period.

[2] http://trac29.trac.washington.edu/hov/index.jsp. Accessed August 2013.



Source: Google Maps; modified by Texas A&M Transportation Institute.

Figure A-32. Location of Average Vehicle Occupancy Corridor Sample Points

The morning and afternoon peak period average vehicle occupancy levels for non-transit vehicles on SR 522 remained relatively constant in both directions of travel. In the morning peak period, the average non-transit vehicle occupancy level declined from 1.08 to 1.09 in the eastbound direction of travel and from 1.14 to 1.11 in the westbound direction, both representing a 2 percent decline. In the afternoon peak period, average vehicle occupancy declined from 1.30 for both directions of travel to 1.17, a 10 percent reduction, for the eastbound direction of travel and to 1.24, a 5 percent reduction, in the westbound direction.

Table A-12. Change in the Average Vehicle Occupancy of Non-Transit Vehicles in the LWC

Period	Direction	Average Vehicle Occupancy (persons)			
		Pre-Deployment	Post-Deployment	Change	Percent Change
SR 520 at Yarrow Point					
A.M. Peak	EB	1.04	1.04	0.00	0%
	WB	1.22	1.11	-0.11	-9%
P.M. Peak	EB	1.23	1.17	-0.06	-5%
	WB	1.40	1.21	-0.19	-14%
I-90 at Island Crest Way					
A.M. Peak	EB	1.10	1.09	-0.01	-1%
	WB	1.07	1.06	-0.01	-1%
P.M. Peak	EB	1.16	1.13	-0.03	-2%
	WB	1.20	1.18	-0.02	-1%
SR 522 Near Bothell Park-N-Ride					
A.M. Peak	EB	1.08	1.09	0.01	-1%
	WB	1.14	1.11	-0.03	-2%
P.M. Peak	EB	1.30	1.17	-0.13	-10%
	WB	1.30	1.24	-0.06	-5%

Source: Texas A&M Transportation Institute.

Using the information on average vehicle occupancy and vehicle throughput, the effects of the UPA improvements on total person throughput were also examined for the SR 520, I-90, and SR 522 corridors. Person throughput was estimated by multiplying vehicle throughput by the average number of occupants per vehicles observed on each facility. The total peak period person throughput for the non-transit improvements was computed for both peak directions of flow for the pre- or post-deployment evaluation periods and are summarized in Table A-13.

Table A-14 presents the changes in average transit ridership in both the peak periods from Appendix C – Transit Analysis. The average peak period transit ridership increased on bus routes using SR 520 in both the morning and afternoon peak-periods in both directions of travel. The average peak period ridership on routes using the I-90 HOV lane declined in the morning westbound direction, but increased in the afternoon eastbound direction. Average peak period transit ridership on SR 522 declined in the eastbound direction, but increased in the westbound direction during both the morning and afternoon peak-periods.

Table A-15 presents the changes in the pre- and post-deployment total person throughput for both directions of travel on SR 520, I-90, and SR 522 during the morning and afternoon peak periods. Total person throughput was computed by summing the non-transit and the transit person throughput for each evaluation period for each facility. Figure A-33 provides a graphical comparison of the pre- and post-deployment total person-throughput in the evaluation corridors.

The total peak period throughput on SR 520 declined by approximately 20 percent in the eastbound direction and 14 percent in the westbound direction in the morning peak period and declined by 23 percent in the eastbound direction and 11 percent in the westbound direction in the afternoon peak period. Total peak-period throughput on I-90 increased by 17 percent in the eastbound direction and declined by 6 percent in the westbound direction in the morning peak period. In the afternoon peak period the total peak-period person throughput on I-90 declined by 13 percent in the eastbound direction and increased by 14 percent in the westbound direction. The total peak-period person throughput on SR 522 increased by approximately 12 percent in the morning peak period in both directions of travel and by almost 2 percent in both directions of travel in the afternoon peak period. These results indicate that tolling the SR 520 bridge resulted in a reduction in total peak-period person throughput on the bridge. At the same time, peak-period person throughput on I-90 declined during the morning and afternoon peak periods in the peak direction of travel, probably resulting from increased congestion levels. Total peak-period person throughput increased on I-90 in the off-peak direction of travel and also increased on SR 522 in both the morning and afternoon peak periods, probably reflecting travelers diverting from SR 520 to avoid paying the toll on the SR 520 bridge.

Table A-13. Computation of the Non-Transit Peak-Period Person Throughput

Period	Direction	Pre-Deployment			Post-Deployment		
		Vehicle Throughput	Average Vehicle Occupancy	Person Throughput	Vehicle Throughput	Average Vehicle Occupancy	Person Throughput
SR 520							
A.M. Peak	EB	12604	1.04	13119	9476	1.04	9896
	WB	15838	1.22	19307	13878	1.11	15364
P.M. Peak	EB	10731	1.23	13172	7199	1.17	8406
	WB	14861	1.40	20798	14799	1.21	17893
I-90							
A.M. Peak	EB	13168	1.10	14495	15507	1.09	16965
	WB	15613	1.07	16710	15642	1.06	16616
P.M. Peak	EB	12871	1.16	14899	14271	1.13	16153
	WB	12970	1.20	15543	11350	1.18	13408
SR 522							
A.M. Peak	EB	4741	1.08	5140	5422	1.09	5901
	WB	4751	1.14	5404	5364	1.11	5954
P.M. Peak	EB	5510	1.30	7171	6263	1.17	7335
	WB	5361	1.30	6973	5675	1.24	7025

Source: Texas A&M Transportation Institute.

Table A-14. Change in Pre- and Post-Transit Ridership

Period	Direction	Pre-Deployment	Post-Deployment
		Average Peak Period Ridership	Average Peak Period Ridership
SR 520			
A.M. Peak	EB	1,343	1,701
	WB	3,098	3,893
P.M. Peak	EB	2,977	4,033
	WB	1,957	2,388
I-90			
A.M. Peak	EB	–	–
	WB	3,708	2,615
P.M. Peak	EB	3,684	4,265
	WB	–	–
SR 522			
A.M. Peak	EB	184	139
	WB	955	1,185
P.M. Peak	EB	598	550
	WB	142	219

Source: Texas A&M Transportation Institute.

Table A-15. Computation of Total Peak-Period Person Throughput

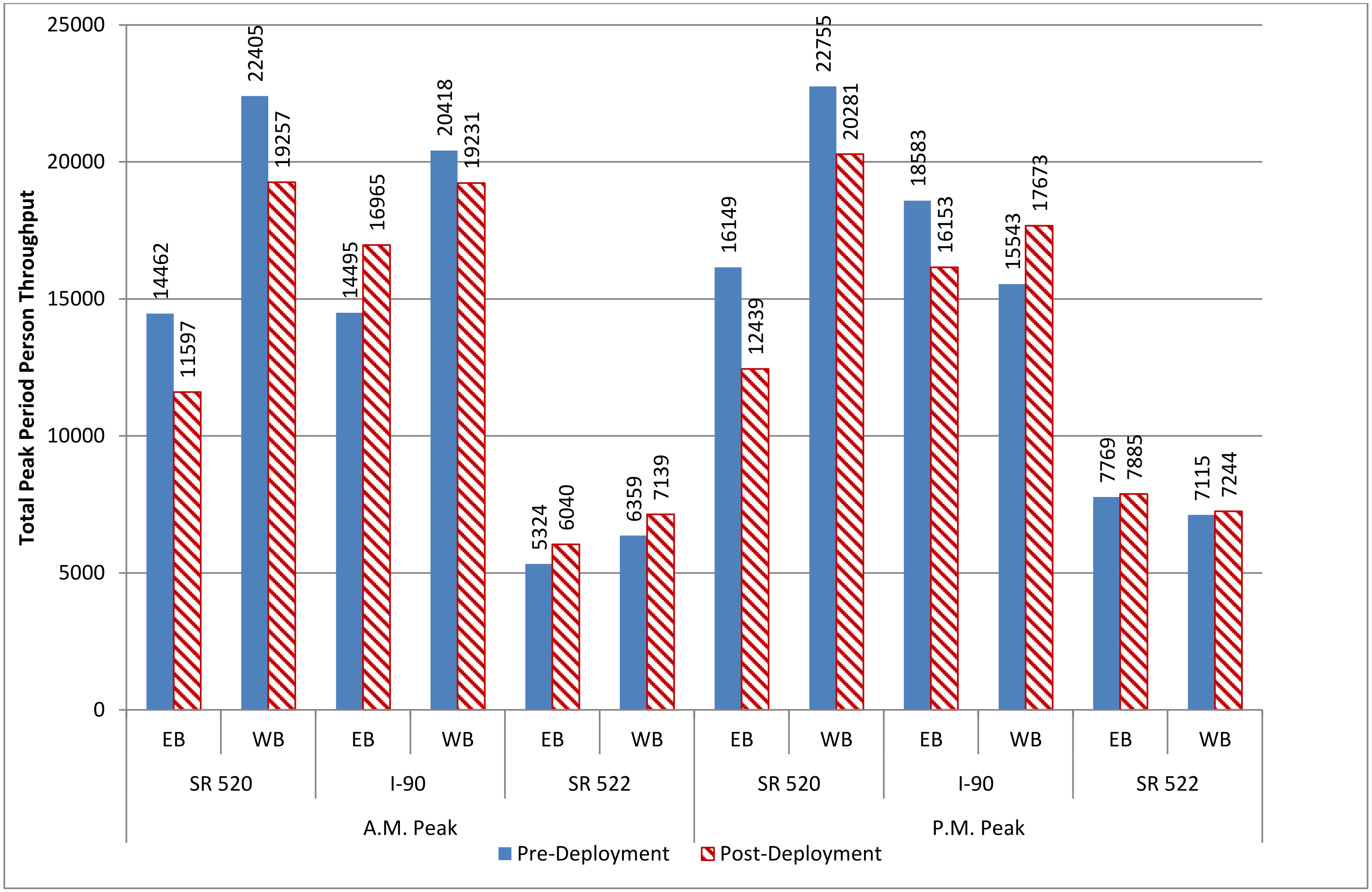
Period	Direction	Pre-Deployment			Post-Deployment		
		Non-Transit Person Throughput	Transit Person Throughput	Total Person Throughput	Non-Transit Person Throughput	Transit Person Throughput	Total Person Throughput
SR 520							
A.M. Peak	EB	13119	1,343	19,962	9896	1,701	11,597
	WB	19307	3,098	22,405	15364	3,893	19,257
P.M. Peak	EB	13172	2,977	16,149	8406	4,033	12,439
	WB	20798	1,957	22,755	17893	2,388	20,281
I-90							
A.M. Peak	EB	14495	–	14,495	16965	–	16,965
	WB	16710	3,708	20,418	16616	2,615	19,231
P.M. Peak	EB	14899	3,684	18,583	16153	4,265	20,418
	WB	15543	–	15,543	13408	–	13,408
SR 522							
A.M. Peak	EB	5140	184	5,324	5901	139	6,040
	WB	5404	955	6,359	5954	1,185	7,139
P.M. Peak	EB	7171	598	7,796	7335	550	7,885
	WB	6973	142	7,115	7025	219	7,244

Source: Texas A&M Transportation Institute

Table A-16. Percent Change in Peak Period Person Throughput Over and Around Lake Washington

Period	Direction	Peak Period Person Throughput			
		Pre-Deployment	Post-Deployment	Change	Percent Change
SR 520					
A.M. Peak	EB	19,962	11,597	-8,365	-41.9%
	WB	22,405	19,257	-3,148	-14.1%
P.M. Peak	EB	16,149	12,439	-3,710	-23.0%
	WB	22,755	20,281	-2,474	-10.9%
I-90					
A.M. Peak	EB	14,495	16,965	2,470	17.0%
	WB	20,418	19,231	-1,187	-5.8%
P.M. Peak	EB	18,583	20,418	1,835	9.9%
	WB	15,543	13,408	-2,135	-13.7%
SR 522					
A.M. Peak	EB	5,324	6,040	716	13.4%
	WB	6,359	7,139	780	12.3%
P.M. Peak	EB	7,796	7,885	89	1.1%
	WB	7,115	7,244	129	1.8%
Total Crossing Lake					
A.M. Peak	EB	39,781	34,602	-5,179	-13.0%
	WB	49,182	45,627	-3,555	-7.2%
P.M. Peak	EB	42,528	40,742	-1,786	-4.2%
	WB	45,413	40,933	-4,480	-9.9%

Source: Texas A&M Transportation Institute.



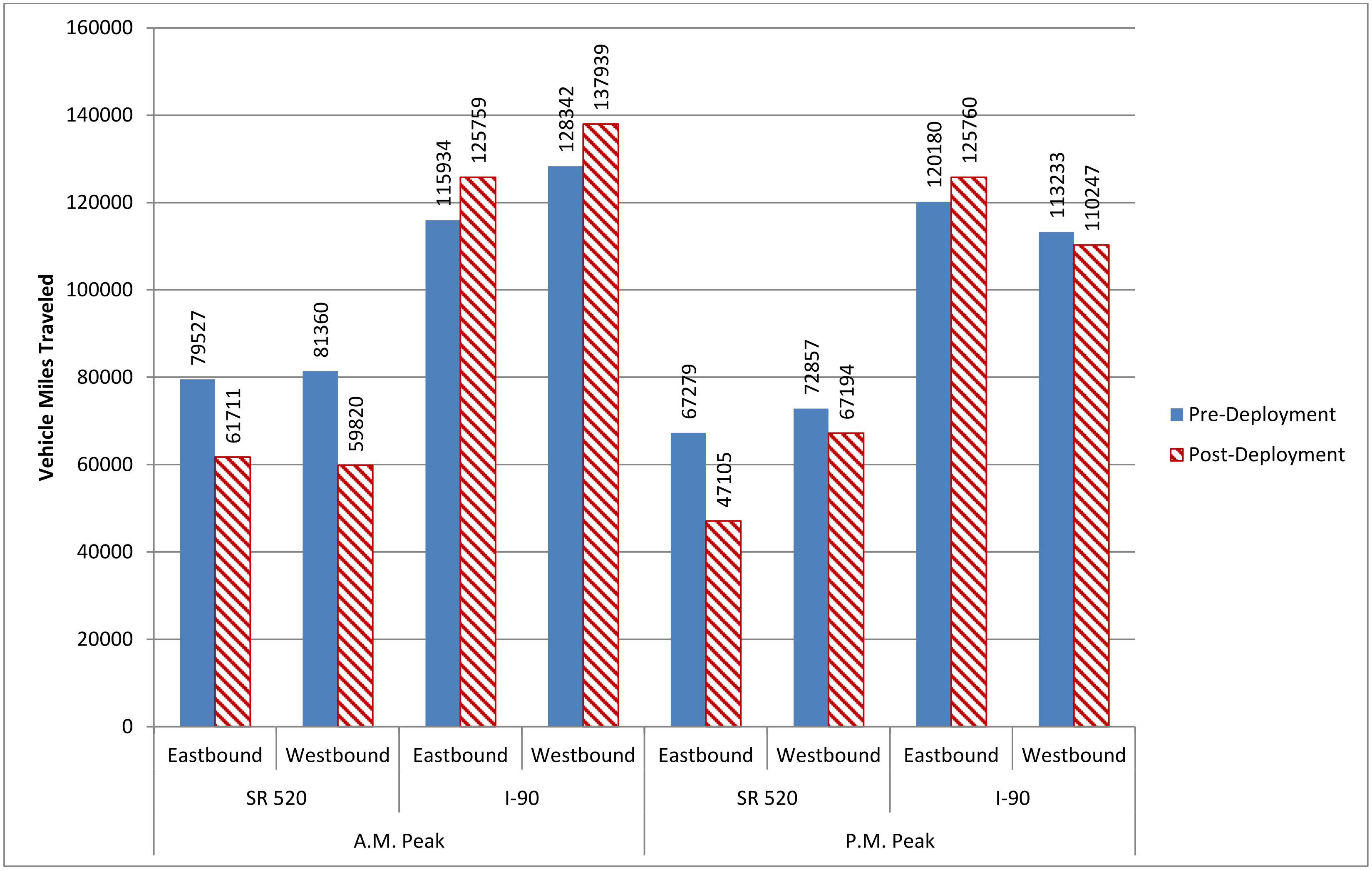
Source: Texas A&M Transportation Institute.

Figure A-33. Screenline Total Peak Period Throughput for SR 520, I-90, and SR 522 in the LWC (I-405 to I-5)

A.6 Changes in Vehicle Miles Traveled

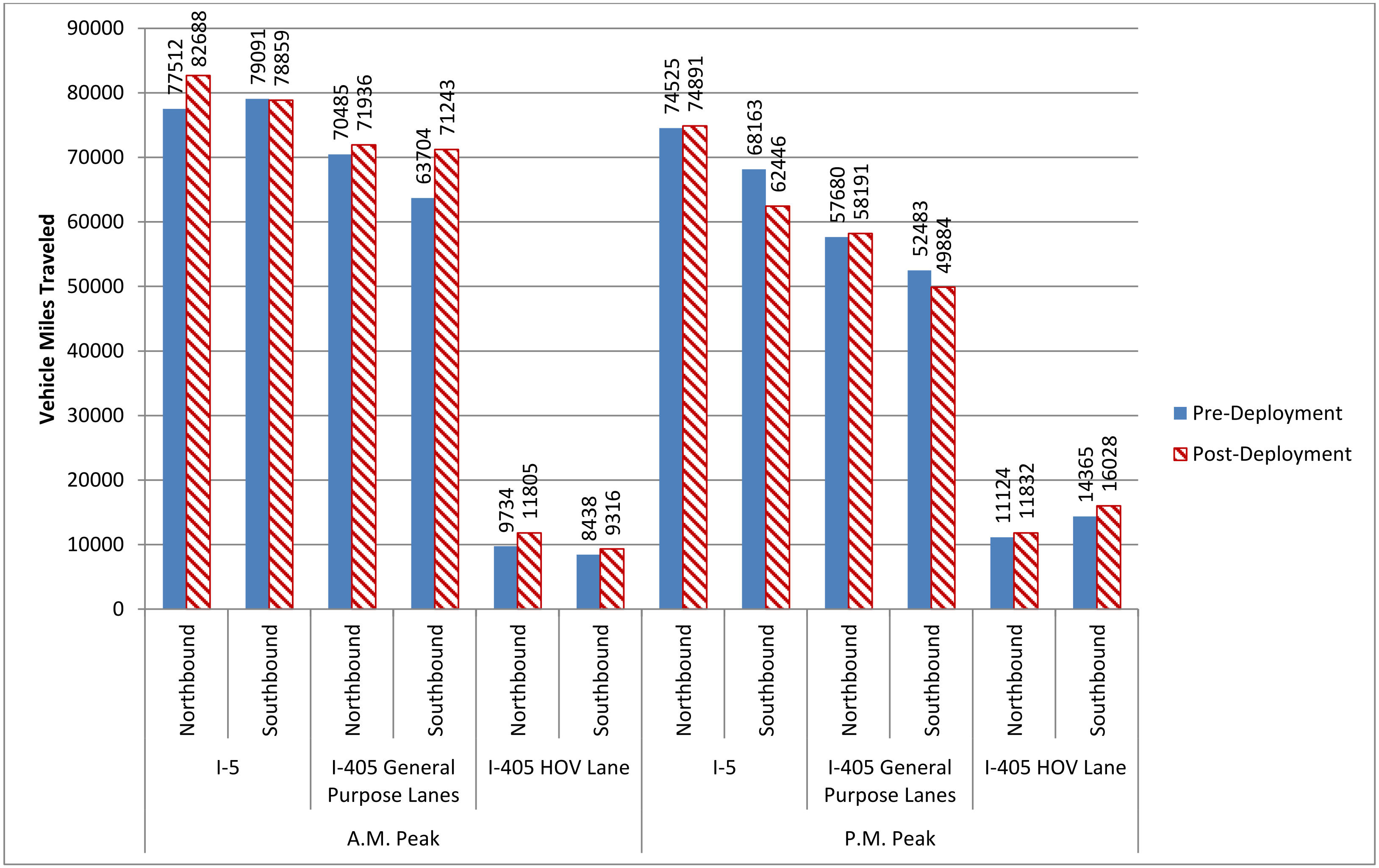
Figure A-34 through Figure A-37 present the changes in peak period VMT on SR 520, I-90, and the other freeways. Table A-17 and Table A-18 present the same information, along with the total changes and the percent change. As highlighted in Figure A-34, VMT on SR 520 declined in the morning and afternoon peak periods in both directions of travel. The morning peak period VMT declined 22 percent in the eastbound direction and 26 percent in the westbound direction. During the afternoon peak period, VMT declined by 30 percent in the eastbound direction and by 7 percent in the westbound direction. On I-90, VMT increased by 8 percent in the eastbound direction and 7 percent in the westbound direction in the morning peak period. In the afternoon peak period, VMT on I-90 increased by 5 percent in the eastbound direction, but declined by approximately 3 percent in the westbound direction.

Figure A-35 provides a comparison of VMT on I-5 and I-405 between SR 520 and I-90. In the morning peak period, VMT in the northbound direction on I-5 increased by approximately 7 percent, and remained relatively unchanged in the southbound direction. In the afternoon peak period, VMT in the southbound direction on I-5 declined by approximately 8 percent, while VMT remained the same in the northbound direction. On I-405, VMT in the general purpose lanes in the southbound direction increased by approximately 12 percent in the morning peak period and remained relatively constant in the northbound direction. In the afternoon peak period, VMT in the northbound direction on I-405 decreased by 5 percent and remained unchanged in the southbound direction. The I-405 HOV lanes experienced a slight increase in VMT in the morning and afternoon peak periods in both the northbound and southbound direction of travel. As illustrated in Figure A-36 and Figure A-37, VMT remained generally the same or changed only slightly on the other freeway segments. In most cases, the changes reflect increases in VMT in the peak direction of travel.



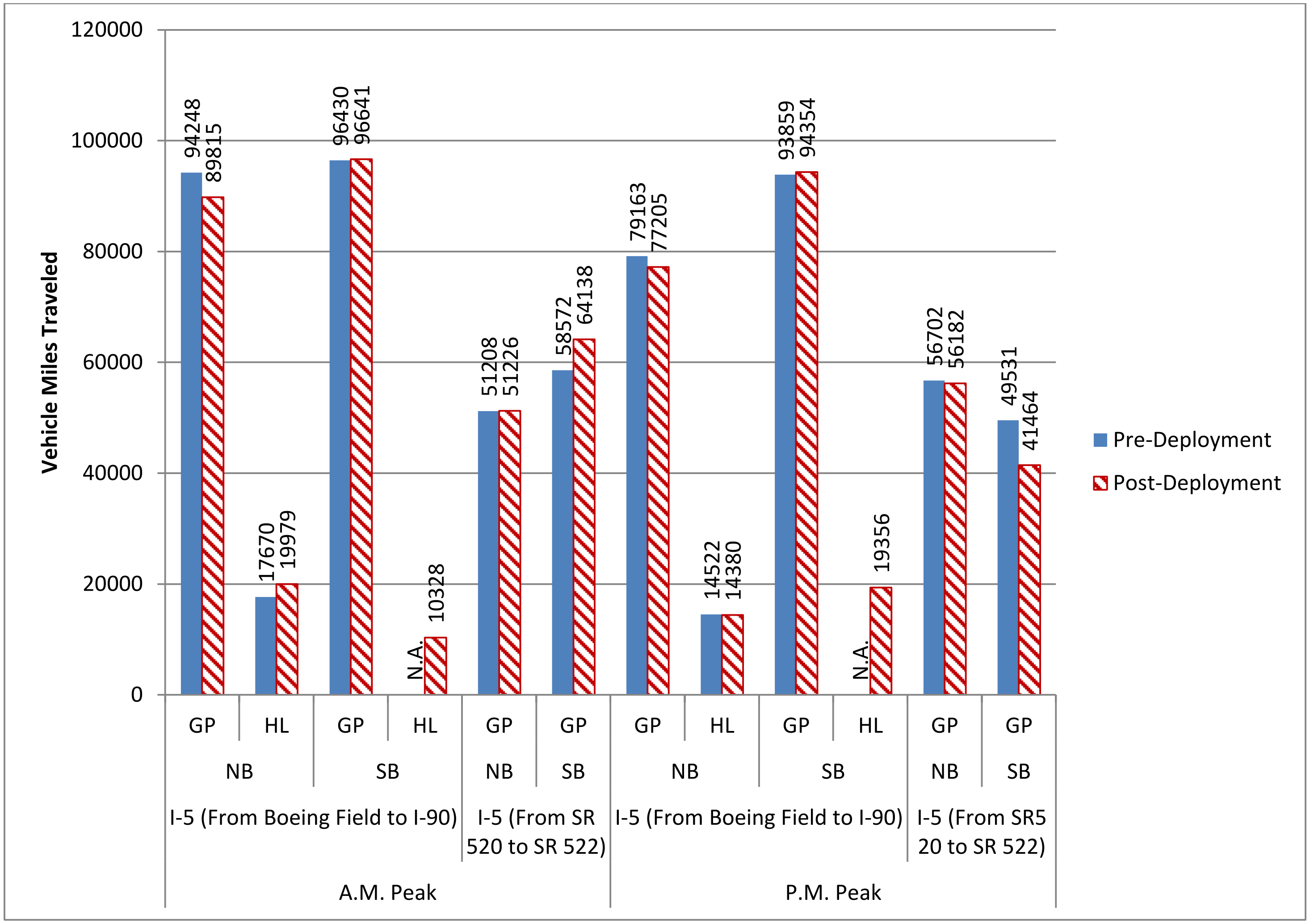
Source: Texas A&M Transportation Institute.

Figure A-34. Comparison of Vehicle Miles Traveled for SR 520 and I-90



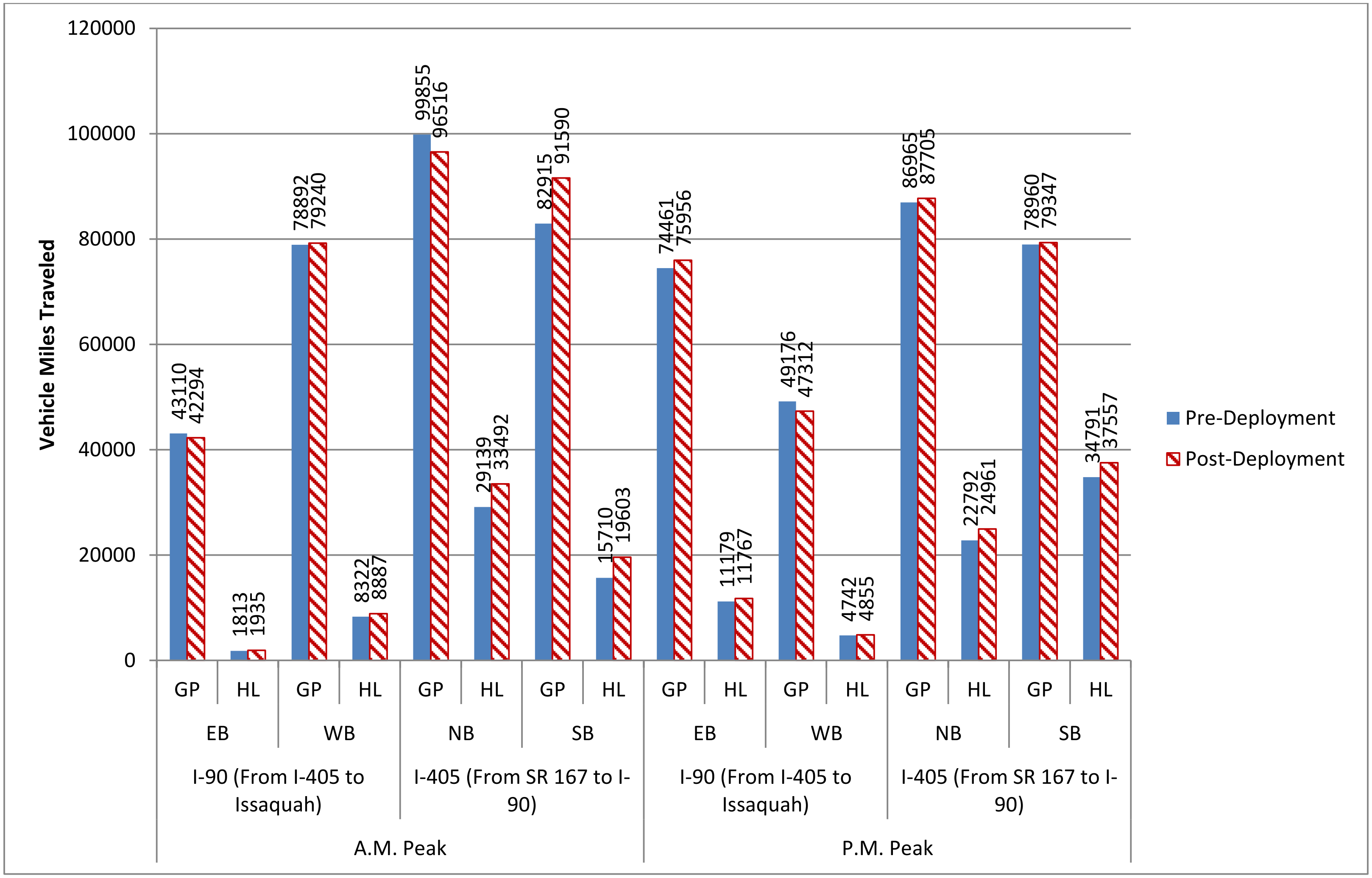
Source: Texas A&M Transportation Institute.

Figure A-35. Comparison of Vehicle Miles Traveled on I-5 and I-405 between SR 520 and I-90



Source: Texas A&M Transportation Institute.

Figure A-36. Vehicle Miles Traveled on Links Approaching the LWC during the A.M. and P.M. Peak Periods



Source: Texas A&M Transportation Institute.

Figure A-37. Vehicle Miles Traveled on Links Approaching the LWC during the A.M. and P.M. Peak Periods

Table A-17. Pre- and Post-Deployment VMT – A.M. Peak

Roadway	Limits	Direction	VMT – a.m. peak			
			Pre-Deployment	Post-Deployment	Change	Percent Change
SR 520	I-405 to I-5	EB	79527	61710	-17816	-22.4%
		WB	81360	59820	-21540	-26.5%
I-90	I-405 to I-5	EB	115934	125759	9825	8.5%
		WB	128342	137939	9598	7.5%
	I-405 and Issaquah (GP)	EB	44923	44229	-693	-1.5%
		WB	87213	88127	914	1.0%
	I-405 and Issaquah (HOV)	EB	1813	1935	123	6.8%
		WB	8322	8887	566	6.8%
I-5	SR 522 to SR 520	NB	51208	51226	18	0.0%
		SB	58572	64138	5566	9.5%
	SR 520 to I-90	NB	77512	82688	5176	6.7%
		SB	79091	78859	-232	-0.3%
	I-90 and Boeing Field (GP)	NB	94248	89815	-4433	-4.7%
		SB	96430	96641	211	0.2%
	I-90 and Boeing Field (HOV)	NB	17670	19973	2309	
		SB	N.A.	10328	N.A.	N.A.
I-405	I-90 to SR 169 (GP)	NB	99855	96516	-3338	-3.3%
		SB	82915	91590	8675	10.5%
	I-90 to SR 169 (HOV)	NB	29139	33492	4353	14.9%
		SB	15710	19603	3893	24.8%
	I-90 to SR 520 (GP)	NB	70485	71936	1451	2.1%
		SB	63704	71243	7539	11.8%
	I-90 to SR 520 (HOV)	NB	9734	11805	2071	21.3%
		SB	8438	9316	878	10.4%
	SR 520 to SR 522 (GP)	NB	128809	127555	-1254	-1.0%
		SB	184787	182041	-2746	-1.5%
	SR 520 to SR 522 (HOV)	NB	11649	12997	1348	11.6%
		SB	37850	38843	992	2.6%

Source: Texas A&M Transportation Institute.

Table A-18. Pre- and Post-Deployment VMT – P.M. Peak

Roadway	Limits	Direction	VMT– p.m. peak			
			Pre-Deployment	Post-Deployment	Change	Percent Change
SR 520	I-405 to I-5	EB	67279	47105	-20174	-30.0%
		WB	72857	67194	-5663	-7.8%
I-90	I-405 to I-5	EB	120180	125760	5580	4.6%
		WB	113233	110247	-2986	-2.6%
	I-405 and Issaquah (GP)	EB	74461	75956	1495	2.0%
		WB	49176	47312	-1864	-3.8%
	I-405 and Issaquah (HOV)	EB	11179	11767	588	5.3%
		WB	4742	4855	112	2.4%
I-5	SR 522 to SR 520	NB	56702	56182	-519	-0.9%
		SB	49531	41464	-8067	-16.3%
	SR 520 to I-90	NB	74525	74891	366	0.5%
		SB	68163	62446	-5717	-8.4%
	I-90 and Boeing Field (GP)	NB	79163	77205	-1958	-2.5%
		SB	93589	94354	765	0.8%
	I-90 and Boeing Field (HOV)	NB	14522	14380	-142	-1.0%
		SB		19356		
I-405	I-90 to SR 169 (GP)	NB	86965	87705	740	0.9%
		SB	78960	79347	387	0.5%
	I-90 to SR 169 (HOV)	NB	22792	24961	2170	9.5%
		SB	34791	37557	2766	8.0%
	I-90 to SR 520 (GP)	NB	57680	58191	511	0.9%
		SB	52483	49884	-2599	-5.0%
	I-90 to SR 520 (HOV)	NB	11124	11832	708	6.4%
		SB	14365	16028	1663	11.6%
	SR 520 to SR 522 (GP)	NB	166044	142105	-23940	-14.4%
		SB	130788	132214	1426	1.1%
	SR 520 to SR 522 (HOV)	NB	39541	40258	717	1.8%
		SB	22528	25410	2883	12.8%

Source: Texas A&M Transportation Institute.

A.7 User Perceptions

Information on the perceptions of travelers in the areas related to the impact of tolling the SR 520 bridge and other UPA projects on traffic congestion on SR 520, I-90, and other freeways is available from surveys sponsored by Volpe, WSDOT, and King County Metro Transit. The WSDOT-sponsored interviews with WSP troopers, IRT operators, and King County Metro Transit bus operators also included questions on changes in congestion levels resulting from tolling the SR 520 bridge and other UPA projects. This section summarizes the results from the congestion-related questions included in these surveys and interviews.

A.7.1 SR 520 Corridor Household Panel Study

To support the Seattle/LWC National Evaluation, Volpe-sponsored a household panel study in the SR 520 and I-90 corridors. The study included a structured survey and a 48-hour travel diary of individuals in households in the pre- and post-deployment periods. The same households were surveyed in both time periods. The survey consisted of a demographic questionnaire, a travel diary, and follow-up questions on current travel patterns and attitudes. The travel diary covered a 48-hour period in which respondents recorded the details of all trips, including origin, destination, time, travel mode, and purpose. There were specific follow-up questions related to trip satisfaction for travel on SR 520 and I-90.

The Wave 1 or pre-deployment surveys were conducted in November 2010 and the Wave 2 or post-deployment surveys were conducted in April and May, 2012. The survey was conducted by the Resource Systems Group (RSG). Participants were identified by recording vehicle license plates in the SR 520 and I-90 corridors and by intercepting transit riders in both corridors. Vanpoolers were recruited by email through the King County Vanpool program. The panel was comprised of 2,063 households, with a total of 3,698 adults. The overall response rate in Wave 1 was 10 percent and 61 percent of Wave 1 households completed Wave 2 surveys, reflecting a 6 percent response rate overall.

Based on the weighted Wave 1 and 2 panels, the survey respondents were more females, 52 percent, than males, 48 percent. In terms of race, 81 percent of the respondents reported they were white, compared to 1 percent black, 15 percent Asian, and 4 percent multiple races. In terms of age, 69 percent of the respondents were in the 25-to-54 age group, 19 percent were 55-to-65 years of age, 7 percent were 65 years of age and older, and 5 percent were 18-to-24 year olds. In terms of household income, 30 percent reported household incomes of $50,000-to-$99,999 a year, 24 percent made $100,000-to-$150,000, 21 percent made over $150,000, 11 percent made under $50,000, and 14 percent did not provide a response. A total of 64 percent of the households were adult-only households and 36 percent were households with children. A total of 49 percent of households reported two vehicles, 30 percent reported one vehicle, 20 percent reported three or more vehicles, and 1 percent reported no vehicles. A total of 79 percent of the respondents reported education levels of a bachelor's degree or higher. A total of 68 percent of the respondents reported being employed full-time, 8 percent were employed part-time, 6 percent were self-employed, 4 percent were students, 7 percent were homemakers, 7 percent were retired, and 3 percent were unemployed.

A comparison of the Wave 1 and Wave 2 survey results and travel diaries provides insight into the use of SR 520 and I-90, changes in travel behavior resulting from the tolling the SR 520 bridge, and perceptions on changes in congestion levels on the SR 520 bridge and I-90. Differences from Wave 1 to Wave 2 were found to be significant at the 95 percent level unless noted, using paired and unpaired t-test and chi-squared as appropriate. Examples of these changes are highlighted in the following.

- The number of reported trips in the LWC declined. Corridor trips, using both SR 520 and I-90, recorded in travel diaries declined by 18 percent and by 19 percent in respondent's estimate of typical weekly travel in the corridor. Travel on SR 520 recorded in the diaries declined by 43 percent, while travel on I-90 declined 13 percent. An offsetting increase in non-corridor travel did not occur.
- The share of corridor trips on SR 520 declined, while the share of corridor trips for I-90 and SR 522 increased. Avoiding the SR 520 bridge toll was the reported motivation for 86 percent of those noting a change from SR 520 to I-90 or SR 522.
- Changes did occur among respondents reporting using SR 520 as their primary route in Wave 1. In Wave 2, 55 percent of those individuals were still using SR 520 as the primary route, 24 percent had changed to using I-90 as their primary route, 7 percent had switched to SR 522, 8 percent had changed to riding the bus, 4 percent had changed to another route or mode, and 1 percent stopped making trips across the lake on a regular basis.
- Trip satisfaction, as reported for each trip on a 7-point scale (1 = strongly disagree, 3 = neutral, 7 = strongly agree), increased on SR 520 in Wave 2. The mean score for satisfaction with peak period travel speeds on the SR 520 bridge increased from 3.4 to 5.2 from Wave 1 to Wave 2. The satisfaction with trips on I-90 declined slightly. The statement "Tolling on SR 520 has improved my travel" received a mean score of 3.3 in Wave 2. The question was not asked in Wave 1.

A.7.2 WSDOT SR 520 Tolling Surveys

WSDOT sponsored a number of surveys and focus groups as part of implementing the SR 520 bridge tolling system. Initial market research activities focused on gauging public support for the project, identifying factors influencing individuals to open a toll account, and developing and testing marketing messages. Baseline and midpoint surveys were conducted in April and August 2010 to measure the effectiveness of the marketing efforts aimed at educating the public on the basic elements of the SR 520 bridge project and tolling.

The final evaluation telephone survey of 800 households was conducted from October 26 to November 4, 2012 by PRR to obtain information on the impact of the marketing and education programs on the purchase of toll tags, and the understanding of the tolling system, and the impact of tolling on travel behavior and attitudes. The survey used Computer Assisted Telephone Interviewing (CATI) software. A random digital dialing telephone sample for King County residents and a list of cell phone numbers for King County were both purchased by PRR for use in the survey. A minimum quota was set for 20 percent of completed interviews from cell phone-only users or mostly cell phone users. The final composition of survey respondents was 57 percent landline phone interviews and 43 percent cell phone interviews. Four attempts at different times of the day and different days of the week were made to contact the randomly selected households. The overall margin of error for the telephone survey was +/- 3.46 percent at the 95 percent confidence interval.

The survey included a number of questions related to use of the SR 520 bridge tolling system, changes in travel behavior due to the bridge tolling, and perceptions of the impact of the tolling system on congestion on SR 520, I-90, and other freeways in the area. The responses to questions related to changes in congestion are summarized here.

- Reported use of the SR 520 bridge declined from the baseline survey, through the midpoint survey to the final survey. The majority of respondents, 69 percent, reported they had not changed their time of travel on the SR 520 bridge, but 32 percent indicated they had changed their time of travel. Of those reporting a change in travel time, 50 percent indicated they had done so to use the bridge when the toll was lower, while 19 percent did so to use the bridge when traffic was lighter. There was a slight decline – from 25 percent to 23 percent – in reported travel during the weekday morning peak period (5:00 a.m. to 9:00 a.m.) and in the evening (after 7:00 p.m. and before 10:00 p.m.) – 34 percent to 31 percent. Mid-day travel (after 9:00 a.m. and before 3:00 p.m.) remained constant at 53 percent, while travel in the afternoon peak period (3:00 p.m. to 7:00 p.m.) increased slightly from 40 percent to 43 percent.
- Survey respondents reported a perception that traffic congestion had decreased on the SR 520 bridge. Approximately half, 51 percent, of the respondents in the final survey indicated that the SR 520 bridge was not congested at all since tolling was implemented, compared to 21 percent in the baseline survey. The majority of respondents, 62 percent, in the final survey reported their trips were faster across the bridge since tolling began.

A.7.3 King County Metro Transit Surveys of Bus Riders

Two surveys were conducted of riders on routes operated by King County Metro Transit using the SR 520 bridge, including the Sound Transit routes operated by King County Metro Transit. The first survey was administered in March 2011, prior to tolling on the SR 520 bridge. The second survey was conducted in May 2011, approximately five months after tolling was initiated. The margin of error for the pre-toll survey was +/- 2.6 percent at the 95 percent confidence level and the margin of error for the post-toll survey was +/- 2.5 percent at the 95 percent confidence level.

A total of 82 percent of riders responded that the SR 520 bridge was less congested since the tolling was initiated. Riders were split on the influence of tolling on bus travel times and travel speeds, with 47 percent indicating that travel speeds were the same and 46 percent reporting they were faster. More information from the surveys is presented in Appendix C – Transit Analysis.

A.7.4 Interviews with Washington State Patrol Troopers, IRT Operators, and King County Metro Transit Bus Operators

WSDOT sponsored interviews with WSP troopers, IRT operators, and King County Metro Transit bus operators as part of the national evaluation. The primary purpose of the interviews was to obtain the perspective of individuals who travel the SR 520 and I-90 corridors on a regular basis and who are responsible for traffic enforcement, traffic safety, and incident response. Questions in the interviews focused on perceived changes in safety, the number and severity of crashes, congestion levels, and incident response and clearance times due to the travel time signs, and the ATM variable speed and lane controls on SR 520 and I-90, and the SR 520 toll system and toll signage. One of the interview questions asked if the individuals if they had noticed any changes in congestion on the SR 520 bridge before-and-after the implementation of tolling and if they thought the changes were related to tolling.

The three sets of interviews were conducted by Jacobs Engineering Group. A total of 3 WSP troopers, 2 IRT operators, and 3 King County Metro Transit bus operators were interviewed. Responses to the questions focusing on changes in congestion and the potential impacts on the UPA projects on these changes are summarized in this section.

Participants in all three sets of interviews indicated that based on their experience and observations, congestion levels on SR 520 had declined. Participants also noted that traffic congestion and crashes and incidents had increased on I-90. These changes were attributed primarily to the implementation of tolling on the SR 520 bridge. The WSP troopers suggested that drivers were diverting to I-90 rather than paying a toll to use the SR 520 bridge. IRT operators also noted lower levels of traffic congestion on the SR 520 bridge since tolling was implemented, with increased congestion and incidents on I-90. They suggested the public is avoiding the SR 520 bridge and using I-90 and other routes because of the tolling. Bus operators noted that travel speeds were faster on the SR 520 bridge since tolling was implemented. They also noted congestion levels were worse on I-90 and on SR 522 after tolling was initiated.

A.8 Summary of Congestion Analysis

As highlighted in Table A-19, the implementation of tolling on the SR 520 bridge and other UPA projects achieved results that were consistent with the expectations of the local partners in term of congestion impacts. The impacts related to the 11 hypotheses are summarized in this section.

The national evaluation team found that after all the UPA improvements were deployed, mean travel times reduced and travel speed increased on SR 520 in both the morning and afternoon peak periods. The morning mean peak period travel time was reduced by approximately 2 minutes in both directions of travel – a 25 percent reduction – and mean travel speeds on SR 520 increased from approximately 45 mph to 56 mph in the eastbound direction in the morning peak period and from approximately 47 mph to 58 mph in the westbound direction. In the afternoon peak period, the mean travel time declined by 2 minutes in the eastbound direction of travel and by approximately 8 minutes in the westbound direction. This change caused mean travel speeds on SR 520 during the afternoon peak period to increase from approximately 47 mph to 60 mph in the eastbound direction and from 27 to approximately 45 mph in the westbound direction.

The evaluation also found that implementing the UPA improvements had mixed effects on travel times and average speeds on the other routes (such as I -90 and SR 522) crossing Lake Washington. Mean travel times on I-90 increased by only approximately 1 minute in both directions of travel in the morning peak-period. This means that morning peak period travel speeds on I-90 dropped slightly from approximately 60 mph to 57 mph in the eastbound direction and from 57 mph to 56 mph in the westbound direction. In the afternoon peak period, mean travel times and average travel speeds remained approximately the same in the eastbound direction; however, mean travel times on I-90 in the westbound direction increased from 10.6 minutes to 13.6 minutes and mean travel speeds declined almost 50 mph to 41 mph. This suggests that westbound travelers on I-90 experience a noticeable degradation in performance during the evening commute after the UPA deployments were implemented.

Changes in mean travel times on other area freeways were also mixed. In general, travel times increased in the peak direction of travel and remained the same or declined slightly in the off peak direction. Similar trends occurred in changes in travel speeds. Changes in mean travel speeds on the other freeways were similar to the changes in mean travel times, with some travel speeds decreasing in the peak direction of travel on some facilities and remaining constant or increasing in the off-peak direction.

As expected, implementing the UPA improvements also resulted in improving travel time reliability on SR 520, as measured by the 95th percentile travel time and the Buffer Index. The 95th percentile travel time on SR 520 declined by approximately 3 minutes in the eastbound direction and 6 minutes in the westbound direction in the morning peak period, and by 6 minutes in the eastbound direction and 13 minutes in the westbound direction in the afternoon peak period. This implies that travel on SR 520 for I-5 to I-405 became more stable once the UPA improvements were implemented. The Buffer Index on SR 520 increased slightly in the eastbound direction in the morning peak period and the westbound direction in the afternoon, but declined in the morning westbound direction and afternoon eastbound direction. Travel time reliability on I-90, I-5, I-405, and SR 522 experienced mixed changes. Except for the westbound direction in the afternoon peak period, the 95th percentile travel time on I-90 were generally the same after the UPA improvements was implemented compared to the before. The Buffer Index on I-90 declined for traffic traveling eastbound in the morning peak period and westbound in the afternoon peak period, but increased for traffic traveling westbound in the morning peak period and eastbound in the afternoon peak period.

As expected by the local partners, the UPA improvements were successful at reducing travel demands on SR 520. Average vehicle throughput on SR 520 in the morning and afternoon peak period in both directions of travel declined. In the morning peak period, average vehicle throughput declined by 25 percent in the eastbound direction of travel and by 12 percent in the westbound direction. In the afternoon peak-period, vehicle throughput on SR 520 declined by 33 percent in the eastbound direction. This implies that implementing tolling on SR 520 caused travelers to seek alternate routes or cancel trips altogether over Lake Washington.

Vehicle throughput on I-90 increased in the eastbound direction in the morning peak period and the eastbound direction in the afternoon peak period, remained unchanged in the westbound direction in the morning peak period, and declined in the westbound direction in the afternoon peak period. Vehicle throughput on I-5, I-405, and SR 522 experienced similar mixed changes, with no major dramatic change. The same trends were evident in changes in person throughput on SR 520, I-90, I-5, SR 522, and I-405.

These changes in vehicle throughput caused the total person throughput for the roadways across and around Lake Washington to decline slightly between the pre- to post-deployment periods. For example, total person throughput for SR 520, I-90, and SR 522 in the morning peak period declined from 39,781 persons to 28,568 persons in the eastbound direction – a 13 percent reduction. Total combined person throughput in the westbound direction dropped by only 7 percent (from 49,182 persons to 45,627 persons). The combined total afternoon peak-period person throughput on these three facilities declined by only 4 percent from 42,528 persons to 40,742 persons in the eastbound direction and by 10 percent (from 45,413 to 40,993 persons) in the westbound direction. These changes suggest that implementing the UPA improvements may have even caused some travelers to change shift their travel out of the peak periods altogether.

The analysis indicates that congestion did increase during some parts of the morning and afternoon peak periods; however, with the exception of I-90, these increases appear to be relatively minor. On I-90, there appeared to be substantial spreading of peak period congestion temporally. An analysis of travel times and travel speeds by 30 minute intervals within the peak periods showed a congestion forming earlier in the peak on I-90 particularly in the westbound direction in the afternoon peak The duration of congestion beyond the morning and afternoon peak periods was not examined in this analysis.

The results of the Volpe household travel survey, the WSDOT-sponsored survey of corridor travelers, and the King County Metro Transit survey of bus riders indicated that users perceived that congestion levels on the SR 520 bridge have declined since tolling was implemented. The responses to these same surveys indicated that travelers' perceived congestion was worse on I-90 as a result of tolling the SR 520 bridge. The comments made during the WSDOT-sponsored interviews of WSP troopers, IRT operators, and King County Metro Transit bus operators also support the perception that congestion was reduced on SR 520, but increased on I-90 and SR 522. Information on perceptions of changes in congestion on I-5 and I-405 was not obtained in the surveys or interviews.

Table A-19. Summary of Impacts Across Congestion Hypotheses

Hypotheses	Result	Evidence
Deploying the UPA projects will reduce travel times and increase speeds on SR 520 over Lake Washington between I-5 and I-405.	Supported	Travel times on SR 520 were reduced and travel speeds were increased in both directions of travel in the morning and afternoon peak periods. During the a.m. peak, mean travel time reduced by approximately 2 minutes in both direction of travel. In the p.m. peak, mean travel times reduced by over 3 minutes in the eastbound direction and by approximately 8 minutes in the westbound direction. Mean travel speeds during the a.m. peak increased from approximately 45 mph to over 55 mph in both directions. In the p.m. peak, mean travel speed increased from 47 mph to over 60 mph in the eastbound direction and from 27 mph to over 45 mph in the westbound direction. The travel time index, the ratio of median travel time to free-flow speed, showed significant improvements in both directions for each peak periods.
Deploying the UPA projects will not increase travel times or decrease speeds on I-90, I-5, SR 522, and I-405.	Supported	Except for the westbound direction during the p.m. peak, mean peak period travel times remained at or near pre-deployment level after the UPA improvements were deployed. Travel time in the westbound direction on I-90 during the p.m. peak increased from 10.6 minutes to 13.6 minutes. Changes in the mean travel times on other freeways were mixed, with increases, decreases, and no change occurring. Connecting roadways (I-5 and I-405) in the southbound direction in the p.m. peak showed the greatest increases in travel times. Due to limitations in the data, the National Evaluation Team was unable to assess the impacts of the UPA improvement on travel times and travel speeds in SR 522.
Deploying the UPA projects will improve travel time reliability on SR 520 over Lake Washington between I-5 and I-405.	Supported	The 95th percentile travel time decreased in both directions of travel in both the morning and afternoon peak periods. The Buffer Index either improved or remained at or near pre-deployment levels following the full deployment of the UPA improvements.
Deploying the UPA projects will not decrease travel time reliability on I-90, I-5, SR 522, and I-405.	Mostly Supported	With the exception of the westbound direction in the p.m. peak period, the 95th percentile travel time on I-90 generally remained the same after the UPA improvements were implemented. The southbound direction of both I-5 and I-405 in the southbound direction showed increases in the 95th percentile travel times during the p.m. peak.

Table A-19. Summary of Impacts Across Congestion Hypotheses (Continued)

Hypotheses	Result	Evidence
Total corridor throughput of the roadways around and over Lake Washington will remain the same or will increase as a result of deploying the UPA projects.	Mostly Supported	With the exception of the eastbound direction in the a.m. peak, the combined total vehicle throughput from SR 520, I-90, and SR 522 decreased by less than 5 percent in both the a.m. and p.m. peak. There was less than a 1 percent reduction in total corridor vehicle throughput in the eastbound direction during the a.m. peak. The combined total peak period person throughput declined for each direction in each peak. Reductions in total peak period person throughput in the eastbound direction ranged from 4 percent in the a.m. peak to 13 percent in the p.m. peak. For westbound traffic, total corridor peak period person throughput declined by 7 percent in the a.m. peak and 10 percent in the p.m. peak.
Vehicle and person throughput on SR 520 will remain the same or will increase as a result of the UPA projects.	Not Supported	As expected by the local partners, vehicle and person throughput on SR 520 declined in the post-deployment period in both directions of travel in the morning and afternoon peak periods.
The UPA projects will not reduce the vehicle and person throughput on I-90, I-5, SR 522, and I-405.	Mostly Support	With the exception of the westbound direction in the p.m. peak, peak period vehicle throughput on I-90 remained the same or increased in the post-deployment period. Westbound peak period vehicle throughput reduced by 12 percent in the p.m. peak. On I-90, peak period person throughput declined by 6 percent and 14 percent in the eastbound direction and increased by 17 percent and 10 percent in the westbound direction for each peak respectively. SR 522 experience an increased in both peak period vehicle and person throughput in both directions for both peaks in the post deployment period Changes in vehicle and person throughput on I-5 and I-405 were not examined in this study.
The UPA projects will improve average speeds on SR 520 (to be consistently above 45 mph as agreed upon in advance by the local partners and U.S. DOT.	Supported	The average travel speeds on SR 520 during the peak periods improved in the post-deployment period and remained about 45 mph except for part of the p.m. peak period. Travel speeds on SR 520 remained at or above 45 mph at least 90 percent of the time during the peak hours.

Table A-19. Summary of Impacts Across Congestion Hypotheses (Continued)

Hypotheses	Result	Evidence
The UPA projects will not increase the temporal or spatial extent of congestion on I-90, I-5, SR 522, and I-405.	Mixed Support	Vehicle and person throughput on I-90 increased in the eastbound direction in the morning peak period and in the eastbound direction in the afternoon peak period, remained unchanged in the westbound direction in the afternoon peak-period. Other freeways exhibited similar mixed changes. The changes in person throughput also reflected these same patterns.
Travelers will perceive that congestion has been reduced in the SR 520 corridor.	Supported	The results from surveys of corridor travelers and bus riders, as well as interviews with WSP troopers, IRT operators, and King County Metro Transit bus operators, indicate that users perceive that congestion has been reduced on the SR 520 bridge and the SR 520 corridor between I-5 and I-405.
Travelers will not perceive that congestion has increased on I-90, I-5, SR 522, and I-405.	Mixed Support	The results from the same surveys and interviews indicate that many users perceive that congestion has increased on I-90, and to a lesser extent on SR 522. Information on perceptions of changes in congestion on I-5 and I-405 is not available.

Source: Texas A&M Transportation Institute.

Appendix B. Tolling Analysis

This analysis focuses on the effect that tolling of the SR 520 bridge had on travel behavior, vehicular access, and traffic congestion. Table B-1 presents the question and the hypothesis for the tolling analysis. The question is how will travelers use the SR 520 tolling system? The hypothesis is that variable pricing on the SR 520 bridge will regulate vehicular access so as to improve the operation of SR 520. The tolling analysis is closely related to the congestion, transit, and equity analyses.

Table B-1. Tolling Question and Hypothesis

Hypotheses/Questions
• How will travelers utilize the SR 520 tolling system?
• Variable pricing on SR 520 will regulate vehicular access so as to improve the operation of SR 520

Source: Seattle/Lake Washington UPA National Evaluation Tolling Corridor Test Plan, U.S. DOT, September 14, 2011.

This appendix is divided into six sections. The data sources used in the analysis are described in Section B.1, followed by a description of the SR 520 toll rates, toll payment methods, and the number of toll accounts by payment type in Section B.2. Section B.3 presents information on the use of the SR 520 bridge tolling system. Section B.4 discusses the toll revenues collected on the SR 520 bridge by quarter in 2012. Section B.5 summarizes the results related to tolling from the household panel of SR 520 users sponsored by the Volpe National Transportation Center (Volpe), surveys of users of the SR 520 bridge sponsored by the Washington State Department of Transportation (WSDOT), and the surveys of bus riders on routes using the SR 520 bridge conducted by King County Metro Transit. The appendix concludes with a review of the SR 520 tolling question and hypothesis in Section B.6.

B.1 Data Sources

The tolling analysis relied primarily on seven data sources. First, information on the *Good To Go!* payment options and tolling rates was obtained from the WSDOT SR 520 Webpage[1]. Second, WSDOT provided the national evaluation team with the monthly total of new SR 520 toll accounts by type for 2011 and 2012. Third, WSDOT also provided the national evaluation team with the data files for all SR 520 transactions in 2012. Fourth, the SR 520 Bridge Quarterly Financial Statements were used to obtain the toll revenue generated by quarter on the bridge. Fifth, information from the household panel study sponsored by Volpe was used to examine user perceptions. Sixth, information on the WSDOT-sponsored surveys was obtained from the reports prepared by the consultants conducting the surveys. Seventh, the results of surveys of bus riders on routes using the SR 520 bridge conducted by King County Metro Transit and summarized in Appendix C – Transit Analysis were reviewed.

[1] http://www.wsdot.wa.gov/tolling/520/

B.2 SR 520 Bridge Toll Rates and Toll Payment Options

B.2.1 SR 520 Bridge Toll Rates

The SR 520 bridge toll rates are established by the Washington State Transportation Commission (WSTC) working with WSDOT and the public. The WSTC reviews SR 520 bridge traffic performance and revenue each winter to assess if changes in the toll rates are necessary to cover operating costs and debt payments. New toll rates are implemented the following July, if necessary. The WSTC set the initial toll rates for the SR 520 bridge that were in effect from the December 29, 2011 opening until June 30, 2012. The WSTC increased the tolls slightly on July 1, 2012. Toll rates for the *Good To Go!* pass increased by $.04 to $.09 depending on the time period. The *Good To Go!* Pay By Mail rates increased by $.08 to $.13.

Table B-2 presents the SR 520 toll rates for two-axle vehicles for the time-period covered in the national evaluation – January 1, 2012 through December 31, 2012. As noted, the toll rates increased slightly on July 1, 2012.

Table B-2. SR 520 Two-Axle Toll Rates for January 1, 2012 through December 31, 2012

Monday – Friday	*Good To Go!* Pass		Pay By Mail	
	1/1/12 – 6/30/12	7/1/12 – 12/31/12	1/1/12 – 6/30/12	7/1/12 – 12/31/12
Midnight to 5 a.m.	$0.00	$0.00	$0.00	$0.00
5 a.m. to 6 a.m.	$1.60	$1.64	$3.10	$3.18
6 a.m. to 7 a.m.	$2.80	$2.87	$4.30	$4.41
7 a.m. to 9 a.m.	$3.50	$3.59	$5.00	$5.13
9 a.m. to 10 a.m.	$2.80	$2.87	$4.30	$4.41
10 a.m. to 2 p.m.	$2.25	$2.31	$3.75	$3.84
2 p.m. to 3 p.m.	$2.80	$2.87	$4.30	$4.41
3 p.m. to 6 p.m.	$3.50	$3.59	$5.00	$5.13
6 p.m. to 7 p.m.	$2.80	$2.87	$4.30	$4.41
7 p.m. to 9 p.m.	$2.25	$2.31	$3.75	$3.84
9 p.m. to 11 p.m.	$1.60	$1.64	$3.10	$3.18
11 p.m. to 11:59 p.m.	$0.00	$0.00	$0.00	$0.00
Weekends and Holidays	***Good To Go!* Pass**		**Pay By Mail**	
Midnight to 5 a.m.	$0.00	$0.00	$0.00	$0.00
5 a.m. to 8 a.m.	$1.10	$1.13	$2.60	$2.67
8 a.m. to 11 a.m.	$1.65	$1.69	$3.15	$3.23
11 a.m. to 6 p.m.	$2.20	$2.26	$3.70	$3.79
6 p.m. to 9 p.m.	$1.65	$1.69	$3.15	$3.23
9 p.m. to 11 p.m.	$1.10	$1.13	$2.60	$2.67
11 p.m. to 11:59 p.m.	$0.00	$0.00	$0.00	$0.00

Source: WSDOT SR 520 Bridge Website.

The toll rates vary by time-of-day and by toll payment option. On weekdays, tolls are highest during the morning and afternoon peak periods (7:00 a.m. to 9:00 a.m. and 3:00 p.m. to 6:00 p.m.) and lower during the other times of the day. The highest *Good To Go!* pass toll after July 2, 2012 was $3.59 and the lowest was $1.64. The toll rates for weekends and holidays are lower overall, with the highest toll of $2.26 from 11:00 a.m. to 6:00 p.m. The tolls are higher for travelers using the *Good To Go!* Pay By Mail option. No tolls are charged between 11:00 p.m. and 5:00 a.m. during the week, and on weekends and holidays until the new bridge is open to accommodate construction as the corridor is rebuilt

There are separate tolling rates for three-axle, four-axle, five-axle, and six-axle vehicles. Vehicles in these categories included articulated buses and tractor-trailer trucks. The toll rates increase by the number of axles. For example, the *Good To Go!* base toll rate for morning peak period from 7:00 a.m. to 9:00 a.m. after July 1, 2012 ranged from $5.38 for three-axle vehicles to $10.76 for six-axle vehicles. The Pay By Mail base toll rate for the same time period was $7.69 for three-axle vehicles and $15.38 for six-axle vehicles.

B.2.2 SR 520 Bridge Toll Payment Options

There are four basic ways to pay tolls on the SR 520 Bridge through the *Good To Go!* program. These methods are a *Good To Go!* pass account, a *Good To Go!* Pay By Plate account, a *Good To Go!* Short Term account, and *Good To Go!* Pay by Mail. The Pay By Mail option does not require an individual to open an account. Table B-3 presents the requirements, tolls, and fees associated with each of the payment options. Individuals can open a *Good To Go!* account on-line, by telephone, by mail, and at three customer service centers in Seattle, Bellevue, and Gig Harbor. *Good To Go!* sticker passes may also be purchased at participating retail stores in the region, which are listed on the SR 520 bridge website.

There are five *Good To Go!* sticker pass options available, ranging in price from $5.00-to-$12.00. Table B-4 presents the costs and attributes associated with the five sticker pass options. According to the WSDOT website, the Sticker Pass is the most popular with travelers.

Table B-5 presents the number of accounts opened by type from February 2011 through December 2012. The basic *Good To Go!* pass is by far the most frequently used type of toll account, representing approximately 88 percent of the total 275,311 accounts opened during the 23-month period. Pay By Plate accounts were a distant second, representing approximately 9 percent of the total accounts; followed by short-term accounts, with almost 2 percent; commercial accounts, with 0.4 percent; unregistered accounts, with 0.1 percent; and government accounts, with 0.1 percent. As noted in Table B-3, short-term accounts are limited to one vehicle and automatically close after 14 days. As noted in Table B-3, many accounts allow multiple or unlimited transponders. For example, Seattle Metro has one account for buses with 1,523 active transponders, one account for Metro Access vehicles with 512 active transponders, and one account for Metro vanpools with 575 active passes.

An account is closed after 24 consecutive months of inactivity or no toll usage. Two attempts are made to reach a toll pass holder by *Good To Go!* customer service before closing an account. A first attempt is made after 18 months of no toll activity and the second attempt is made after 24 months of inactivity. An account is closed and a $5 fee is charged after 24 months of no toll activity.

As vehicles drive through the toll gantries on SR 520, images of the front and rear license plates are taken. The toll equipment detects a *Good To Go!* pass and deducts the appropriate toll from a *Good To Go!* account. If a pass is not detected, the system matches the image of the license plate to an account. When an account is located by plate, the toll is posted at the *Good To Go!* toll rate plus a $.25 cent photo fee per transaction. If an account is not located, it means that the plate is not on an account and/or an account has a negative account balance. In this case, a toll bill is mailed to the registered owner of the vehicle.

If a *Good To Go!* account does not have sufficient funds or if a driver does not have an account, a toll bill is mailed to the vehicle's registered owner. Vehicle owners have 15 days to pay the toll bill. If additional trips are made after the first toll bill, those toll charges are included in the next billing cycle. Thirty days after the first bill, a second toll bill is generated that includes new toll transactions during that period and any unpaid tolls from the first bill, plus a $5 reprocessing fee. If a toll remains unpaid after 80 days, a $40 notice of civil penalty is issued for each unpaid toll transaction, plus all accumulated tolls and fees, as required by state law. If the vehicle owner has civil penalties that have not been paid or disputed after 20 days, the Department of Licensing may place a hold on their vehicle registration and the unpaid amount may be sent to collections.

Individuals who do not have a *Good To Go!* account can pay a toll bill using a credit card, debit card, check or electronic check using the following options:

- Pay online: http://www.wsdot.wa.gov/GoodToGo;
- By phone;
- By mail;
- In person at a customer service center in Seattle, Bellevue or Gig Harbor.

Individuals with a *Good To Go!* account can choose to pay a bill using the methods listed above. However, WSDOT recommends that they contact *Good To Go!* customer service so that they can save money on their toll charges. They can contact customer service by:

- By email;
- By phone;
- By mail;
- In person at a customer service center in Seattle, Bellevue or Gig Harbor.

Once an individual contacts *Good To Go!* customer service, customer service can update the account by adding money, adding a vehicle, and updating the plate of the vehicle that received the toll bill. Customer service can transfer the toll(s) associated with the toll bill to the *Good To Go!* account allowing customer to pay the lowest toll rate. By transferring the toll from the billing system to an account, the customer receives the *Good To Go!* discounted toll rate and only pays an additional $.25 per toll transaction.

Table B-3. SR 520 Bridge Toll Payment Options

Toll Payment Option	Requirements	Eligible Facilities	Toll and Fees
Account Options			
Good To Go! Pass Account	At least one *Good To Go!* Vehicle pass and license plate number required. Passes range from $5-$13, plus tax. Up to 6 vehicles and/or *Good To Go!* Passes per account.	SR 520 Bridge Tacoma Narrows Bridge SR 167 HOT Lanes	Pay lowest toll rate
Commercial Pass Account	Must have at least 6 vehicles; can have an unlimited number of vehicles on the account.	SR 520 Bridge Tacoma Narrows Bridge SR 167 HOT Lanes with a pass	Pay *Good To Go!* toll rate.
Government Agency Pass Account	At least one *Good To Go!* vehicle pass and license plate number is required. Passes range from $5 to $12 plus tax. Federal, state, local, and transit agencies eligible.	SR 520 Bridge Tacoma Narrows Bridge SR 167 HOT Lanes with a pass	Pay appropriate rate for time-of-day and number of axles, unless they have an approved discount.
Unregistered Pass Account	Identifying contact information not required. One *Good To Go!* pass must be assigned. Must apply in person at a customer service center.	SR 520 Bridge Tacoma Narrows Bridge SR 167 HOT Lanes with a pass	Pay appropriate rate for time-of-day and number of axles, no additional fees.
Pay By Plate Account	Does not require a *Good To Go!* vehicle pass. Requires registration of each vehicle's license plate on account. No limitation on the number of vehicles that can be registered.	SR 520 Bridge Tacoma Narrows Bridge	Pay *Good To Go!* toll rate plus a $0.25 fee per toll transaction
Short Term Account	Does not require a *Good To Go!* vehicle pass. Registration of vehicle license plate required. Only one vehicle allowed. Valid up to 14 days – Account automatically closes. Drivers have up to 72 hours after traveling on a tolled facility to set up a Short Term Account.	SR 520 Bridge Tacoma Narrows Bridge	Toll rates are $0.50 less than Pay by Mail toll rates. Tolls are charged directly to debit or credit card.
Non-Account Option			
Pay By Mail	No account is needed. License plates are read electronically and a bill is mailed to the vehicle owner.	SR 520 Bridge Tacoma Narrows Bridge	Users pay the Pay By Mail toll, which is higher than the *Good To Go!* pass toll.

Source: WSDOT SR 520 Bridge Webpage.

Table B-4. *Good To Go!* Pass Options

Pass Option	Cost	Attributes
Sticker Pass	$5.00	The sticker toll pass, which is approximately the size of a band aid, adheres to the front windshield near the rear-view mirror. The pass cannot be moved and must be deleted from an account when the vehicle is sold or the windshield is replaced. WSDOT reports it is the most popular toll pass.
Movable Pass	$8.00	The movable toll pass, which is about the size of a popsicle stick, adheres to the front windshield near the rear view mirror by Velcro. This pass is movable between vehicles. The toll pass can be removed and stored in a static bag when carpooling on the SR 167 HOT lanes.
Switchable Pass	$12.00	The switchable toll pass, which is about the size of a candy bar, is placed in a hard case, which is mounted on the front windshield by Velcro. This pass is movable between vehicles. The toll pass can be turned off when carpooling on the SR 167 HOT lanes.
License Plate Pass	$12.00	This pass mounts to the top of the front license plate by screws.
Motorcycle Pass	$8.00	This toll pass adheres to the motorcycle head lamp with clear sticker backing. It cannot be moved between motorcycles and must be deleted from an account when the motorcycle is sold or the head lamp is replaced.

Source: WSDOT SR 520 Bridge Webpage.

Table B-5. SR 520 Toll Bridge Accounts by Type

Month Purchased	*Good To Go!* Pass Account		Government Agency Pass Account		Unregistered Pass Account		Commercial Pass Account		Pay By Plate Account		Short Term Account		Grand Total
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
2011													
February	13,583	96.0%	4	0.03%	5	0.04%	79	0.6%	485	3.4%			14,156
March	24,660	95.6%	27	0.1%	11	0.04%	166	0.6%	928	3.6%			25,792
April	21,776	96.1%	24	0.1%	20	0.1%	112	0.5%	739	3.3%			22,671
May	4,788	91.0%	48	0.9%	5	0.1%	45	0.9%	378	7.2%			5,264
June	4,825	90.9%	41	0.8%	7	0.1%	32	0.6%	401	7.6%			5,306
July	3,513	89.9%	8	0.2%	1	0.0%	15	0.4%	369	9.4%			3,906
August	3,292	79.7%	8	0.2%	4	0.1%	25	0.6%	802	19.4%			4,131
September	2,251	76.9%	4	0.1%	2	0.1%	11	0.4%	660	22.5%			2,928
October	2,048	87.8%	1	0.0%	2	0.1%	9	0.4%	273	11.7%			2,333
November	3,687	92.3%	6	0.2%	4	0.1%	18	0.5%	281	7.0%			3,996
December	44,037	93.6%	26	0.06%	49	0.1%	299	0.6%	2,525	5.4%	101	0.2%	47,037
2012													
January	33,833	91.1%	17	0.05%	60	0.2%	109	0.3%	2,761	7.4%	354	1.0%	37,134
February	12,510	85.1%	12	0.08%	21	0.1%	44	0.3%	1,781	12.1%	337	2.3%	14,705
March	10,152	82.9%	12	0.10%	5	0.0%	35	0.3%	1,675	13.7%	374	3.1%	12,253
April	8,265	82.4%	4	0.04%	4	0.0%	25	0.2%	1,393	13.9%	335	3.3%	10,026
May	8,200	80.4%	1	0.01%	7	0.1%	26	0.3%	1,553	15.2%	407	4.0%	10,194
June	7,702	80.0%	4	0.04%	6	0.1%	20	0.2%	1,427	14.8%	463	4.8%	9,622
July	6,907	78.8%	1	0.01%	4	0.0%	24	0.3%	1,284	14.6%	546	6.2%	8,766
August	6,636	77.1%	1	0.01%	7	0.1%	20	0.2%	1,303	15.1%	635	7.4%	8,602
September	6,341	78.8%	2	0.02%	3	0.0%	25	0.3%	1,226	15.2%	455	5.7%	8,052
October	5,456	76.8%	5	0.07%	1	0.0%	15	0.2%	1,207	17.0%	423	6.0%	7,107
November	4,495	76.8%	5	0.09%	4	0.1%	14	0.2%	976	16.7%	362	6.2%	5,856
December	4,166	76.2%	1	0.02%	4	0.1%	7	0.1%	941	17.2%	351	6.4%	5,470
Grand Total	243,123	88.3%	262	0.10%	236	0.1%	1,175	0.4%	25,368	9.2%	5,143	1.9%	275,307

Source: WSDOT.

B.3 Use of the SR 520 Bridge Toll System

Data on the use of the SR 520 bridge was provided to the national evaluation team by WSDOT, including summary tables with transactions by account type and other information. Files with all the individual transaction data for 2012 were provided, along with files with the transactions during the pre-deployment period. The pre-deployment data were collected from October 1 to December 28, 2011. The tolling equipment was being tested during this period, allowing transponder data to be captured even though individuals were not being charged a toll.

The 2012 files included data from 342,879 individual transponders. The transactions include both toll tag transactions and license plate image transactions. How the license plate image transactions are actually recorded in the toll system is not determined until processing occurs at the Customer Service Center (CSC). The license plate image transactions are either Pay by Plate transactions, which are charged to a *Good To Go!* account, or Pay by Mail transactions, which are billed to the vehicle owner. The status of these transactions is determined at the CSC. As a result, identifying the exact toll payment method for all transactions on the files was not possible. WSDOT did provide a summary of transactions by month for account options, except Pay By Mail. This summary is discussed in Section B.3.4.

The SR 520 bridge was closed due to a major snow storm and subsequent power outages for most of Saturday, January 14 and Sunday, January 15. In addition, reflecting weekend closures of the SR 520 bridge for construction and maintain activities, data for the following weekends were very low or missing from the files – February 25 and 26, March 10 and 11, April 28 and 29, June 2 and 3, July 14 and 15, August 11 and 12, September 22 and 23, October 20, and November 17 and 18.

In addition, the toll system records license plates and toll tags on a 24 hour basis, seven days a week, including the time period from 11:00 p.m. to 5:00 a.m. when no tolls are currently charged. The transactions for the non-toll period from 11:00 p.m. to 5:00 a.m. were removed from the data set, allowing the analysis to focus on the tolling period from 5:00 a.m. to 11:00 p.m.

The national evaluation team analyzed the data set in a number of ways, including assessing transactions by month, day of the week, and time-of-day. The results of this analysis are presented in this section. Information on the use of the SR 520 Bridge before-and-after tolling was implemented is presented first. Total toll transactions by month, day of the week, and time-of-day are summarized next. Information on frequency of use and toll transactions by account type is also presented. The influence of the seven missing days of data, as well as weather incidents impacting the SR 520 bridge traffic, is noted as appropriate in the analysis.

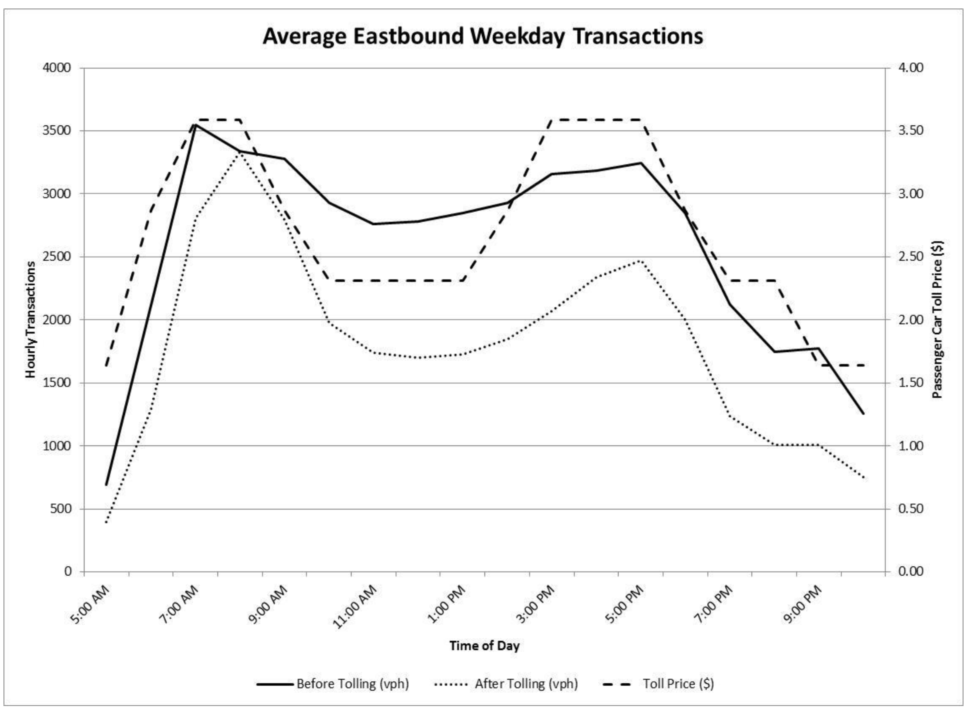
B.3.1 Pre- and Post-Deployment Use of the SR 520 Bridge

The congestion analysis documented a reduction in traffic on the SR 520 bridge after tolling was implemented. According to the congestion analysis, vehicle miles traveled (VMT) in the morning peak period decreased by approximately 26 percent in the westbound direction of travel and 22 percent in the eastbound direction of travel from the pre-deployment period to the post-deployment period. Overall, WSDOT reported traffic volumes approximately 34 percent lower than pre-toll levels.

The results of the tolling analysis reflect similar trends. As illustrated in Figure B-1 and Figure B-2, the average weekday post-deployment toll transactions are lower than the levels recorded during the pre-deployment test phase when toll tags were read, but no tolls were actually charged. The average post-deployment toll transactions are lower during all times, except the eastbound toll transactions at approximately 8:00 a.m., which are approximately the same as those recorded in the post-deployment. The figures, which include the variable toll charges, highlight the interaction of price and demand. No major changes in time of travel appear to have occurred, although the morning peak period appears to have shifted slightly later, which may reflect the same toll charge from 7:00 a.m. to 9:00 a.m.

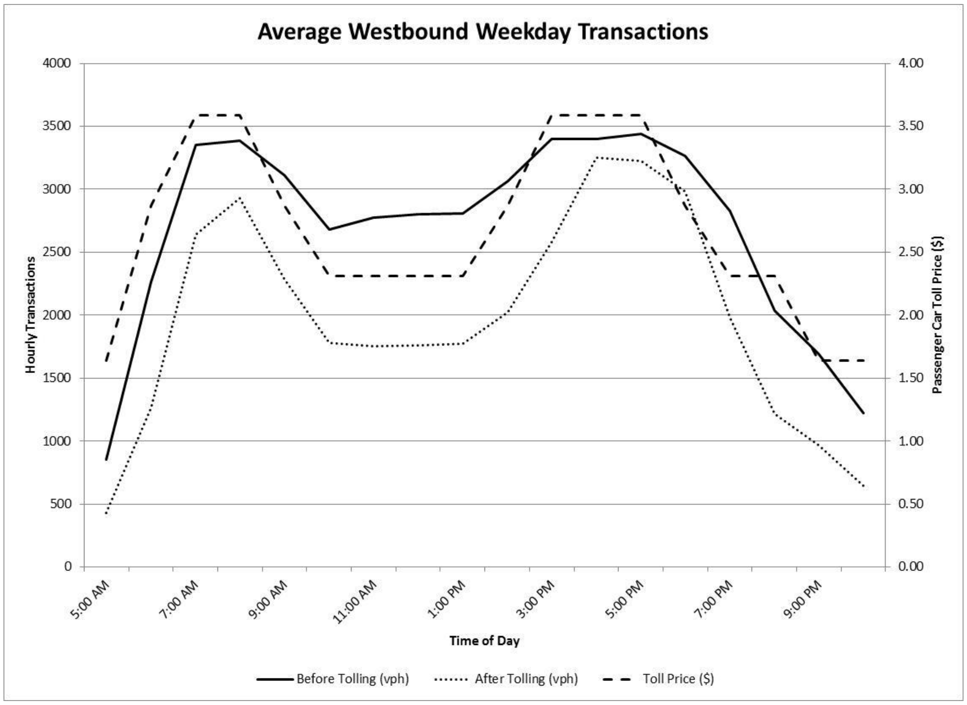
B.3.2 Total Toll Transactions by Month, Day of Week, and Time-of-Day

Figure B-3 presents the total toll transactions per month for 2012, which is the post-deployment period. A heavy snowstorm occurred the week of January 14-20, 2012. The combination of snow and ice also caused power outages, resulting in the bridge being closed for part of the time. WSDOT reported that the SR 520 bridge was also closed on nine other weekends during the year for construction and maintenance activities. This situation resulted in a lower total number of transactions in January. As illustrated in Figure B-1, the monthly transactions were relatively constant through the remainder of the year, with some fluctuation reflecting seasonality and holidays. The total transactions for July, September, October, and November would be slightly higher if the bridge had not been closed one weekend per month for construction and maintenance activities.



Source: Texas A&M Transportation Institute, based on data from WSDOT, July 2013.

Figure B-1. SR 520 Bridge Average Eastbound Weekday Pre- and Post-Deployment Toll Transactions



Source: Texas A&M Transportation Institute, based on data from WSDOT, July 2013.

Figure B-2. SR 520 Bridge Average Westbound Weekday Pre- and Post-Deployment Toll Transactions

Figure B-4 presents the total yearly toll transactions by day of week. As illustrated in the figure, toll transactions are higher during the work week and lower on weekends. Figure B-5 presents the average yearly trips by non-holiday weekdays. As illustrated in Figure B-5, the highest level of transactions occurred on Thursday, followed by Wednesday, Tuesday, and Friday. Mondays had the lowest level of weekday transactions.

Figure B-6 and Figure B-7 present the average morning and afternoon toll transactions by time-of-day for non-holiday weekdays, normalized per hour. The time periods match the toll rate time periods. The number of tolls are averaged per hour within each toll rate time period to provide comparison by hour. As could be expected, the highest average hourly toll transactions occurred during the morning and afternoon peak periods. The average transactions for all time periods during the year are relatively constant. The slight variations among months probably reflects seasonal changes more than anything associated with the tolls.

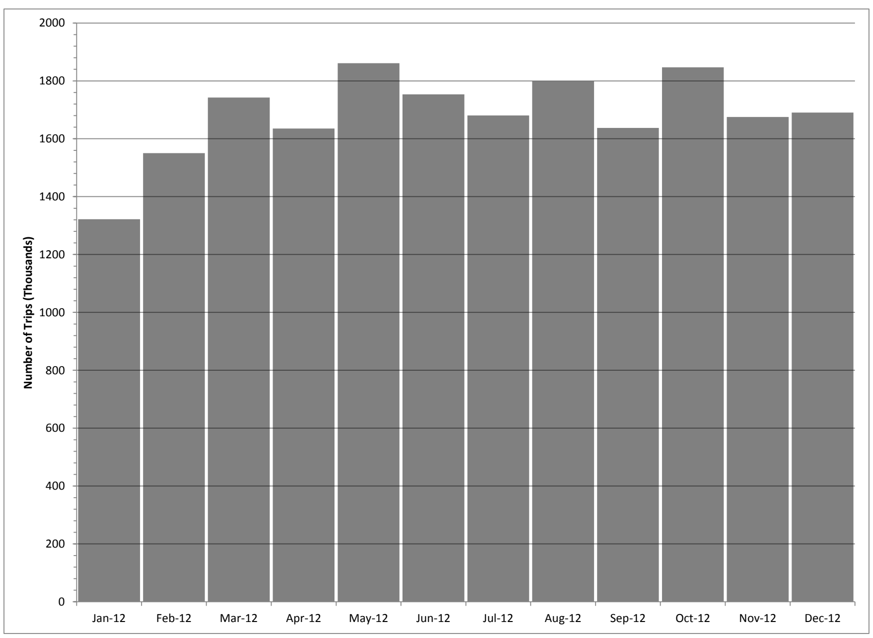
B.3.3 Frequency of Use

Figure B-8 presents the frequency of trips by toll transactions by month for February, May, August, and October, 2012. The column representing zero trips in the month reflects the number of active accounts, which has continued to increase, not recording a transaction during the month. The months were selected to provide examples of use during different times of the year. As illustrated in Figure B-3, overall use of the SR 520 bridge was highest in May, August, and October, while February was the second lowest.

Figure B-8 reflects the different groups using the SR 520 Bridge. The toll tags recording more than four trips during the tolling period, as well as those with two-to-four daily trips, probably represent mostly King County Metro Transit buses and commercial or business vehicles used for multiple trips across the bridge. Transponders in the next three sets of columns, or those tags recording transactions once-to-twice weekly to once-to-twice daily, probably reflect individuals making work and school trips on a regular basis. The remaining columns reflect groups with infrequent use. Most frequent users of the bridge probably obtained *Good To Go!* pass accounts prior to the initiation of the tolling system or shortly after opening of the system. The continued increase in *Good To Go!* pass accounts discussed in Section B.2.2 and presented in Table B-5 may reflect individuals signing up for accounts, knowing they will use the bridge infrequently.

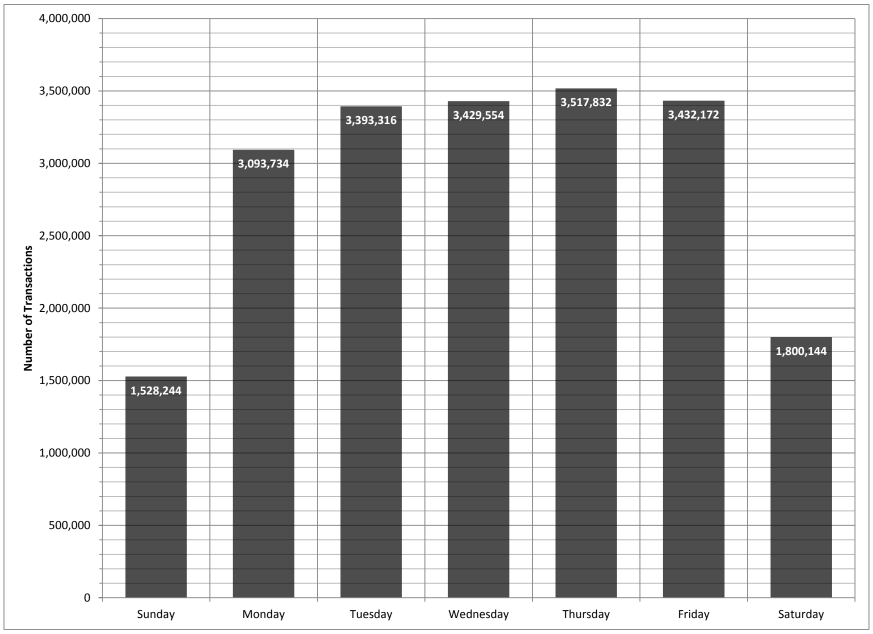
B.3.4 Transactions by Type of Account and Vehicle

Table B-6 presents the transactions per month by account type from December 2011 to December 2012. Individuals with *Good To Go!* pass accounts, which represent 88 percent of total accounts, were responsible for approximately 87 percent of the total transactions. *Good To Go!* commercial accounts, which represented only 0.4 percent of the total accounts, accounted for almost 6 percent of the total transactions. *Good To Go!* Pay By Plate accounts represented 9 percent of the total accounts, but only 5 percent of the transactions. *Good To Go!* short term accounts, which are valid for only 14 days, accounted for almost 2 percent of total accounts, and approximately 0.05 percent of total transactions. *Good To Go!* government agency accounts represented 0.1 percent of total accounts and 2.2 percent of transactions. King County Metro Transit buses, access vehicles, and vanpools probably account for a large share of the government transactions. *Good To Go!* unregistered accounts represented 0.1 percent of total accounts and .07 percent of total transactions.



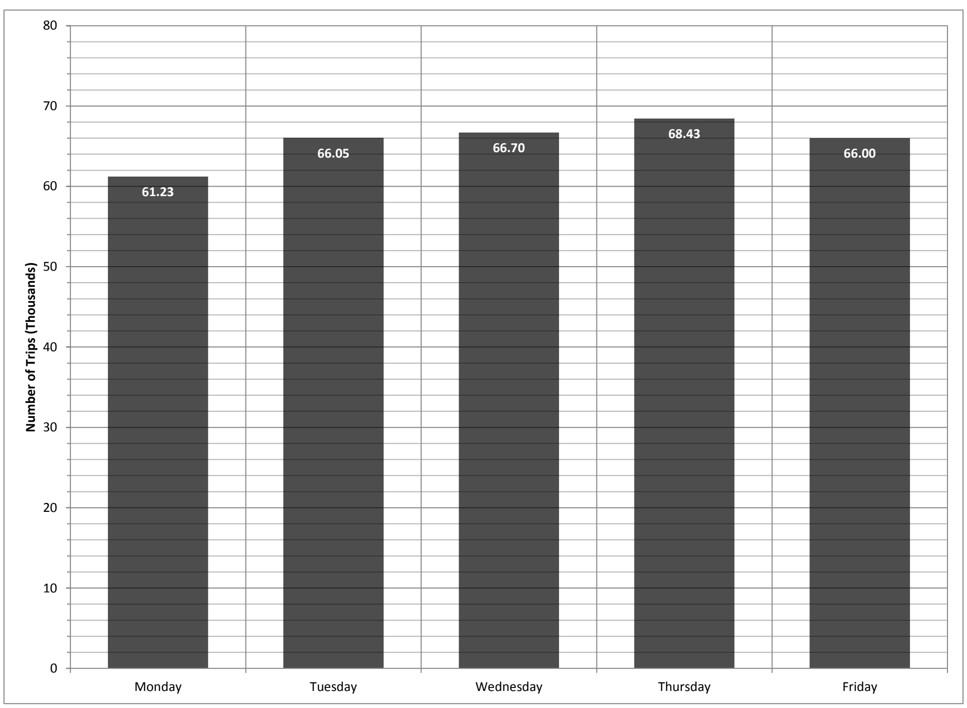
Source: Texas A&M Transportation Institute, based on data from WSDOT, July 2012.

Figure B-3. SR 520 Bridge Total Transactions per Month in 2012



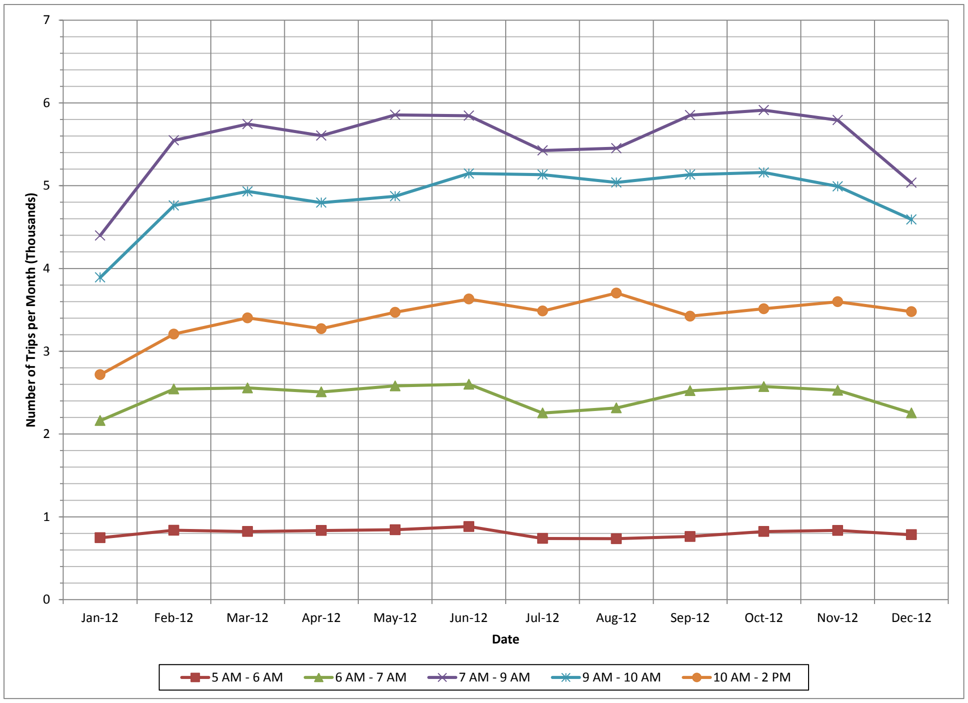
Source: Texas A&M Transportation Institute, based on data from WSDOT, July 2012.

Figure B-4. SR 520 Bridge Average Transactions by Day of the Week in 2012



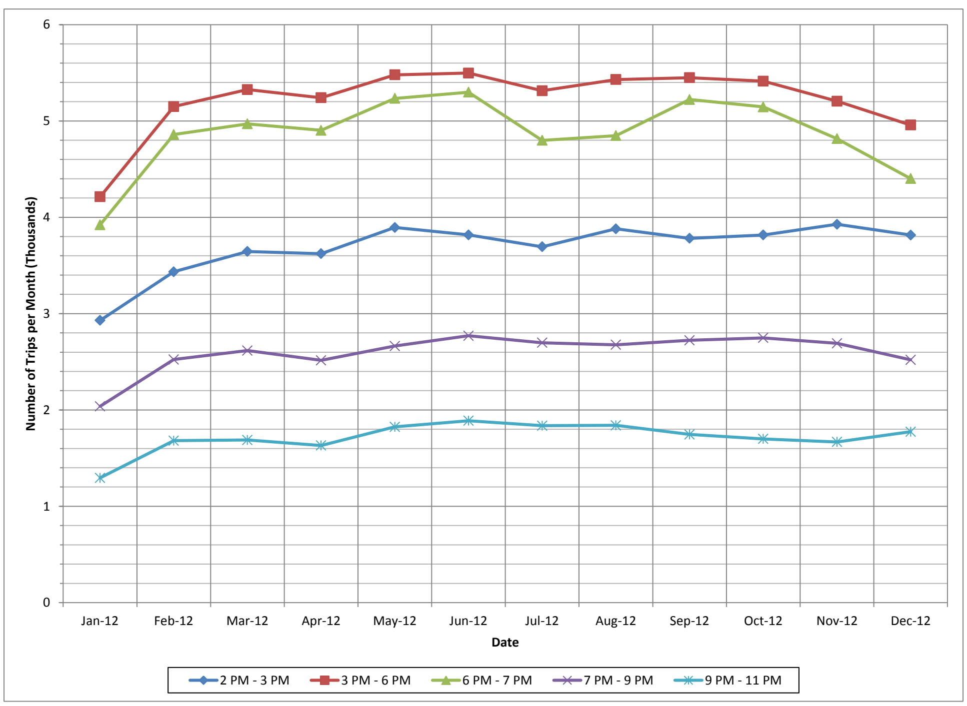
Source: Texas A&M Transportation Institute, based on data from WSDOT, July 2012.

Figure B-5. SR 520 Bridge Average Transactions by Non-Holiday Weekday in 2012



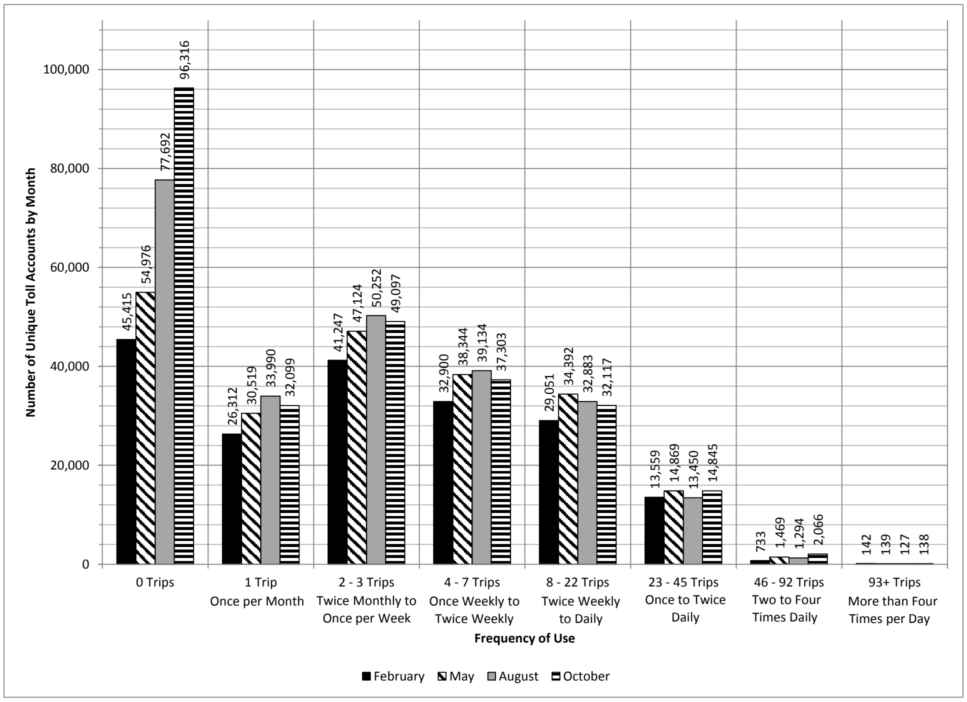
Source: Texas A&M Transportation Institute, based on data from WSDOT, July 2012.

Figure B-6. Average Morning Monthly Transactions by Time of Day: Non-Holiday Weekdays – Normalized Per Hour



Source: Texas A&M Transportation Institute, based on data from WSDOT, July 2012.

Figure B-7. Average Afternoon Monthly Transactions by Time-of-Day: Non-Holiday Weekdays – Normalized Per Hour



Source: Texas A&M Transportation Institute, based on data from WSDOT, July 2012.

Figure B-8. Trip Frequency by Toll Transactions for Selected Months in 2012

Table B-6. *Good To Go!* Transactions by Account Type

Month	Good To Go! Pass Account		Government Agency Pass Account		Unregistered Pass Account		Commercial Pass Account		Pay By Plate Account		Short Term Account		Grand Total
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
Dec-2011[1]	69,179	88.6%	1,780	2.3%	46	0.06%	5,302	6.8%	1,794	2.3%	12	0.02%	78,113
Jan-2012	929,213	89.3%	22,793	2.2%	615	0.06%	63,678	6.1%	23,242	2.2%	497	0.05%	1,040,038
Feb-2012	1,111,533	88.6%	26,293	2.1%	903	0.07%	81,280	6.5%	33,558	2.7%	526	0.04%	1,254,093
Mar-2012	1,253,184	88.2%	27,928	2.0%	972	0.07%	85,343	6.0%	52,294	3.7%	601	0.04%	1,420,322
Apr-2012	1,180,657	87.8%	28,598	2.1%	883	0.07%	76,530	5.7%	58,020	4.3%	563	0.04%	1,345,251
May-2012	1,337,415	87.7%	30,985	2.0%	988	0.06%	84,436	5.5%	71,409	4.7%	600	0.04%	1,525,833
Jun-2012	1,237,365	86.7%	31,715	2.2%	827	0.06%	80,499	5.6%	76,503	5.4%	735	0.05%	1,427,644
Jul-2012	1,177,602	85.8%	31,126	2.3%	860	0.06%	77,665	5.7%	83,552	6.1%	893	0.07%	1,371,698
Aug-2012	1,252,067	86.0%	33,112	2.3%	972	0.07%	85,928	5.9%	83,359	5.7%	814	0.06%	1,456,252
Sep-2012	1,169,549	86.6%	28,052	2.1%	978	0.07%	76,230	5.6%	74,851	5.5%	816	0.06%	1,350,476
Oct-2012	1,331,783	86.7%	34,515	2.2%	999	0.07%	90,307	5.9%	77,413	5.0%	597	0.04%	1,535,614
Nov-2012	1,201,258	86.9%	31,744	2.3%	905	0.07%	78,826	5.7%	69,850	5.1%	469	0.03%	1,383,052
Dec-2012	1,213,723	87.1%	30,366	2.2%	876	0.06%	74,323	5.3%	73,269	5.3%	504	0.04%	1,393,061
Grand Total	14,464,528	87.2%	359,007	2.2%	10,824	0.07%	960,347	5.8%	779,114	4.7%	7,627	0.05%	16,581,447

[1] Tolling on the SR 520 Bridge was implemented on December 29, 2011, resulting in the lower number of transactions for December.

Source: WSDOT.

B.4 SR 520 Bridge Revenues

The tolls collected on the SR 520 bridge are maintained in a separate account within the state treasury that is dedicated to the SR 520 program. Spending from the account is appropriated by the Washington State Legislature and monitored by the Office of Financial Management. The Quarterly SR 520 Toll Financial Statements, which include information on revenues, expenses, and changes in fund balance, are available on the SR 520 bridge website. The Quarterly Financial Statements for 2012 were reviewed by the national evaluation team. Table B-7 presents the gross toll revenues by quarter reported in the Quarterly Financial Statement. Gross toll revenues equaled almost $55 million in 2012. Additional revenues were received from toll transponder purchases and other sources. The highest quarterly gross toll revenues, of approximately $15 million, were recorded in the October-to-December 2012 quarter. During 2012, WSDOT reported that 95 percent of all tolls were paid on time. Further, WSDOT reported that from December 29, 2011 through April 30, 2013, approximately 1.5 percent of all tolls went unpaid long enough to trigger the $40 notice of civil penalty.

Table B-7. Gross Tolling Revenues by Quarter for 2012

Quarter	Gross Toll Revenue
January-March	$11,648,744
April-June	$14,173,251
July-September	$13,867,862
October-December	$15,180,548
Total	**$54,870,405**

Source: Texas A&M Transportation Institute, based on data from the Division of Accounting and Services, July 2013.

B.5 Perceptions of SR 520 Bridge User Perceptions

Information on the perceptions of users of the SR 520 bridge related to tolling and the influence of tolling on travel behavior is available from surveys conducted by Volpe, WSDOT, and King County Metro Transit. This section summarizes the results from the tolling-related questions included in these surveys.

B.5.1 SR 520 Corridor Household Panel Study

To support the Seattle/LWC National Evaluation, Volpe conducted a household panel study in the SR 520 corridor. The study included a structures survey and a 48-hour travel diary of individuals in households in the pre- and post-deployment periods. More information on the study methodology is provided in Appendix A – Congestion Analysis. The same households were surveyed in both time periods. The Wave 1, or pre-deployment surveys, were conducted in November 2010 and the Wave 2 surveys were conducted in April and May, 2012. Participants were identified by recording license plates in the SR 520 and I-90 corridors and by intercepting transit riders in both corridors. The panel was comprised of 2,063 households, with a total of 3,698 adults, reflecting a 6 percent response rate overall.

A comparison of the Wave 1 and Wave 2 survey results and travel diaries provides insight into the use of the SR 520 tolling system, changes in travel behavior resulting from the tolling, and vehicle access to SR 520 due to the tolling. Examples of these changes are highlighted in the following.

- The number of reported trips in the LWC declined. Travel on SR 520 recorded in the diaries declined by 43 percent, while travel on I-90 declined 13 percent. An offsetting increase in non-corridor travel did not occur.
- The share of corridor trips on SR 520 declined, while share of corridor trips for I-90 and SR 522 increased. Avoiding the SR 520 bridge toll was the reported motivation for 86 percent of those noting a change from SR 520 to I-90 or SR 522.
- Changes did occur among respondents reporting using SR 520 as their primary route in Wave 1. In Wave 2, 55 percent of those individuals were still using SR 520 as the primary route, 24 percent had changed to using I-90 as their primary route, 7 percent had switched to SR 522, 8 percent had changed to riding the bus, 4 percent had changed to another route or mode, and 1 percent stopped making trips across the lake on a regular basis. Males, members of lower income households, and individuals with limited flexibility in their work schedules were more likely to switch from using SR 520 to using I-90.
- Trip satisfaction, as reported for each trip on a 7-point scale (1 = strongly disagree, 3 = neutral, 7 = strongly agree), increased on SR 520 in Wave 2. The mean score for satisfaction with peak period travel speeds on the SR 520 bridge increased from 3.4 to 5.2 from Wave 1 to Wave 2. The satisfaction with trips on I-90 declined slightly. The statement “Tolling on SR 520 has improved my travel” received a mean score of 3.3 in Wave 2. The question was not asked in Wave 1.

B.5.2 WSDOT SR 520 Tolling Surveys

WSDOT sponsored a number of surveys and focus groups as part of implementing the SR 520 bridge tolling system. Initial market research activities focused on gauging public support for the project, identifying factors influencing individuals to open a toll account, and developing and testing marketing messages. Baseline and midpoint surveys were conducted in April and August 2010 to measure the effectiveness of the marketing efforts aimed at educating the public on the basic elements of the SR 520 bridge project and tolling.

The final evaluation telephone survey of 800 households was conducted from October 26 to November 4, 2012 by PRR to obtain information on the impact of the marketing and education programs on the purchase of toll tags, the understanding of the tolling system, and the impact of tolling on travel behavior and attitudes. The survey used Computer Assisted Telephone Interviewing (CATI) software. A random digital dialing telephone sample for King County residents and a list of cell phone numbers for King County were both purchased by PRR for use in the survey. A minimum quota was set for 20 percent of completed interviews from cell phone-only users or mostly cell phone users. The final composition of survey respondents was 57 percent landline phone interviews and 43 percent cell phone interviews. Four attempts at different times of the day and different days of the week were made to contact the randomly selected households. The overall margin of error for the telephone survey was +/- 3.46 percent at the 95 percent confidence interval.

The survey included a number of questions related to use of the SR 520 bridge tolling system, changes in travel behavior due to the bridge tolling, and perceptions of the impact of the tolling system. The responses to these questions and others related to the tolling analysis are summarized here.

- Reported use of the SR 520 bridge declined from the baseline survey, through the midpoint survey to the final survey. Fewer people reported using the bridge four or more times a week, two-to-three times a week, one time a week, and one-to-three times a month. Individuals reporting four or more trips a week declined from 13 percent in the baseline survey to 11 percent in the final survey. Individuals reporting using the bridge two-to-three times a week declined from 14 percent to 9 percent, travelers using the bridge one-to-three times per month declined from 33 percent to 31 percent. Travelers reporting using the bridge less than one time a month increased from 28 percent to 40 percent.
- The majority of respondents, 69 percent, reported they had not changed their time of travel on the SR 520 bridge, but 32 percent indicated they had changed their time of travel. Of those reporting a change in travel time, 50 percent indicated they had done so to use the bridge when the toll was lower, while 19 percent did so to use the bridge when traffic was lighter. There was a slight decline – from 25 percent to 23 percent – in reported travel during the weekday morning peak period (5:00 a.m. to 9:00 a.m.) and in the evening (after 7:00 p.m. and before 10:00 p.m.) – 34 percent to 31 percent. Mid-day travel (after 9:00 a.m. and before 3:00 p.m.) remained constant at 53 percent, while travel in the afternoon peak period (3:00 p.m. to 7:00 p.m.) increased slightly from 40 percent to 43 percent.
- Some increase in the use of alternative modes was reported by survey respondents, including a 15 percent increase in carpooling, a 9 percent increase in the use of transit, and 4 percent increase in vanpooling. An 11 percent increase in working from home was also reported.
- Survey respondents reported a perception that traffic congestion had decreased on the SR 520 bridge. Approximately half (51 percent) of the respondents in the final survey indicated that the SR 520 bridge was not congested at all since tolling was implemented, compared to 21 percent in the baseline survey. The majority of respondents, 62 percent, in the final survey reported their trips were faster across the bridge since tolling began.
- Survey respondents indicated a perception that safety on the SR 520 bridge had improved. 62 percent of the respondents in the final survey indicated their driving experience was very safe on the SR 520 bridge, compared to 34 percent in the midpoint survey.
- Knowledge of the tolling system and usage of the toll revenues to pay for a new bridge, and awareness of the *Good To Go!* tolling system increased in the final survey.
- 45 percent of the respondents to the final survey reported paying the SR 520 bridge toll by using a transponder, followed by 30 percent reporting they paid by mail after receiving a bill, and 16 percent indicating they paid through an account connected to their vehicle license plate. 9 percent of the respondents did not know how their toll was paid. Respondents 35 years of age and above were more likely to pay using a transponder, 52 percent, compared to those under the age of 35 years of age, 32 percent. Respondents with incomes below $75,000 were more likely to pay by

mail after receiving a bill, 50 percent, compared to those with incomes above $75,000, 25 percent.

B.5.3 King County Metro Transit Surveys of Bus Riders

Two surveys were conducted of riders on routes operated by King County Metro Transit using the SR 520 bridge, including the Sound Transit routes operated by King County Metro Transit. The first survey was administered in March 2011, prior to tolling on the SR 520 bridge. The second survey was conducted in May 2012, approximately five months after tolling was initiated. The margin of error for the pre-toll survey was +/- 2.6 percent at the 95 percent confidence level and the margin of error for the post-toll survey was +/- 2.5 percent at the 95 percent confidence level. The questions relating to the influence of tolling the SR 520 bridge are summarized next. More information from the surveys is presented in Appendix C – Transit Analysis.

- 19 percent of the riders responding to the second survey indicated that they began riding the bus after tolling was implemented on the SR 520 bridge. Of those individuals, 55 percent responded that they began riding the bus because of the bridge tolls. Further, 41 percent indicated that they previously drove alone and 9 percent reported changing from carpooling to riding the bus.
- 82 percent of riders responded that the SR 520 bridge was less congested since the tolling was initiated. Riders were split on the influence of tolling on bus travel times and travel speeds, with 47 percent indicating that travel speeds were the same and 46 percent reporting they were faster.

B.6 Summary of Tolling Impacts

Table B-8 summarizes the information presented in this appendix in response to the question and hypothesis related to the SR 520 bridge tolling system. The information presented in the appendix on the number of *Good To Go!* accounts opened, and toll transactions by month, day of the week, and time-of-day highlight how travelers are using the SR 520 Bridge. The information in this appendix and the congestion analysis in Appendix A highlight the improved operation of the SR 520 bridge since the tolling system was implemented. A total of 275,307 toll accounts were opened over the 23-month period from February 2011 to December 2012. As forecasted, use of the SR 520 bridge declined with the implementation of the tolling system. Use levels remained relatively constant throughout 2012, with transactions per month and by time-of-day reflecting seasonal variations. There are both frequent users of the SR 520 bridge, including individuals who use it on a daily basis, and individuals who use it only a few times a month or less. The congestion analysis in Appendix A further supports the decline in VMT and congestion on the SR 520 Bridge since tolling was initiated. The results from the surveys sponsored by Volpe, WSDOT, and Metro Transit indicated that most people using the bridge before tolling continue to use it, but that some people have changed travel routes and travel modes. The survey results further indicate that travelers perceive the tolling system has reduced congestion on the SR 520 bridge and improved travel conditions on the bridge.

Table B-8. Summary of Tolling Impacts Across Hypotheses/Questions

Question and Hypothesis	Result	Evidence
• How will travelers utilize the SR 520 tolling system?	Travelers have opened *Good To Go!* accounts and are using the SR 520 tolling system on both a regular basis and an infrequent basis	275,307 *Good To Go!* accounts were opened over the 23-month period from February 2011 to December 2012. Use of the SR 520 bridge declined with the implementation of the toll system. Monthly transactions on the SR 520 bridge remained relatively constant in 2012, averaging between 1 million and 1.5 million. Usage levels by day-of-the-week and time-of-day also remained relatively constant through 2012. The tolling system is used by frequent users making daily trips and infrequent users making only a few trips a year. The results of the surveys of travelers in the corridor indicate that many pre-deployment bridge users continue to travel on the bridge and pay a toll, but that some have changed travel routes and modes due to the tolling system.
• Variable pricing on SR 520 will regulate vehicular access so as to improve the operation of SR 520	Supported	VMT and congestion levels on the SR 520 bridge have declined with the implementation of the tolling system. The results of surveys of bridge users and travelers in the SR 520 corridor indicate that people perceive the tolling system has reduced congestion and improved travel conditions on the bridge.

Source: Texas A&M Transportation Institute.

Appendix C. Transit Analysis

The Seattle/LWC UPA's transit enhancements included: 44 new buses and 90 additional one-way peak period trips; improvements to transit stops and park-and-ride lots; and new travel time signs. King County Metro Transit and Sound Transit added transit service to SR 520 in two stages prior to tolling. In October 2010, service was added to existing Routes 255, 265, and 271, and the new Route 542 was initiated. Most of the new service was in the peak period, but additional midday and evening service was added to the Route 271 also. In February 2011, even more peak period and midday service was added to Route 255, and peak period service was added to Route 311. Part of the UPA funding for the 90 additional peak period trips also went to the Route 309, a new peak period service on SR 522.

Table C-1 presents the three hypotheses and one question for the Seattle/LWC UPA transit analysis. The first hypothesis states that the Urban Partnership Agreement (UPA) projects (i.e., tolling on SR 520 and the transit enhancements listed in the above paragraph) will enhance bus travel speeds, travel times, and reliability. The second and third hypotheses state that the UPA projects will facilitate increased ridership, a mode shift to transit, and a reduction in congestion. The last hypothesis is a question that seeks to quantify the extent to which the UPA projects contributed to increased ridership and reduced congestion.

Table C-1. Transit Analysis Approach

Hypotheses/Questions
• The Seattle/LWC UPA projects will enhance transit performance in the SR 520 corridor through reduced travel times, increased reliability, and increased capacity.
• The Seattle/LWC UPA projects will facilitate an increase in ridership and mode shift to transit on the SR 520 corridor.
• The mode shift to transit will result in less congestion on the SR 520 corridor.
• What was the relative contribution of each Seattle/LWC UPA project element to increased ridership and mode shift to transit?

Source: CUTR.

The remainder of this appendix is divided into six sections. The data sources used in the analysis are presented in Section C.1. Information on bus travel times and bus on-time performance is presented in Section C.2. Park-and-ride lot usage data are provided in Section C.3. Changes in transit ridership are discussed in Section C.4. The results from the March 2011 and May 2012 on-board rider surveys are presented in Section C.5. A summary of the impacts to transit from the UPA projects is in Section C.6.

C.1 Data Sources

A variety of data from the King County Metro Transit was used to analyze the Seattle/LWC UPA transit projects. These included bus travel times, ridership, revenue miles and hours, park-and-ride lots counts, and on-board surveys of riders.

With regards to the ridership data, a brief explanation is required of how King County Metro Transit parses its data. King County Metro Transit conducts service changes three times a year. The spring service change covers February to May; the summer service change covers June to September; and the fall service change covers October to January of the following year. Since only about 15 percent of the bus fleet is equipped with automated passenger counters (APCs), the APC buses are rotated throughout the system to collect ridership samples. The average weekday ridership figures used in this analysis are composite figures that represent what the ridership was during the service period.

The ridership data was analyzed by comparing the same service change periods. Using the same service change periods helps to control for seasonal variations that could potentially impact ridership levels. As shown in Table C-2 in bold, the summer service change period was selected for analysis over the other service periods because no key UPA events occurred in the summer months. Using the summer service change periods allowed for a cleaner division line between the pre-deployment, intermediate, and post-deployment periods.

Table C-2. UPA Analysis Periods

Service Change Period	Months Covered	UPA Event
Summer 2010	**Jun 2010 to Sep 2010**	**Pre-deployment analysis period**
Fall 2010	Oct 2010 to Jan 2011	Stage 1 transit improvements Oct. 2010
Spring 2011	Feb 2011 to May 2011	Stage 2 transit improvements Feb. 2011
Summer 2011	**Jun 2011 to Sep 2011**	**Intermediate analysis period**
Fall 2011	Oct 2011 to Jan 2012	Tolling commenced Dec. 29, 2011
Spring 2012	Feb 2012 to May 2012	
Summer 2012	**Jun 2012 to Sep 2012**	**Post-deployment analysis period**

Source: CUTR.

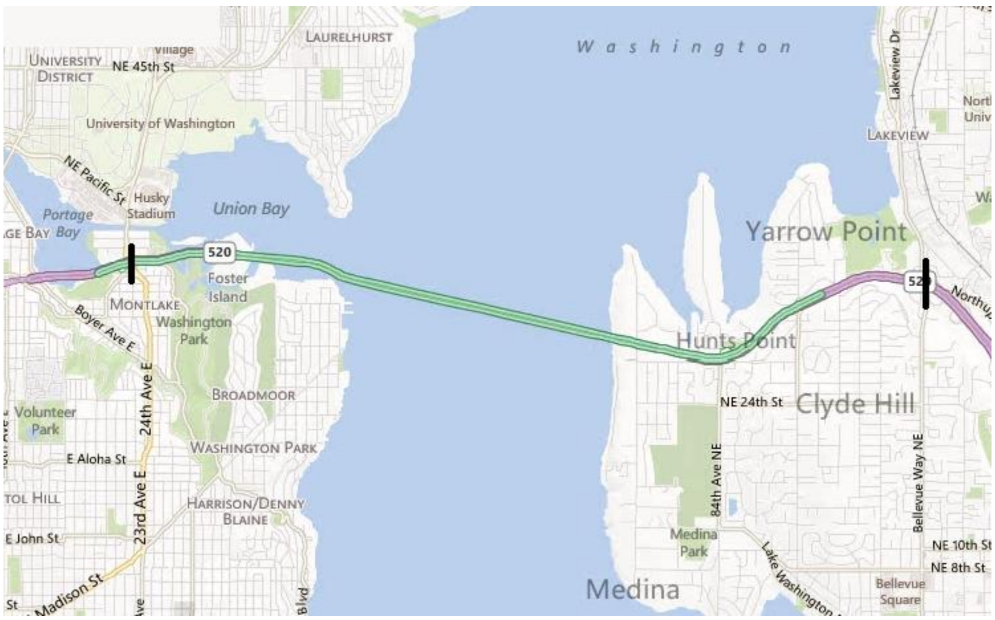
This method of comparing similar months from year to year is consistent with the UPA/CRD transit analyses conducted in Miami and Minnesota. The ridership was also analyzed by looking at the overall trend from the beginning of data collection in January 2010 to the end of data collection in January 2013. This helps illustrate what was occurring over the entire evaluation period.

Bus travel time and on-time performance data was analyzed the same way as ridership. Park-and-ride lot data was taken from King County Metro Transit's quarterly park-and-ride lot reports. Each month, King County collects the data for all of the park-and-ride lots in the transit service area.

Two surveys were conducted of SR 520 bus riders. The first was done in March 2011 prior to tolling. The second was conducted in May 2012 after tolling. More information on the survey methodology can be found in Section C.5.

C.2 Travel Time, Speed, and On-Time Performance

On-time performance and travel times on the SR 520 Bridge were calculated using a 2.7 mile screenline from the ramps near the South Kirkland Park-and-Ride Lot on the east side and the ramps at Montlake on the west side (see Figure C-1). The purpose of doing this was to focus the analysis on bridge traffic conditions. Table C-3 and Table C-4 show the results for the three analysis periods. On-time performance improved greater in the eastbound direction both mornings and afternoons. From Summer 2010 to Summer 2012, it improved from 47 percent to 67 percent in the morning peak and from 40 percent to 57 percent in the afternoon peak. In the westbound direction, on-time performance improved from 63 percent to 67 percent in the morning peak but dropped from 51 percent to 47 percent in the afternoon peak.



Note: Screenline boundaries shown are the black lines

Source: Bing Maps modified by CUTR.

Figure C-1. SR 520 Screenline

Table C-3. AM Peak Period On-Time Performance (6:00 to 9:00 AM)

Corridor	Summer 2010	Summer 2011	Summer 2012
SR 520 eastbound	47%	46%	67%
SR 520 westbound	63%	65%	67%

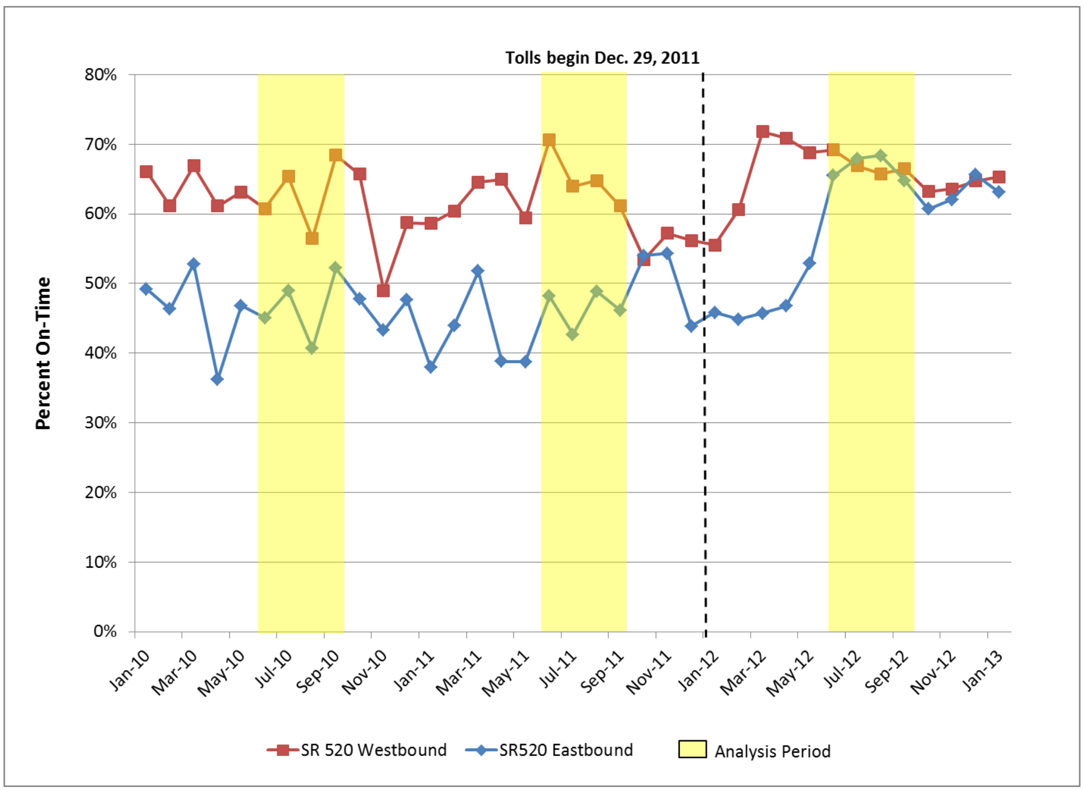
Source: King County Metro Transit.

Table C-4. PM Peak Period On-Time Performance (3:00 to 7:00 PM)

Corridor	Summer 2010	Summer 2011	Summer 2012
SR 520 eastbound	40%	44%	57%
SR 520 westbound	51%	44%	47%

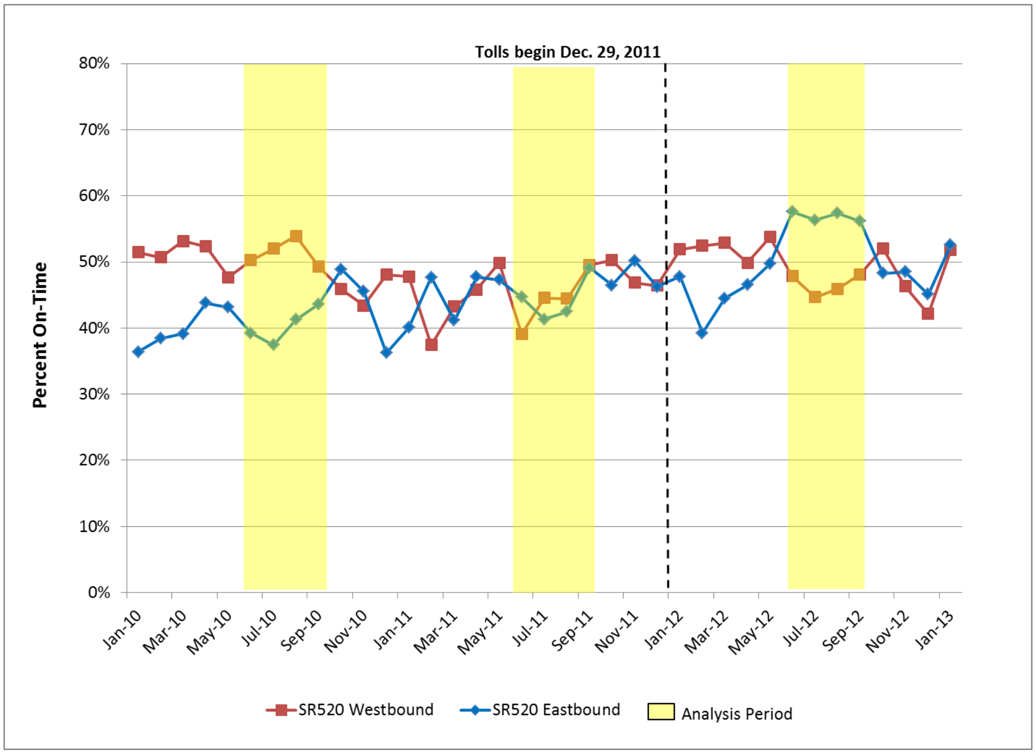
Source: King County Metro Transit.

The on-time performance trend from January 2010 to January 2013 is shown in Figure C-2 and Figure C-3. The yellow columns are the months used in the calculations for the analysis periods. Looking at the two figures, one can see that the improvements in on-time performance did not occur immediately after tolling. For example, morning on-time performance in the westbound direction was not noticeably better until March 2011. In the eastbound direction, it was not noticeably better until June 2012. June is also the first month of the summer service change. It is therefore likely that the improvement in on-time performance was due to a combination of schedule adjustments and improved traffic flow from the variable tolls.



Source: King County Metro.

Figure C-2. AM Peak Period On-Time Performance Trend



Source: King County Metro.

Figure C-3. PM Peak Period On-Time Performance Trend

As shown in Table C-5 and Table C-6, peak period travel times across the bridge improved in both directions between Summer 2010 and Summer 2012 with eastbound travel times improving the most. They were 0.9 to 1.7 minutes shorter. Bus travel times improved in the non-peak shoulder periods also. The only two exceptions were the 5 to 6 a.m. period and the 2 to 3 p.m. period in the westbound direction.

Table C-5. Bus Travel Times SR 520 Bridge Westbound

Time of Day	Summer 2010	Summer 2011	Summer 2012	Change 2010 to 2012
5-6 AM	4.8	4.7	4.9	+0.1
6-9 AM	5.3	5.0	5.1	-0.1
9-10 AM	5.4	5.4	5.2	-0.3
2-3 PM	4.9	5.2	5.6	+0.8
3-7 PM	6.6	5.9	6.3	-0.4
7-8 PM	5.6	5.0	5.0	-0.6

Times are in minutes; reported figures are 50th percentile; AM Peak Period is 6-9 AM; PM Peak Period is 3-7 PM

Source: King County Metro Transit.

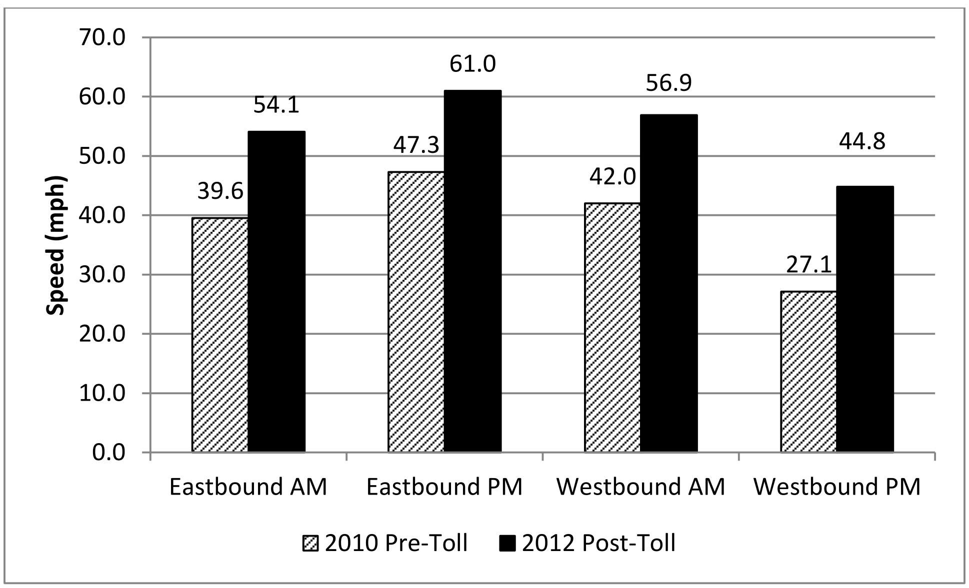
Table C-6. Bus Travel Times SR 520 Bridge Eastbound

Time of Day	Summer 2010	Summer 2011	Summer 2012	Change 2010 to 2012
5-6 AM	4.5	4.6	4.7	0.2
6-9 AM	6.1	6.2	5.2	-0.9
9-10 AM	7.0	7.4	5.2	-1.7
2-3 PM	5.6	5.5	5.2	-0.4
3-7 PM	7.1	6.8	5.4	-1.7
7-8 PM	5.4	5.4	5.0	-0.4

Times are in minutes; reported figures are 50th percentile; AM Peak Period is 6-9 AM; PM Peak Period is 3-7 PM

Source: King County Metro Transit.

A year's worth of loop detector data on the SR 520 Bridge was collected in 2010 (pre-toll) and 2012 (post-toll) in order to measure travel speeds across the bridge. The average speeds for each entire year are shown in Figure C-4. Speeds improved in both directions in the a.m. and p.m. peak periods. The improvements ranged from 14 to 18 mph depending on direction and time of day.

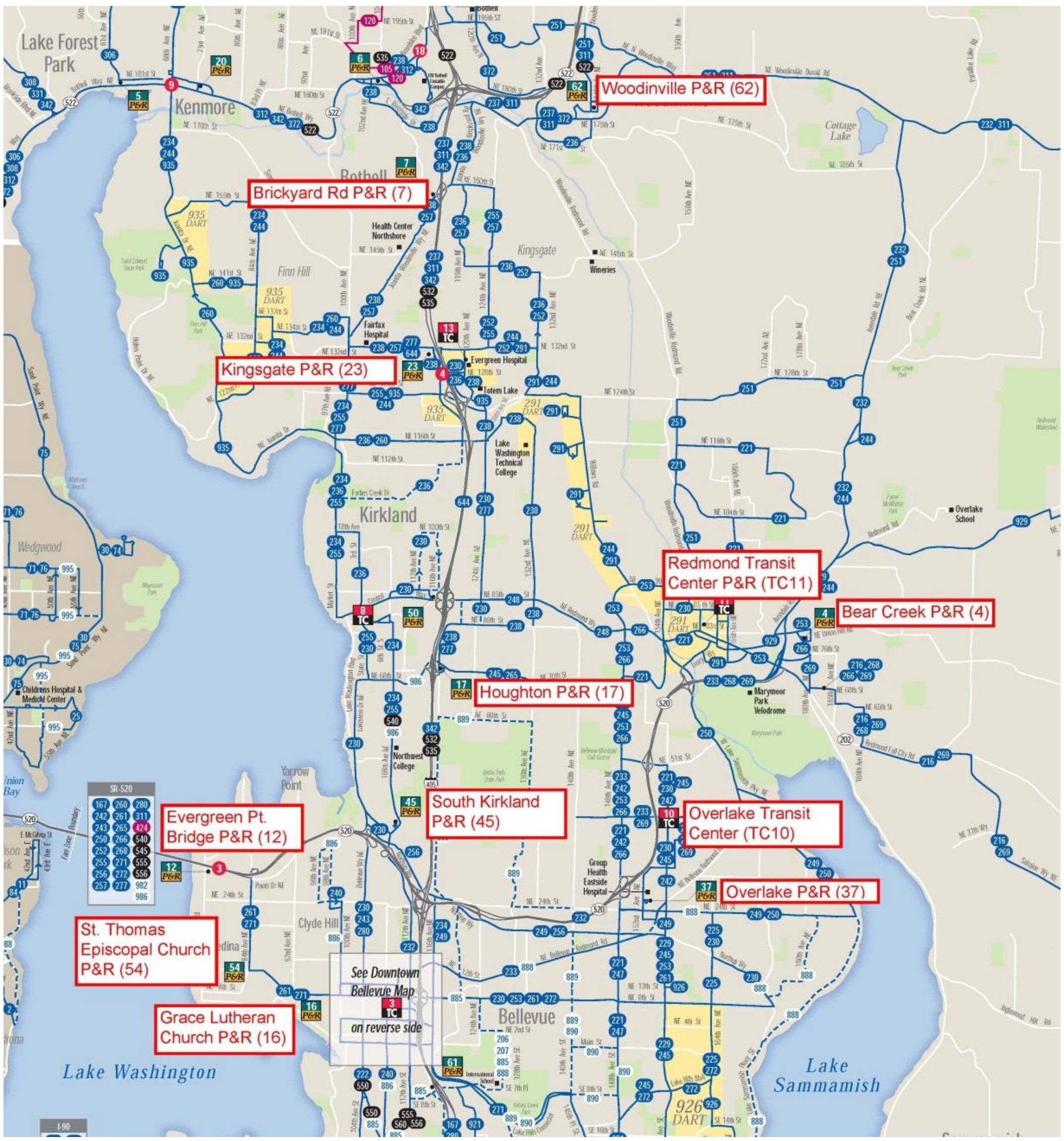


Source: WSDOT.

Figure C-4. Travel Speeds on SR 520 Bridge

C.3 Park-and-Ride Lot Use

The UPA included funding for improvements at two park-and-ride lots. These two lots are located at the Redmond and South Kirkland Transit Oriented Developments. The Redmond parking garage opened in July 2009, but the South Kirkland parking garage will not open until 2014 after the UPA evaluation is complete. For that reason, the South Kirkland parking garage (not to be confused with the existing lot) was not included in the evaluation. Besides the Redmond parking garage, the evaluation included 11 other park-and-ride lots that are served by routes that cross the SR 520 Bridge. The locations of the lots are shown in Figure C-5.



Source: King County Metro map modified by CUTR.

Figure C-5. Park-and-Ride Lot Locations

Table C-7 compares the number of occupied spaces at the twelve lots for September 2010, 2011, and 2012. Parking demand increased steadily during the three-year evaluation. In September 2010, only one of the twelve lots (Kingsgate) was over 90 percent occupied. In September 2011, the number increased to six, and in September 2012, it increased again to eight. A more detailed description of several of the park and rides follows.

The Redmond Park-and-Ride was closed at the end of June 2008 so that construction could begin on the new UPA-funded parking garage. The garage opened in July 2009 and is located on the south side of NE 83rd Street across from the Redmond Transit Center. The 385-space parking capacity on three above-ground floors includes 377 regular commuter parking spaces and 8 ADA accessible spaces on the first level. Twelve of the commuter parking spaces on the first level have charging outlets for electric vehicles. The garage has allowed for construction of a mixed-use housing project on the remaining two-thirds of the former park-and-ride site. In September 2010, it was 86 percent occupied. In September 2011 and 2012 it was 100 percent and 99 percent occupied, respectively.

Construction at the South Kirkland lot began on August 20, 2012 resulting in a reduction of capacity from 596 spaces to 465 spaces. Total occupied spaces remained high. In September 2010, it was 89 percent occupied. In September 2011 and 2012, it was 88 percent and 104 percent occupied, respectively.

The Evergreen Point Bridge Park-and-Ride lot was relocated in July 2011 to a temporary site on the north side of SR-520 to accommodate construction of the Eastside Transit and HOV Project. Due to limited space and to avoid cutting down six mature trees, the temporary lot had a reduced capacity (19 spaces instead of the original 51). Despite less capacity, parking demand has continued unabated. In fact, it was over 100 percent occupied in September 2011 and September 2012, which indicates cars are parking wherever they can find room regardless of whether they are in a marked space. In July 2013, the Evergreen Point Bridge lot was moved from its temporary location to its permanent location in the southeast corner of the SR-520/Evergreen Point lid. However, because of ongoing construction of the Eastside Transit and HOV Project, only the northern portion of the lot with 31 spaces is available. The remaining spaces will not be restored until sometime in early 2014.

Utilization of the St. Thomas Episcopal Park-and-Ride lot increased remained fairly steady from September 2010 to September 2012 (between 21 and 28 vehicles). This experienced reduced capacity. In October 2010, the number of parking spaces was reduced from 52 to 33 when the church temporarily leased some of the lot to the City of Medina during the renovation of Medina's city hall. In December 2011, the lease ended and Metro was able to recapture and add to its former park and ride spaces. The total capacity increased from 33 to 64 spaces.

Utilization of the Grace Lutheran Park-and-Ride was also fairly steady from September 2010 to September 2012 (between 42 and 49 vehicles). Unlike St. Thomas Episcopal, the Grace Lutheran lot did not have any change in capacity.

Table C-7. Park-and-Ride Lot Usage

	September 2010			September 2011			September 2012		
Park-and-Ride Lot	**Total Spaces**	**Spaces Occupied**	**Percent Occupied**	**Total Spaces**	**Spaces Occupied**	**Percent Occupied**	**Total Spaces**	**Spaces Occupied**	**Percent Occupied**
Redmond (UPA funded)	377	326	86%	377	376	100%	377	373	99%
Bear Creek Park and Ride	283	251	89%	283	287	101%	283	291	103%
Brickyard	443	220	50%	443	295	67%	443	404	91%
Evergreen Point	51	45	88%	19	35	184%	19	44	232%
Grace Lutheran Church	50	42	84%	50	48	96%	50	49	98%
Houghton	470	147	31%	470	161	34%	470	196	42%
Kingsgate	502	506	101%	502	473	94%	502	490	98%
Overlake Transit Center	170	147	86%	170	175	103%	222	226	102%
Overlake Park and Ride	203	39	19%	203	55	27%	203	91	45%
South Kirkland	596	531	89%	596	523	88%	465	485	104%
St. Thomas Episcopal Church	52	21	40%	33	28	85%	64	21	33%
Woodinville	438	202	46%	438	162	37%	438	178	41%

Source: King County Metro.

C.4 Transit Ridership Data

Table C-8 shows the change in average daily ridership during the morning and afternoon peak periods across the SR 520 Bridge during the three analysis periods. Summer 2010 represents the baseline. Summer 2011 represents the period after the new UPA-funded service was added but before tolls began. Summer 2012 is the post-toll analysis period. Overall, ridership across the bridge increased 38 percent. It increased 17 percent after the UPA-funded service was added (Summer 2010 to Summer 2011), and then it increased another 18 percent after tolling (Summer 2011 to Summer 2012).

Table C-8. Average Daily Ridership on SR 520

Time Period	Direction	Summer 2010	Summer 2011	Summer 2012	% Change 2010 - 2012
6:00-9:00 a.m.	eastbound	1,603	1,787	2,020	26%
6:00-9:00 a.m.	westbound	3,098	3,586	4,236	37%
3:00-7:00 p.m.	eastbound	3,313	3,954	4,675	41%
3:00-7:00 p.m.	westbound	1,947	2,336	2,775	43%
Total		**9,961**	**11,663**	**13,706**	**38%**

Source: King County Metro Transit.

Ridership on the SR 520 Bridge was compared to ridership on the I-90 Bridge, which is a parallel facility across Lake Washington, and to the rest of King County Metro's bus system. The results are shown in Table C-9. Ridership across the SR 520 Bridge increased by a larger margin than ridership across the I-90 Bridge (38 percent versus 23 percent). It increased by an even larger margin when compared to the rest of King County Metro bus service (38 percent versus 8 percent).

Table C-9. Average Daily Ridership Corridor Comparison

UPA Corridor	Time Period	Direction	Summer 2010	Summer 2012	Percent Change
SR 520 Bridge	6:00-9:00 a.m.	eastbound	1,603	2,020	26%
SR 520 Bridge	6:00-9:00 a.m.	westbound	3,098	4,236	37%
SR 520 Bridge	3:00-7:00 p.m.	eastbound	3,313	4,675	41%
SR 520 Bridge	3:00-7:00 p.m.	westbound	1,947	2,775	43%
Total			**9,961**	**13,706**	**38%**
I-90 Bridge	6:00-9:00 a.m.	eastbound	901	1,044	16%
I-90 Bridge	3:00-7:00 p.m.	westbound	3,414	4,314	26%
I-90 Bridge	6:00-9:00 a.m.	westbound	4,142	5,077	23%
I-90 Bridge	3:00-7:00 p.m.	eastbound	1,166	1,423	22%
Total			**9,623**	**11,858**	**23%**
Rest of System	6:00-9:00 a.m.	eastbound	74,584	80,658	8%
Rest of System	3:00-7:00 p.m.	eastbound	108,879	116,733	7%
Total			**183,463**	**197,390**	**8%**

Note: The ridership figures for the "Rest of the System" exclude ridership from the SR 520 and I-90 routes.

Source: King County Metro Transit.

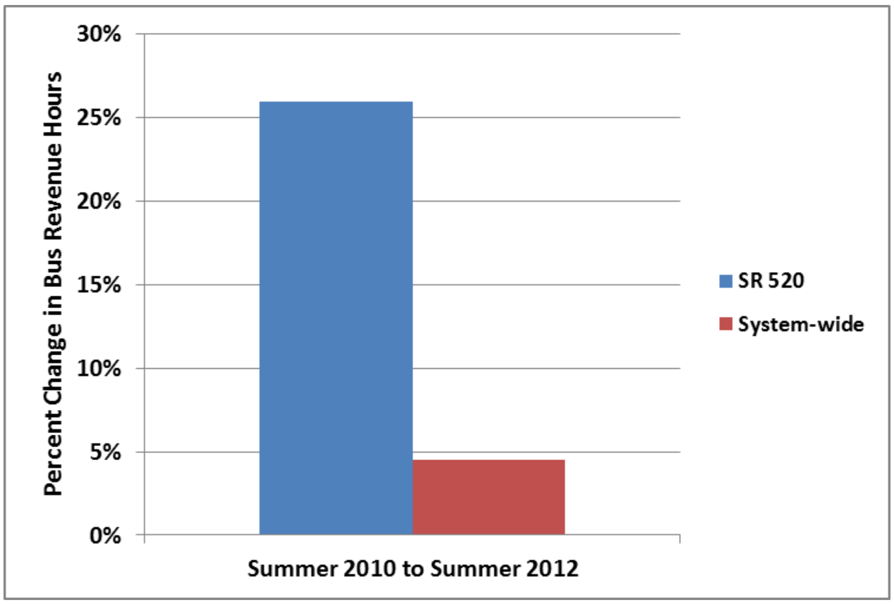
Microsoft operates its own transit service for its employees. Although the service is not a UPA project, it is impacted by the UPA because some of the Microsoft buses cross the SR 520 Bridge. Microsoft provided ridership data for inclusion in the UPA report. Table C-10 below shows that in the four corridors where Microsoft operates transit service, the service across the SR 520 Bridge had an 18 percent increase. The other three corridors had either percentage declines or a very small percentage gain.

Table C-10. Microsoft Transit Ridership

UPA Corridor	Summer 2010	Summer 2012	Percent Change
SR 520 Bridge	128,717	151,837	18%
SR 520	30,937	23,884	-23%
I-90	4,749	4,877	3%
I-405	56,112	48,193	-14%

Source: Microsoft.

Total bus revenue hours represent the amount of time the vehicles are available to the general public. It excludes “deadhead” time to/from the garage as well as time spent in maintenance. It is a measure of service quantity, which can impact ridership. More revenue hours translates into more service, which hopefully leads to more riders. On the other hand, cuts in revenue hours can sometimes lead to fewer riders. Figure C-6 compares the percentage change in revenue hours from Summer 2010 (baseline) to Summer 2012 (post-deployment). It shows that while there was a 26 percent increase in revenue hours on the SR 520 Bridge, there was only a 4 percent increase across King County Metro Transit system-wide. In other words, the increase in bus service on the SR 520 Bridge from Summer 2010 to Summer 2012 was six times greater than the rest of King County Metro Transit. This explains, at least partially, why the ridership gains on the SR 520 Bridge were higher than the rest of the system.



Note: Calculation is based on revenue hours for the AM and PM peak periods combined.

Source: King County Metro.

Figure C-6. Percentage Change in Revenue Hours

To see if there were any external factors influencing the changes in ridership, the evaluation included an analysis of gasoline prices and the unemployment rate. The results are shown in Table C-11. One would expect to see a positive correlation between ridership and gasoline prices and a negative correlation with the unemployment rate. In fact, this was observed. The increase in ridership from Summer 2010 to Summer 2012 coincided with a rise in gasoline prices and a drop in the unemployment rate. These findings are included in the report to show that a variety of factors influenced ridership in the SR 520 corridor.

Table C-11. Exogenous Factors

Measure	Summer 2010	Summer 2011	Summer 2012
SR 520 Peak Period Riders (AM + PM)	9,961	11,663	13,706
Avg. Price per Gallon of Gas	$3.00	$3.84	$3.92
Avg. Unemployment Rate	9.2	8.2	7.4

Sources: King County Metro Transit; U.S. Energy Information Administration; Washington State Employment Security Department.

C.5 On-Board Transit Ridership Survey

The results of the pre-toll and post-toll passenger surveys were reported on in the interim tech memo. No additional surveys have been done since then. The majority of the findings reported below are identical to what was in the interim report.

The surveys were conducted on the SR 520 routes operated by King County Metro Transit, including the Sound Transit routes operated by King County Metro Transit. Table C-12 shows the number of surveys that were collected on each route. The pre-toll survey was conducted in March 2011 after the extra transit service was added. The post-toll survey was conducted in May 2012. The overall response rate of the pre-toll survey was 76 percent. The overall response rate of the post-toll survey was 62 percent. The responses to both surveys were weighted based on the ridership of each route.

The margin of error of the pre-toll survey was ± 2.6 percent at the 95 percent confidence level. This was calculated using an average ridership on SR 520 of 3,768 riders as the population size and the 1,042 collected surveys as the sample size. The margin of error of the post-toll survey was ± 2.5 percent at the 95 percent confidence level. This was calculated using an average ridership on SR 520 of 4,090 riders as the population size and the 1,099 collected surveys as the sample size.

There were no significant changes in the demographics of riders on SR 520 before and after tolls. SR 520 bus riders in general are young, Caucasian, affluent, predominately male, and have access to their own vehicle.

Table C-12. Number of Collected Surveys by Route

Route	Pre-Toll Survey	Post-Toll Survey
167	37	39
242	35	34
243	16	19
250	16	31
252	92	50
255	352	366
257	0	41
260	14	16
261	19	0
265	32	44
268	26	0
271	294	362
272	25	0
277	17	18
311	67	79
TOTAL	**1,042**	**1,099**

Source: King County Metro Transit.

Table C-13. Socio-Economic Characteristics of SR 520 Bus Riders

	Response	Pre-toll Survey	Post-toll Survey
Age	Under 18	1%	1%
	18-24	18%	20%
	25-34	34%	30%
	35-44	17%	18%
	45-54	15%	16%
	55-64	13%	12%
	65 or over	2%	3%
Ethnicity	African American/Black	3%	4%
	American Indian or Alaskan Native	1%	1%
	Asian	25%	23%
	Caucasian/White	66%	69%
	Mixed race	2%	0%
	Other	1%	4%
Gender	Male	57%	55%
	Female	43%	45%
Annual Household Income	Less than $10,000	4%	5%
	$10,000 to $24,999	7%	6%
	$25,000 to $34,999	6%	7%
	$35,000 to $49,999	8%	9%
	$50,000 to $74,999	14%	14%
	$75,000 to $99,999	14%	15%
	$100,000 to $149,999	21%	20%
	$150,000 to $199,999	5%	7%
	$200,000 to $249,999	3%	3%
	$250,000 or more	2%	2%
	Prefer not to answer	16%	13%
Access to an automobile	Yes	66%	72%
	No	34%	28%

Source: CUTR based on data from King County Metro Transit.

Respondents were asked where they started their trip and to where they were traveling. The two most common trip origins were Kirkland (22 percent) and Redmond (20 percent). There was a wider variety of trip destinations, but the most common were Downtown Seattle (23 percent), University District (23 percent), Redmond (16 percent), and Downtown Bellevue (12 percent).

Table C-14 shows that in both surveys, the majority of the SR 520 bus riders are going to work or school.

Table C-14. Trip Purposes of SR 520 Riders

Response	Pre-toll Survey		Post-toll Survey	
	Frequency	Percent	Frequency	Percent
Work	1,522	79%	1,536	76%
School	235	12%	281	14%
Shopping	14	1%	15	1%
Personal business	50	3%	74	4%
Social/entertainment	48	2%	38	2%
Medical appointment	9	0%	28	1%
Jury duty	8	0%	8	0%
Other	51	3%	39	2%
Total	**1,937**	**100%**	**2,019**	**100%**

Source: CUTR based on data from King County Metro Transit.

Recall that new service was added in two waves (October 2010 and February 2011). In the pre-toll March 2011 survey, riders were asked whether they were influenced to take transit because of the extra UPA funded transit service. Table C-15 shows the responses from new riders, meaning first time riders and riders who had been riding for less than six months. Of all new riders, 19 percent said they were influenced; 48 percent said they were not influenced; and 33 percent were not aware of the service changes.

Table C-15. Did UPA Funded Bus Service Influence You to Ride this Bus?

Response	Frequency	Percent
Yes	84	19%
No	206	48%
Not aware of change	141	33%
Total	**431**	**100%**

Note: Responses are from new riders only.

Source: CUTR based on data from King County Metro Transit.

In the May 2012 post-toll survey, riders were asked whether they began taking the bus before or after the SR 520 tolls began and whether they were influenced to take transit because of the tolls. As would be expected in a corridor where there was already a lot of transit service, most riders (81 percent) had already been riding the bus prior to tolling (see Table C-16). Consequently, most of the riders were not influenced by the tolls to take transit. However among riders that only began taking transit after the start of tolls, 55 percent said they were influenced to take transit because of the tolls (see Table C-17). This finding is similar to what was reported in another part of the UPA evaluation, the Volpe Household Travel Behavior Survey. The most common reason cited by the participants for switching to transit was avoiding the tolls (45 percent). WSDOT conducted a post-toll phone survey of 800 households who use the SR 520 Bridge. In that survey, 9 percent reported increasing their use of transit after tolling.

Table C-16. When Did You Start Riding the Bus?

Response	Frequency	Percent
Before tolling started	1,623	81%
After tolling started	390	19%
Total	**2,013**	**100%**

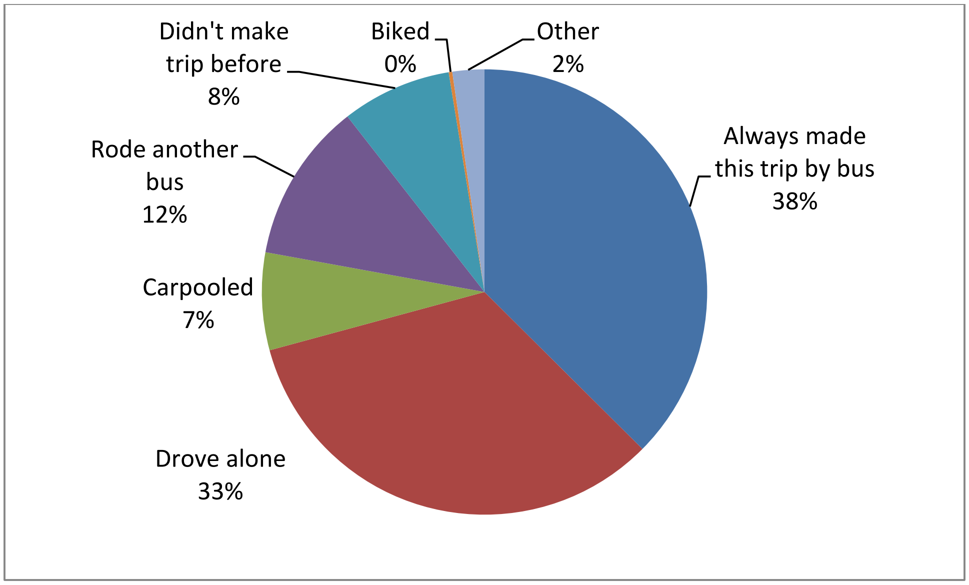
Source: CUTR based on data from King County Metro Transit.

Table C-17. Did the SR 520 Tolls Influence You to Take the Bus?

Began Using Transit	Yes		No		Total	
	Freq	Percent	Freq	Percent	Freq	Percent
Before Tolling	395	25%	1,210	75%	1,605	100%
After Tolling	210	55%	174	45%	384	100%
All Riders	605	30%	1,384	70%	1,989	100%

Source: CUTR based on data from King County Metro Transit.

When asked how they used to make the trip across the SR 520 Bridge, 33 percent of new riders said they used to drive alone. New riders were defined as those who were first time riders and riders who had been riding for only up to one year. Only 7 percent reported switching from carpooling to transit. See Figure C-7.



Source: CUTR based on data from King County Metro.

Figure C-7. Previous Mode of Travel

A portion of the UPA funds were used to equip four bus stops with real time bus information technology. Two of the stops were equipped in 2012, and the other two will be equipped in 2014. Riders were asked whether they used a bus stop that was equipped with real time bus arrival information, how easy the information was to understand, and how useful the information was. As shown in Table C-18, a majority responded that the information was both very easy to understand.

Table C-18. Real Time Bus Information Signs

How easy is the info to understand?			How useful is the info?		
Response	**Frequency**	**Percent**	**Response**	**Frequency**	**Percent**
Very difficult	1	0%	Not at all useful	8	1%
Somewhat difficult	19	3%	Not very useful	36	5%
Somewhat easy	178	24%	Somewhat useful	227	33%
Very easy	546	73%	Very useful	408	60%
Total	**745**	**100%**	**Total**	**679**	**100%**

Source: CUTR based on data from King County Metro Transit.

In the March 2011 and May 2012 surveys, riders were asked to rate ten aspects of the service as well as their overall level of satisfaction with Metro Transit or Sound Transit. The average scores from the 2011 and 2012 surveys are shown in Table C-19. On-time performance and travel time perceptions are two service aspects one would expect to be positively impacted by the imposition of variable tolls on SR 520. In the case of on-time performance, the mean score dropped from 4.24 to 4.14. Although this still equates to a rating of "good", the drop was statistically significant at the 95 confidence level. The mean score for perception of travel time increased from 4.22 to 4.23, but the increase was not statistically significant. The mean scores for perceptions of wait time at the station/stop, availability of seats, and parking availability at the park-and-ride lots also decreased at statistically significant levels. Ironically, the drop in ratings for availability of seats and parking availability may be due to increased ridership. More riders translate into fewer seats and fewer available spaces at the park-and-ride lots. On a positive note, the mean score for overall satisfaction with King County Metro Transit by SR 520 riders improved from 3.94 to 4.03 (good) and was statistically significant at the 95 percent confidence level.

Table C-19. Service Element Ratings

Service Element	Pre-toll Survey	Post Toll Survey	Sig Value
On time performance	4.24	4.14	**0.000**
Travel time	4.22	4.23	0.725
Hours of service	3.94	3.89	0.164
Frequency of service	3.86	3.90	0.173
Wait time at station/stop	3.97	3.93	**0.026**
Value of service for the price	4.17	4.25	**0.001**
Availability of seats	3.93	3.74	**0.000**
Parking availability at park-and-ride lots	3.78	3.57	**0.000**
Ability to connect with other transit service	3.93	3.93	n/a
Overall satisfaction with this bus service	4.15	4.14	0.798
Overall satisfaction with Metro	3.94	4.03	**0.004**
Overall satisfaction with Sound Transit	4.21	4.16	0.171

Note: Sig values in bold are significant at the 95 percent confidence level.

Scale:

5 – Very Good

4 – Good

3 – Fair

2 – Poor

1 – Very Poor

Source: CUTR based on data from King County Metro Transit.

In the post-toll survey, SR 520 riders were asked how their travel times after tolls compared to before tolls. The results are shown in Table C-20. Almost the same percentage of riders said their travel time was the same (47 percent) or faster (46 percent). Only 7 percent reported slower travel times. Of those that said their travel time was faster, 27 percent said their average travel time was 5 to 14 minute faster.

Table C-20. Average Travel Time Now Compared to Before SR 520 Tolls

Response	Frequency	Percent	Aggregate Percent
Faster by 30 or more minutes	45	3%	46%
Faster by 15 to 29 minutes	122	7%	
Faster by 5 to 14 minutes	449	27%	
Faster by 1 to 4 minutes	154	9%	
About the same	780	47%	47%
Slower by 1 to 4 minutes	6	0%	7%
Slower by 5 to 14 minutes	33	2%	
Slower by 15 to 29 minutes	43	3%	
Slower by 30 or more minutes	29	2%	
Total	**1,661**	**100%**	

Source: CUTR based on data from King County Metro Transit.

Riders were also asked whether they thought traffic on SR 520 was more or less congested since tolling began or if it was the same. The results are shown in Table C-21. A large majority (82 percent) said that the traffic on SR 520 has been less congested since tolling began.

Table C-21. Is SR 520 Traffic More or Less Congested Since Tolling?

Response	Frequency	Percent
Less congested	1,533	82%
More congested	41	2%
About the same	297	16%

Source: CUTR based on data from King County Metro Transit.

Riders were asked whether they agreed or disagreed with a series of statements related to the SR 520 tolls. The results are shown in Table C-22 through Table C-24. A majority of the riders (57 percent) agreed to various degrees with the statement that the SR 520 tolls have improved their personal travel. A smaller percentage (42 percent) agreed with the statement that the SR 520 tolls have been good for the region. A majority (55 percent) agreed with the statement that the SR 520 tolls are unfair to people on limited incomes.

Table C-22. Tolling on SR 520 has Improved my Travel

Response	Frequency	Percent	Aggregate
Strongly Disagree	69	4%	
Disagree	133	7%	17%
Somewhat Disagree	122	6%	
Neutral	506	26%	26%
Somewhat Agree	377	20%	
Agree	464	24%	57%
Strongly Agree	242	13%	

Source: CUTR based on data from King County Metro Transit.

Table C-23. Tolling on SR 520 has been Good for the Region

Response	Frequency	Percent	Aggregate
Strongly Disagree	131	7%	
Disagree	141	7%	25%
Somewhat Disagree	204	11%	
Neutral	629	33%	33%
Somewhat Agree	350	18%	
Agree	285	15%	42%
Strongly Agree	173	9%	

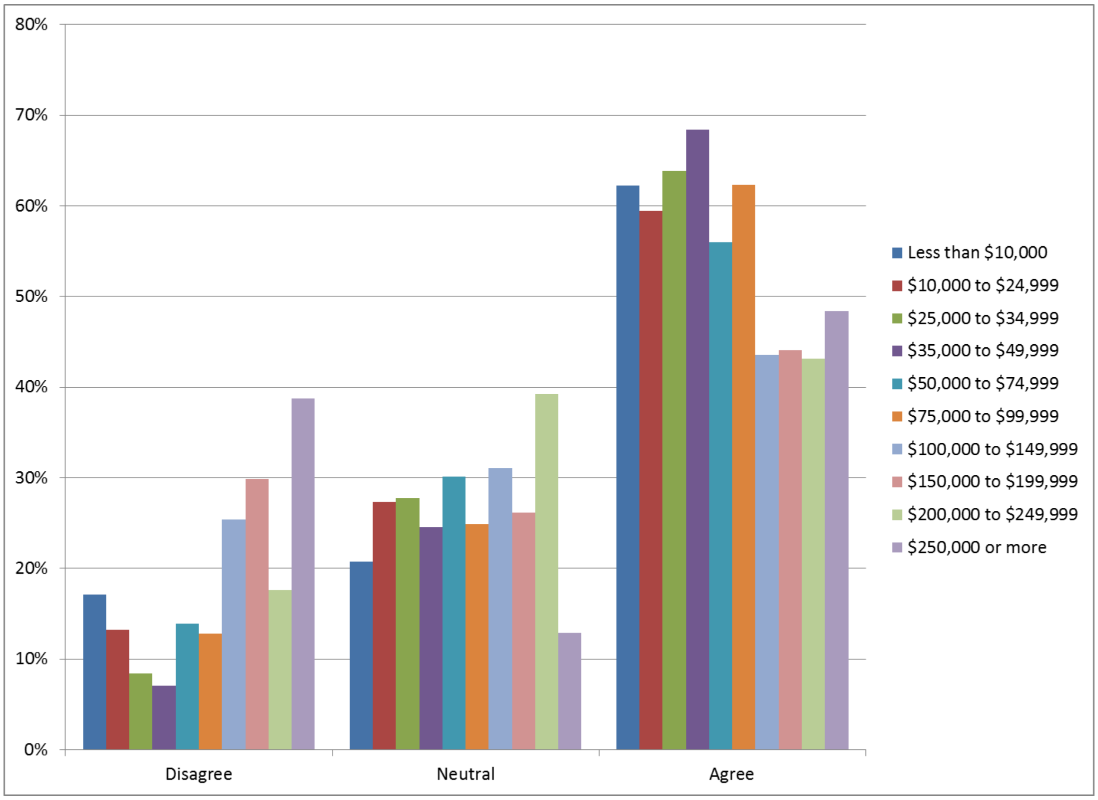
Source: CUTR based on data from King County Metro Transit.

Table C-24. Tolls on SR 520 are Unfair to People on Limited Incomes

Response	Frequency	Percent	Aggregate
Strongly Disagree	77	4%	
Disagree	106	6%	17%
Somewhat Disagree	135	7%	
Neutral	540	28%	28%
Somewhat Agree	391	20%	
Agree	325	17%	55%
Strongly Agree	335	18%	

Source: CUTR based on data from King County Metro Transit.

The responses from Table C-22 through Table C-24 were cross-tabulated against reported incomes to see if there was any disparity in the responses. With regards to the attitudinal statement that tolls on SR 520 are unfair to people on limited incomes, Figure C-8 shows that respondents at the lower end of the income spectrum were more likely to agree with the statement that the tolls are unfair while respondents at the upper end of the income spectrum were less likely to agree.



Source: CUTR based on data from King County Metro.

Figure C-8. Tolls on SR 520 are Unfair to People on Limited Incomes (Cross-tabulation by Income)

Volpe Household Travel Survey

The responses from the May 2012 on-board survey were compared to the responses of bus riders in the Wave 2 household travel survey conducted by the Volpe Center. This latter survey was conducted in April and May 2012. Unlike the on-board survey, which was limited to SR 520 bus riders, the Wave 2 survey included a limited number of responses from I-90 bus riders.

The responses from the two surveys yielded some different results. Although some of the questions were worded slightly differently, comparisons can still be made. For example, bus riders in both surveys were asked to rate their level of satisfaction with several aspects of the transit service. In the on-board survey, riders were asked to respond on a scale of 1 to 5 with 1 meaning ‘very poor’ and 5 meaning ‘very good’. Riders from the Wave 2 survey were asked to respond on a scale of 1 to 7 with 1 meaning ‘very dissatisfied’ and 7 meaning ‘very satisfied’.

Respondents from the on-board survey were more positive about their travel time and the reliability of the transit service than the respondents from the Wave 2 survey. In the on-board survey, 85 percent rated their travel time as good or very good while only 72 percent in the Wave 2 survey said they were somewhat to very satisfied. Similarly, 83 percent in the on-board survey rated the reliability of the transit service as good or very good while only 76 percent in the Wave 2 survey said they were somewhat to very satisfied. In regards to wait time at the bus stop, the percentage of positive responses from the two surveys was about the same. However, a larger percentage of respondents from the Wave 2 survey were negative about their wait time. See Table C-25 through Table C-27.

Table C-25. Volpe Survey Comparison Travel Time

On-Board Survey			Volpe Wave 2 Survey		
Rating	**Frequency**	**Percent**	**Rating**	**Frequency**	**Percent**
Good to Very Good	1,686	85%	Somewhat to Very Satisfied	832	72%
Fair	250	13%	Neutral	133	12%
Poor to Very Poor	39	2%	Somewhat to Very Dissatisfied	182	16%
	1,975	**100%**		**1,147**	**100%**

Source: CUTR based on data from Volpe.

Table C-26. Volpe Survey Comparison Reliability

On-Board Survey			Volpe Wave 2 Survey		
Rating	**Frequency**	**Percent**	**Rating**	**Frequency**	**Percent**
Good to Very Good	1,642	83%	Somewhat to Very Satisfied	876	76%
Fair	255	13%	Neutral	118	10%
Poor to Very Poor	83	4%	Somewhat to Very Dissatisfied	152	13%
	1,980	**100%**		**1,146**	**100%**

Source: CUTR based on data from King County Metro Transit.

Table C-27. Volpe Survey Comparison Wait Time

On-Board Survey			Volpe Wave 2 Survey		
Rating	**Frequency**	**Percent**	**Rating**	**Frequency**	**Percent**
Good to Very Good	1,433	73%	Somewhat to Very Satisfied	869	76%
Fair	455	23%	Neutral	112	10%
Poor to Very Poor	84	4%	Somewhat to Very Dissatisfied	166	14%
	1,972	**100%**		**1,146**	**100%**

Source: CUTR based on data from King County Metro Transit.

Riders from both surveys were provided with several statements regarding the tolls and asked to indicate the extent to which they agreed or disagreed with them. They were asked whether they thought the tolls on SR 520 had improved their travel and whether they thought the tolls were unfair to people on limited incomes. Table C-28 shows that a greater percentage of respondents from the on-board survey than the Wave 2 survey agreed that tolling SR 520 has improved their travel (57 percent versus 35 percent). A possible reason for the lower percentage in the Wave 2 survey is that it included I-90 bus riders, who do not see any personal benefit of the SR 520 tolls.

Table C-28. Volpe Survey Comparison SR 520 Tolls

Statement	On-Board Survey			Volpe Wave 2 Survey		
	Rating	**Frequency**	**Percent**	**Rating**	**Frequency**	**Percent**
Tolling on SR 520 has improved my travel	Agree	1,083	57%	Agree	227	35%
	Neutral	506	26%	Neutral	144	22%
	Disagree	324	17%	Disagree	277	43%
		1,913	**100%**		**648**	**100%**

Source: CUTR based on data from King County Metro Transit.

The percentage of respondents that agreed with the statement that tolls on SR 520 are unfair to people on limited incomes was about the same between 55 percent and 56 percent. A greater percentage of riders from the on-board survey were neutral, and a greater percentage from the Wave 2 survey disagreed.

Table C-29. Volpe Survey Comparison Toll Equity

Statement	On-Board Survey			Volpe Wave 2 Survey		
	Rating	**Frequency**	**Percent**	**Rating**	**Frequency**	**Percent**
Tolling on SR 520 is unfair to people on limited incomes	Agree	1,051	55%	Agree	391	56%
	Neutral	540	28%	Neutral	137	20%
	Disagree	318	17%	Disagree	173	25%
		1,909	**100%**		**700**	**100%**

Source: CUTR based on data from King County Metro Transit.

The Wave 2 survey reported two percent fewer transit trips in the SR 520 corridor compared to the Wave 1 survey in November 2010. However, the mode share of transit rose from 15 percent to 18 percent. The share of commuters who reported using transit as a “typical” commute mode rose 1.5 percentage points. Avoiding tolls was the most common motivation for switching to transit (45 percent), but respondents also mentioned reduced stress (44 percent) and gasoline prices (39 percent). Few cited improved bus service as their motivation (8 percent).

C.6 Summary of Transit Impacts

The Seattle UPA demonstrated strong increases in ridership and park-and-ride lot usage as well as improvements in bus travel times. Customer satisfaction with the transit service as a whole remains good, although there were some rating decreases in areas such as wait time at the stops, availability of seats, and parking availability. Ironically, some of these lower ratings may be due indirectly to the increased demand for transit service.

Ridership on the SR 520 Bridge increased 38 percent after tolling. Although rising gasoline prices and falling unemployment rates may have contributed to some of the ridership increase, the fact remains that ridership across the SR 520 Bridge increased by a greater percentage than it did across the parallel I-90 Bridge (which was 23 percent) and the rest of King County Metro bus (which was 8 percent).

On-time performance across the SR 520 Bridge improved in the eastbound direction from 47 to 67 percent in the a.m. peak period (6:00 to 9:00 a.m.). In the p.m. peak period (3:00 to 7:00 p.m.) it improved from 40 to 57 percent. There was no significant improvement in the westbound direction. In absolute terms, on-time performance remains low. Bus travel times across the SR 520 Bridge improved after tolling. Improvements were greatest in the eastbound direction where bus travel times were 0.9 and 1.7 minutes shorter.

The passenger surveys showed that the Seattle/LWC UPA has helped to shift some commuters to transit. In the first survey, which was done after the new transit service was added but prior to tolling, 19 percent of the riders said they were influenced to take transit because of the new service. In the second survey, which was done after tolling began, 19 percent of the riders said they began riding the bus after tolling began. Of these new riders, 55 percent said they were influenced to take transit because of the tolls. This is the highest percentage observed so far in the UPA/CRD evaluations. When asked how they used to make their trip across the SR 520 Bridge, 41 percent of new riders said they used to drive alone.

The surveys revealed important information regarding riders' perceptions of the transit service and the tolls. The satisfaction rating for on-time performance dropped in the post-toll survey. On a 1 to 5 scale, the mean score dropped from 4.24 to 4.14. Although 4.14 still equates to a rating of good, the drop was statistically significant at the 95 confidence level. The satisfaction rating for bus travel time increased from 4.22 to 4.23 (good), but the change was not statistically significant. Overall satisfaction with King County Metro Transit increased from 3.94 to 4.03 (good). The change was statistically significant at the 95 percent confidence level. Most of the bus riders (82 percent) reported that congestion on SR 520 has been less since tolling began. When asked how their travel times have changed since tolling began, 46 percent reported faster travel times, 47 percent reported that they were the same, and only 7 percent reported longer travel times. A majority of the riders (57 percent) said that the SR 520 tolls have improved their personal travel. A smaller percentage (42 percent) said the SR 520 tolls have been good for the region. However, a majority (55 percent) also believed the SR 520 tolls are unfair to people on limited incomes. Riders with lower incomes were more likely to believe this.

Table C-30 presents a summary of the transit impacts for each of the hypothesis in the transit analysis.

Table C-30. Summary of Transit Impacts Across Hypotheses

Hypotheses/Questions	Result	Evidence
• The Seattle/LWC UPA projects will enhance transit performance in the SR 520 corridor through reduced travel times, increased reliability, and increased capacity.	Supported	• Eastbound improved from 47 to 67 percent in the a.m. peak and improved from 40 to 57 percent in the p.m. peak; no significant improvement in the westbound direction. • Bus travel times were 0.9 to 1.7 minutes shorter in the eastbound direction after tolling.
• The Seattle/LWC UPA projects will facilitate an increase in ridership and mode shift to transit on the SR 520 corridor.	Supported	• Peak period average daily ridership on SR 520 Bridge increased 38 percent. Across the I-90 Bridge, it increased 23 percent. Ridership on the rest of King County Metro's bus system increased only by 8 percent. • Redmond Park-and-Ride garage increased from 86 percent to 99 percent occupied from Sept. 2010 to Sept. 2012. • 8 of 12 park and ride lots serving bus routes crossing the SR 520 Bridge were at least 90 percent occupied in Sept. 2012 (in Sept. 2010, there was only one).
• The mode shift to transit will result in less congestion on the SR 520 corridor.	Supported	• 82 percent of riders reported that congestion on SR 520 has been less since tolling began. • Speeds across the bridge have increased by 14 to 18 mph.
• What was the relative contribution of each Seattle/LWC UPA project element to increased ridership and mode shift to transit?	Supported	• 19 percent of new riders said they were influenced to take transit because of the additional transit service. • 55 percent of new riders said they were influenced to take transit because of the tolls. • 46 percent of all riders reported faster travel times since tolling began; 47 percent reported that they were the same; 7 percent reported longer travel times. • 57 percent said that the SR 520 tolls have improved their personal travel.

Source: CUTR.

Appendix D. TDM Analysis

The transportation demand management (TDM) analysis investigated whether the Seattle/LWC UPA project TDM initiatives and promotion of vanpooling and telecommuting resulted in mode shift and thus removed trips and decreases VMT from SR 520. This was largely performed by using Commute Trip Reduction and Volpe household travel survey data as well as vanpool and telecommuting statistics in a before and after comparison of program activities and impacts. Table D-1 lists the hypothesis and question that guided the TDM analysis.

Table D-1. TDM/Telecommuting Analysis Hypothesis and Question

Hypothesis/Question
• Promotion of commute alternatives and other options (mode, time) removes trips and vehicle miles traveled (VMT) from SR 520
• What was the relative contribution of the various Seattle UPA Telecommuting/TDM initiatives on reducing SR 520 vehicle trips/VMT?

Source: Battelle.

The remainder of this appendix is divided into four sections. The TDM Program in the Seattle/LWC area is presented next in Section D.1. The data sources used in the TDM analysis are presented in Section D.2. Section D.3 discusses the data analysis and findings. Section D.4 presents a summary of the TDM analysis in relation to the hypothesis and question.

D.1 TDM Program

The UPA projects in the LWC are valuable for assessing the effects of tolling on travel behavior, telecommute, and TDM. Traditional commute flows on the SR 520 bridge across Lake Washington were suburb-to-city, westbound in the morning and eastbound in the evening, but there is now an equally large “reverse” commuter flow to the many employment centers on the Eastside, such as downtown Bellevue and the Microsoft campus in Redmond. The telecommuting/TDM element of the Seattle/LWC UPA project involves support for increased telecommuting and vanpooling through outreach with employers and commuters directly. Telecommuting and vanpooling is intended to remove trips and reduce VMT.

The local partners’ telecommuting and other TDM-related activities in the SR 520 corridor (including SR 520 and the alternate routes of I-90 and SR 522) include four types of strategies. The first strategy represents continuation of existing programs. The other three strategies either provide UPA related enhancements to existing activities or introduce new, UPA-supporting TDM elements. More specifically, these strategies include:

- *Enhancement of Existing Vanpool Programs.* One arm of the UPA-related enhancements is to monitor the effect of the tolls on vanpool demand. Vanpool operators in the region focus some resources toward helping meet any increased demand among the SR 520 corridor commuters.

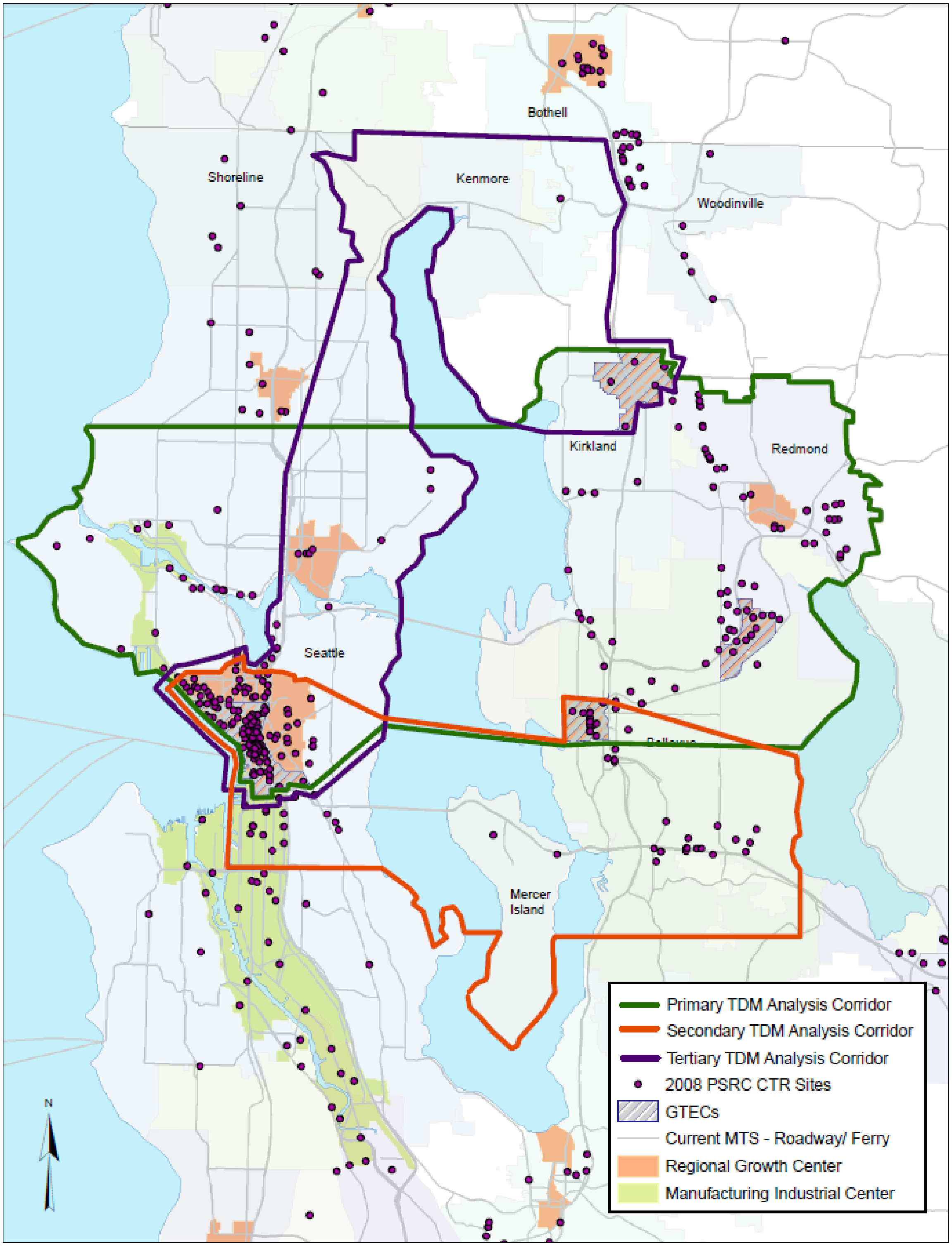
- *Enhanced Employer Technical Assistance for Telecommuting.* The programs also provide enhanced technical assistance on telecommuting to employers. Specifically, area TDM managers work with employers who, according to recent Commute Trip Reduction (CTR) survey data, didn't appear to offer significant opportunities for telecommuting, flexible work schedules and compressed work weeks. For employers who choose to put more emphasis on these programs, coaching, samples, templates, tools and information about how their peer organizations have successfully implemented programs was provided. These programs were focused on Bellevue and downtown Seattle.
- *New, UPA-related Targeted Marketing and Outreach.* The marketing and communication strategy for the SR 520 tolling project and other UPA projects includes information specifically targeted to promotion of travel alternatives. This marketing and communication was coordinated with TDM marketing activities to employers, growth centers and commuters. The marketing did not include any new services or incentives, but was designed to inform affected commuters of alternatives to paying the full toll on SR 520. King County Metro Transit developed and implemented a comprehensive outreach program to employers and commuters to help inform them of commute options available to avoid or lessen the tolls paid on SR 520. The campaign, marketed as —Save More Time Doing Something Else — was focused on promoting alternatives to driving alone of SR 520 (and the SR 99 Alaskan Way Viaduct).
- *Trial Transit Incentive.* King County Metro offered a free Orca card to all *Good to Go!* pass applicants containing $6.00 in E-purse value (equal to one round trip bus fare across the bridge). Some 1,213 Orca cards were distributed in this manner from March – September 2011. Specifically, applicants were asked if they had an Orca card, and if they said no, they were asked if they would like one in order to try the bus as an option. In February 2012, two months after tolling began, an evaluation of Orca card recipients revealed that over half (650) had used their Orca cards.
- *Continuation of Existing TDM Activities in the SR 520 Corridor.* For many years, local and state agencies and employers have provided a wide array of programs intended to reduce trips in the SR 520 corridor. Examples include employer compliance with CTR regulations; transit, vanpool, vanshare and carpool incentives, telecommute programs, and parking fees supportive of TDM. These activities are not new as a result of the UPA project but support the UPA objectives related to TDM.

D.2 Data Sources Used in TDM Analysis

Four data sources were used in the TDM analysis. Pre- and Post-Deployment Commute Trip Reduction (CTR) survey data for employers impacted by SR 520 were provided by WSDOT. As part of the evaluation planning process, the CTR data sets were determined to be the primary source of TDM-related mode shift data. The household travel survey that was conducted by the Volpe was also utilized. Vanpool statistics for vans using SR 520 was provided by King County Metro Transit. Telecommuting outreach statistics for employers in the SR 520 corridor were transmitted to the national evaluation team on a periodic basis by King County Metro Transit.

CTR Survey Data

The Commute Trip Reduction Law was passed in 1991 and requires some 1,100 worksites with 100 or more employees to plan and implement programs to reduce vehicle trips and VMT by promoting commute alternatives. The law applies to all populous counties in the state, including those in the Puget Sound. The law also requires affected worksites to survey employees and submit survey data to WSDOT. These data are used here to assess mode shift at affected worksites in the SR 520 corridor. In fact, the CTR analysis was performed in three analysis areas corresponding to three broad corridors, as identified by WSDOT. These were categorized as primary, secondary and tertiary for the CTR data analysis, corresponding to SR 520 (primary), I-90 (secondary), and SR 522 (tertiary). Such analysis areas were necessary because while CTR data includes O-D data, the specific facility used for commuting needs to be inferred. Likewise, there is some overlap between analysis areas, as shown in Figure D-1, particularly in downtown Seattle. The CTR survey results are useful for assessing mode shift, time shift and trip elimination related to the TDM hypothesis.



Source: PSRC and WSDOT.

Figure D-1. CTR Analysis Areas Boundary Map

Specific requirements for employers include the following, for employers with 100 or more employees who report to work at a single site between 6 and 9 a.m.

- Appoint and maintain an individual to act as an Employee Transportation Coordinator for employees and to be the primary contact with the local jurisdiction;
- Develop and promote a program that helps employees reduce drive-alone commute trips;
- Submit the program to the local jurisdiction for review and approval once every two years;
- Exercise a good faith effort by collaborating with the local jurisdiction in its administration and implementation of the law; and
- Conduct a commuter survey once every two years to measure employees' drive alone rates.

The requirement for conducting the commuter survey yields a rich source of data for the evaluation of the UPA projects effects on mode share in the region. CTR surveys were conducted in 2010 and 2012, corresponding to the pre- and post-deployment periods. Respondents list the number of weekly trips to work made by 9 different travel modes, including drive alone, carpool, vanpool, transit, non-motorized, telecommute, or compressed work week.

The GTEC commuter survey referenced in the Seattle/LWC UPA Telecommuting/TDM Test Plan was not conducted due to lack of funding. In its place, the Volpe household travel survey is used to assess the effects of the UPA projects on telecommute and overall TDM participation in the Seattle region.

Volpe Household Travel Survey – Characteristics and Attitudes of Travelers

The Volpe household travel survey represented all travelers and involved surveying households during the "before" and "after" periods in order to assess changes in travel behavior. The core part of the survey was a 48-hour travel diary, in which respondents recorded the details of all trips taken on their assigned dates, including origin, destination, time, travel mode, and purpose. In addition to the sample chosen using photographic license plate capture along sections of SR 520 and I-90, vanpool members were contacted by emails to specifically enroll vanpool participants, although insufficient responses meant that the vanpool mode was not separated out in the survey findings. More information on the Volpe household travel survey can be found in Appendix A – Congestion Analysis.

Given the differences in findings, as discussed below, it is important to discuss differences in the two data sets up front. The main difference between the data sets is travel population surveyed, the CTR data is derived from commuters and the Volpe survey is based on all travel by all members of a household (to include non-work trips). This might explain differences in mode shift results, such as with carpool findings, as carpooling for all travel, including off peak will likely be different than carpool trends among peak-period travelers. Second, the Volpe survey was focused on specific users of SR 520 and I-90, whereas the CTR survey data may have come from commuters using various routes in the area or perhaps even not using the corridor (given the way in which O-D patterns were assumed). Additionally, the CTR employees have been exposed to the promotion of alternative modes over time, whereas those travelers responding to the Volpe survey may reflect those without much prior prompting to consider travel options. As such, neither data source likely perfectly reflects mode shift due to TDM programs, but the two sources point to some important findings. Therefore, comparison of the CTR and Volpe data should be made with care and with these caveats in mind.

Vanpool Data

King County Metro Transit, which operates public transit and vanpooling in King County, compiled data on the number of vanpools and vanpoolers in the SR 520 corridor, as well as those operating in two parallel corridors, SR 522 and I-90. While most vanpools are operated by King County Metro Transit, data was also assembled from Pierce Transit, Community Transit and Kitsap Transit. Data were reported for May 2010 (19 months before tolling), September 2011 (3 months before tolling), April 2012 (4 months after tolling began), and December 2012 (a year after initiation of tolling).

Telecommuting Outreach Data

A telecommuting outreach program, branded as WorkSmart, to employers in the SR 520 corridor began in the spring of 2011, well before the start of tolling. Implemented by King County Metro Transit, this outreach program complemented similar efforts for employers impacted by the Alaska Way Viaduct project. King County Metro Transit and its contractor conducted a telecommute workshop for employers in February 2011 and then worked one-on-one with several employers impacted by the SR 520 project.

D.3 Data Analysis

This section presents the CTR survey data and analyzes the findings, comparing the two Volpe household travel surveys described in the previous section, and looking at specific data on vanpooling and telecommuting.

Travel changes in the primary corridor (SR 520) are presented below in Table D-2. Relatively small changes are observed in the primary corridor (SR 520). Single occupant vehicle (SOV) commuting decreased by a little over a percent, and carpooling decreased by 2/3 of a percentage point. The largest shift in mode occurred with non-motorized commuters, with an increase of 1.47 percent points. There was also a small change in telecommuting, which shows an increase of 0.15 percentage points. On a relative basis, the percent change of each travel mode, shown in the far right column of Table D-2, are larger.

Table D-2. Pre- and Post-Deployment Work Travel Modes for CTR Employees in Primary Corridor (SR 520)

Travel Mode	Pre-Deployment 2010	Post-Deployment 2012	Change	Percent Change
Drive Alone	43.7%	42.59%	-1.11%	-2.5%
Carpool	10.65%	9.99%	-0.66%	-6.2%
Vanpool	1.97%	1.92%	-0.05%	-2.5%
Transit[1]	32.47%	32.64%	+0.15%	+0.4%
Bike or Walk	5.84%	7.31%	+1.47%	+25.2%
Compressed Work Week	0.34%	0.32%	-0.02%	-5.9%
Other	1.25%	1.34%	+0.09%	+7.2%
Telecommute	3.75%	3.90%	+0.15%	+4.0%

Source: ESTC based on data from WSDOT.

The analysis of CTR data was performed for three broad corridors: primary (focused on SR 520, secondary (focused on I-90), and tertiary (focused on SR 522). Table D-3 compares mode split changes for these corridors. Each CTR analysis area encompasses employment destinations served by each roadway.

[1] Includes bus, train, and ferry. Original CTR results report each individually; total transit is summarized here.

Table D-3. Pre- and Post-Deployment Work Travel Modes for CTR Employees: Comparison by Analysis Area (Corridor)

	Pre-Deployment CTR Data by Corridor			Post-Deployment CTR Data by Corridor		
	Primary SR520	Secondary I-90	Tertiary SR522	Primary SR520	Secondary I-90	Tertiary SR522
SOV	43.73%	35.48%	31.44%	42.59%	37.58%	31.78%
Carpool	10.65%	10.39%	10.22%	9.99%	9.72%	9.60%
Vanpool	1.97%	1.31%	1.41%	1.92%	1.49%	1.39%
Transit (total)	32.47%	41.32%	45.35%	32.64%	38.80%	43.00%
Bike	2.47%	2.07%	2.48%	3.14%	2.33%	3.66%
Walk	3.37%	3.57%	4.29%	4.17%	4.46%	5.25%
Telecommute	3.75%	4.24%	3.11%	3.90%	3.95%	3.62%
Compressed Work Week	0.34%	0.43%	0.38%	0.32%	0.31%	0.39%
Other	1.25%	1.19%	1.33%	1.34%	1.35%	1.34%

Source: ESTC based on data from WSDOT.

As shown in Table D-3, SOV use declined slightly in the post-deployment period in the primary corridor (SR 520). However there was a fairly significant rise of 2.1 percent in SOV use on the secondary corridor (I-90), along with a small increase in the tertiary corridor (SR 522). Interestingly, bike and walk shares also increased in the secondary and tertiary corridors (I-90 and SR 522 respectively).

Table D-4 presents the combination of all analysis areas for all modes as a weighted average of all corridors, where the weight is based on the number of trips in each corridor. Data provided in this table shows that there is a slight increase in drive alone use. There are decreases in shared modes, including carpool and transit though a slight increase in vanpooling (as corroborated by the vanpool operators data discussed below). Further, there are increases in non-motorized modes including bike, walk, and telecommute.

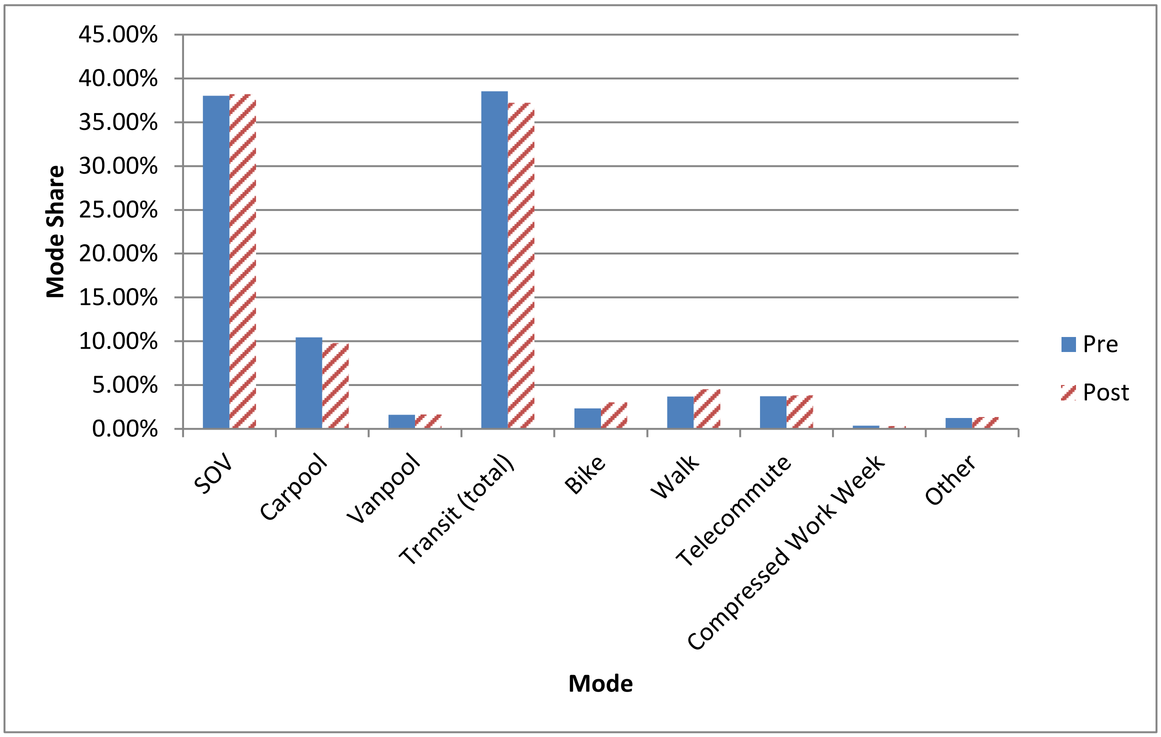
Table D-4. Pre- and Post-Deployment Travel Mode for Employees at CTR Companies (All Corridors, All Analysis Areas)

Travel Mode	Pre-Deployment 2010	Post-Deployment 2012	Percent Change	Absolute Difference
Drive Alone	38.01%	38.22%	0.55%	0.21%
Carpool	10.46%	9.81%	-6.24%	-0.65%
Vanpool	1.62%	1.65%	1.79%	0.03%
Transit[2]	38.53%	37.22%	-3.38%	-1.30%
Bike or Walk	6.02%	7.59%	26.08%	1.57%
Telecommute	3.73%	3.84%	2.95%	0.11%
Compressed work week	0.38%	0.34%	-10.5%	-0.04%
Other trips	1.25%	1.34%	7.2%	0.09%

Source: ESTC based on data from WSDOT.

Figure D-2 presents the same comparison between the pre- and post-deployment periods in graphical form. When examining all three corridors together, aggregate mode share has remained largely the same before and after implementation of tolling.

[2] Includes bus, train, and ferry. Original CTR results report each individually; total transit is summarized here.



Source: ESTC based on data from WSDOT.

Figure D-2. Comparison of Travel by Mode for CTR Employees

A summary of the Volpe household travel survey results are presented in Table D-5. There are differences in these findings in comparison to the CTR findings, including the direction and size of mode shift. The emphasis of the Volpe household travel survey is on all users of SR 520, contrasted with the CTR survey of commuters using any facility (which includes those who do not use SR 520 or perhaps any of the freeway facilities). Thus, the difference in survey populations may be the most likely reason for the differences.

Table D-5. Pre- and Post-Deployment Measurements of Travel Mode from Volpe Survey

	Pre-Deployment	Post-Deployment	Percent Change
Travel Minutes per Day	95	84	-11.6%
Trips per day	8,101	6,681	-17.5%
Drive Alone	76%	69%	-7%
Average Passenger Vehicle Occupancy	1.48	1.56	-0.08%
Carpooling	14%	13%	-1%
Transit	15%	18%	+3%
Telecommute	15%	15%	0%

Source: Volpe.

Baseline Volpe household travel survey results noted a typical SR 520 drive alone rate of 76 percent with carpooling at 14 percent and bike/walk at 1 percent. Follow-on questions about telecommuting showed that 15 percent of travelers telecommute at least one day per week and that telecommuting frequency was positively correlated with higher incomes. Seventy-five (75) percent of travelers have some degree of flexibility in their work schedule, thus potentially making it easier to adjust their commute behavior in response to tolling. Twenty-six (26) percent of travelers said that their employer offered free or discounted vanpooling (with another 20 percent not sure), and 3 percent of the respondents said they had used this benefit.

The following general patterns were found from the results of the Volpe household travel survey, based on travel diaries:

- Overall 18 percent decline in trips in the LWC, with the biggest decrease on SR 520
    - 19 percent in respondents' estimates of typical weekly travel in the corridor
    - 43 percent on SR 520 as recorded in diaries
    - 13 percent on I-90 as recorded in diaries
- Little offsetting increase in non-corridor trips
- Overall recorded travel per person down 14 percent by trip count and 12 percent by total duration.

In terms of mode choice:

- Recorded transit trips in corridor down slightly(-2 percent) but mode share on corridor rose from 15 percent to 18 percent
- Share of commuters reporting transit as a "typical" commute mode rose 1.5 percentage points
- Avoiding tolls was common motivation for switching to transit (45 percent) but respondents also mentioned reduced stress (44 percent) and gasoline costs (39 percent); few cited improved bus service (8 percent)
- Mean private vehicle occupancy rose slightly on the corridor, 1.48 to 1.56
- On SR 520, passenger vehicle occupancy rose from 1.42 to 1.61; solo trips fell from 76 percent to 69 percent
- However, there were no indications of a major shift to carpooling for commuting; held steady at 13 percent - 14 percent.

There was no reported increase in regular carpooling. Based on responses to a question about typical commute modes, carpooling to work had a net loss of 37 respondents (about 1 percent of regular commuters) between waves. In follow-up questions, the most commonly cited reasons for ending a carpool were changes in home or work locations (42 percent of those who stopped carpooling) and other carpool members having dropped out (33 percent). Respondents could select more than one reason for their changes. Among those who started carpooling after Wave 1, the most common stated motivations were sharing vehicle operational costs (33 percent of new carpoolers) and improved convenience or less stress (32 percent). Only 9 percent of new carpoolers specifically mentioned sharing toll costs as one of the reasons that they began carpooling, though it is possible that the salience of the tolls drew commuters' attention to the overall costs of driving.

Although regular carpooling did not increase, there is also little evidence that the newly free-flowing conditions on SR 520 directly led to any drop in carpooling. Based on the Volpe survey, only 3 respondents said that they stopped carpooling because it was now faster to drive alone on SR 520.

Specific Volpe household travel survey findings regarding telecommuting are summarized below. Note that there were two measurements: recorded telecommuting on assigned travel days & self-reported typical telecommuting.

1. Both measures showed no significant change from Wave 1 to Wave 2.
2. About 15 percent of employed respondents telecommuted during at least part of one assigned travel day.
3. In follow-up questions, any changes to telecommuting patterns were most frequently attributed to work-related factors, not transportation- or toll-related factors.

Note again that the Volpe household travel survey reports different findings than the CTR survey. Most of the difference could be attributed to the fact that the CTR survey covers employees at large companies regardless of which roadway facilities they take to get to and from work. The Volpe household travel survey was focused on users of SR 520 or I-90 and includes all travel, not just commute travel.

Telecommuting Data

As part of the Volpe household travel survey, recorded telecommuting held relatively constant between Wave 1 and Wave 2 with no significant change. In both survey waves, 15 percent of respondents telecommuted for at least part of one or both assigned diary days. However there were differences that should be noted.

As compared to the before case (Wave 1), 20 percent of employed respondents reported telecommuting more frequently in the Wave 2 survey, while 14 percent reported telecommuting less frequently. In follow-up questions about the reasons for telecommuting more or less frequently than before, 54 percent of those who increased their telecommuting cited work-related reasons, 20 percent cited reduced commuting costs, 17 percent cited changes in their personal situation, 16 percent cited improvements in their home technology, and 9 percent cited reduced toll costs. (Respondents could select more than one reason.) Among those who reduced their telecommuting, 78 percent cited changes in their work situation. Only six respondents (less than 0.5 percent of those employed) said that they are telecommuting less frequently now because traffic conditions have improved.

Overall, the project does not appear to have increased telecommuting in the affected corridor, based on the Volpe household travel survey. Results from King County Metro Transit's telecommute outreach effort, WorkSmart, revealed modest success. Six employers, representing a significant number of employees, impacted by the tolling project agreed to work with King County Metro Transit during the course of the UPA project. Training of staff and managers and development of policies continued to be ongoing at the conclusion of the post-deployment period. Some of these efforts will be evaluated apart from UPA national evaluation. Program managers noted that the outreach effort was affected by the delays in the start of tolling, with outreach perhaps starting too early. Additionally, employers shared that telecommuting is not necessarily viewed as a response to tolling, but is more important as a business practice and employee benefit.

Vanpool Data

Data from the vanpool operators Kings County Metro Transit, as well as Pierce, Community, and Kitsap Transit show substantial growth in vanpooling from 2010 to 2012. Table D-6 presents the documented numbers of vans and vanpool participants between May 2010 and December 2012.

Table D-6. Vanpool Statistics for SR 520, I-90 and SR 522 from 2010–2012

Period	SR 520		I-90		SR 522		Corridor Total	
	Vans	Riders	Vans	Riders	Vans	Riders	Vans	Riders
May 2010	72	583	56	445	94	791	222	1,819
September 2011	98	785	82	643	88	742	268	2,170
April 2012	125	1,004	98	805	95	796	318	2,605
December 2012	166	1,205	116	827	95	773	377	2,805
Change 2010 – 2012	+130%	+107%	+107%	+86%	+1.1%	-2.4%	+47%	+35%

Source: ESTC based on data from King County Metro Transit.

These statistics show a 35 percent overall increase in the number of vanpoolers on the three main facilities crossing Lake Washington although not reflected in the CTR data shown in Tables D-2 through D-4. Growth in the number of vans and riders on SR 520 where the tolls were implemented and on I-90, which grew as an alternative post-tolling was substantial; the number of riders more than doubled on SR 520 and nearly doubled on I-90. However, these numbers of new vanpoolers are a very small number as compared to total person trips on the facilities.

To place these statistics in context with the much smaller changes in vanpooling reported in the Commute Travel Reduction (CTR) survey reported earlier in this section, it is important to note that Table D-6 refers to vanpooling across three specific facilities while the CTR data is for travel throughout the region whether or not including those specific highways.

In addition, another reason for small changes in vanpooling at CTR sites is that some worksites have instituted vanpool policies for years. As such, the number of new vanpoolers could be muted simply because the market at these sites has already been saturated.

D.4 Summary of Impacts

Table D-7 summarizes the impacts of the TDM program across the hypothesis and question in the national evaluation. As presented in the table, the TDM programs did not support both hypotheses, but without clear causality. The various data sources paint slightly different pictures of nominal shifts in certain modes, especially bike and walk. Vanpooling, as managed by regional providers, doubled in the SR 520 corridor in the post-deployment period. However, carpooling was deemed to decrease very slightly (<1 percent) between both CTR worksites using the SR 520 corridor and among SR 520 travelers captured in the Volpe household travel survey. Appendix A – Congestion Analysis, shows an almost 30 percent decrease in VMT in the SR 520 corridor after the advent of tolling, but it cannot be concluded that the modest mode shifts in non-motorized (CTR), transit options (Volpe) and vanpooling (King County Metro) contributed in any meaningful way to this effect. It should also be noted that the study area already has relatively high non-drive shares (over 50 percent), as reflected in the CTR data.

The CTR data support the ability to see changes in mode, although linking the destination-based worksite data to the study corridors is imperfect. These data show that carpooling actually decreased somewhat, as well as transit use. Telecommuting changed by a small amount (3.73 percent pre-deployment to 3.84 percent post). They also suggest a very slight increase in drive alone rates (from 38.01 to 38.22 percent). Transit decreased from 38.5 to 37.2 percent and carpooling decreased from 10.46 to 9.81 percent.

The Volpe household travel survey data show slightly different results, since they are based on a different set of travelers: those who use SR 520 and I-90. The Volpe household travel survey found a drop in drive alone rates from 76 to 69 percent and slight increase in the occupancy of passenger vehicles (1.48 to 1.56), which is slightly counter to its finding that carpooling decreased by 1 percent. Possibly the number of people per carpool is responsible for the increase. The Volpe household travel survey found an increase in transit use, which rose from 15 percent to 18 percent.

Finally, specific counts of before and after vanpooling data show that vanpooling increased by 35 percent in all three corridors studied and the number of vanpoolers doubled on SR 520 after implementation of tolling. This growth was not reflected in the CTR data and the Volpe survey did not separate out vanpoolers.

Overall, the TDM and telecommuting elements of the UPA project, coupled with ongoing CTR requirements, provide commuters on SR 520 with alternatives to driving alone and paying the full toll. However, changes in travel behavior are likely motivated by the toll itself. Overall, TDM efforts may have contributed by raising awareness of options so those motivated by tolls could determine their best travel alternative.

Table D-7. Summary of Impacts Across Hypotheses

Hypotheses/Questions	Result	Evidence
Promotion of commute alternatives and other options (mode, time) removes trips and vehicle miles traveled (VMT) from SR 520	Not supported	VMT decreased on SR 520 by 28.9 percent according the congestion analysis, yet very modest mode shifts to transit, bike, and walk were likely not contributing factors since these shifts were offset by small increases in drive alone and decreases in carpooling. Vanpooling did grow substantially in the study area, but was not reflected in the mode split data. Telecommuting does not seem to have increased during the evaluation period.
What was the relative contribution of the various Seattle UPA Telecommuting/TDM initiatives on reducing SR 520 vehicle trips/VMT?	Mode shift insignificant	As stated above, the relative contribution of mode shift resulting from TDM/Telecommuting efforts was likely very small.

Source: ESTC.

Appendix E. Technology Analysis

Technology was an important element of the Seattle/Lake Washington Corridor (LWC) Urban Partnership Agreement (UPA) projects. Intelligent transportation systems (ITS) were incorporated into many of the projects, enabling a wide variety of improvements. The technology analysis focuses on the ITS technologies contributing to congestion reduction, rather than those technologies acting as enablers of other congestion reduction strategies, such as tolling. Further, the analysis focused on the role of technology in supporting congestion-reducing objectives, not determining how well the technology performed. The technology components of the Seattle/LWC UPA included in the analysis are the active traffic management (ATM) system on SR 520 and I-90 and travel time signs for SR 520.

Table E-1 presents the five hypotheses for assessing these technology elements. The first hypothesis is that the highway travel time signs will promote a more even distribution of traffic between SR 520 and alternate routes I-90 and SR 522. The second hypothesis focuses on ATM strategies promoting smoother traffic flow and better throughput on SR 520 and I-90 during non-incident conditions. The third hypothesis is that the ATM strategies will reduce the number of congestion-causing collisions on SR 520 and I-90. The fourth hypothesis is that the ATM strategies in the LWC will reduce the duration of congestion-causing incidents on SR 520 and I-90. The final hypothesis focuses on ATM strategies reducing the impact severity of congestion-causing incidents on SR 520 and I-90.

Table E-1. Seattle/LWC Technology Analysis Hypotheses

Hypotheses/Question
• The travel time signs will promote a more even distribution of traffic between SR 520 and alternate routes (I-90 and SR 522).
• Active Traffic Management will promote smoother traffic flow and better throughput on SR 520 and I-90 during non-incident conditions.
• Active Traffic Management will reduce the number of congestion-causing collisions on SR 520 and I-90.
• Active Traffic Management in the Lake Washington Corridor will reduce the duration of congestion-causing incidents on SR 520 and I-90.
• Active Traffic Management will reduce the impact severity of congestion-causing incidents on SR 520 and I-90.

Source: Battelle.

The remainder of this appendix is divided into five sections. The data sources used in the analysis are described in Section E.1. Operation of the ATM and travel time signs on SR 520 and I-90 is discussed in Section E.2. Section E.3 presents the analysis of the impacts of the ATM and travel time signs on SR 520 and I-90 on traffic flow, travel times, incidents, and crashes. Section E.4 summarizes the results of interviews with Washington State Patrol (WSP) troopers, Incident Response Team (IRT) operators, and King County Metro Transit bus operators on the impacts of the ATM system and the travel time signs on congestion levels and incidents. The appendix concludes with a summary of the technology analysis hypotheses in Section E.5.

E.1 Data Sources

The data used in the technology analysis came primarily from five sources. First, the WSDOT Smarter Highways website provided information on the ATM and travel time sign elements, the locations of the signs, and operation of the ATM and travel time sign components. The WSDOT traffic sensor system was used to obtain speed and volume data for the different freeway segments. Archived detector data were obtained by the national evaluation team and analyzed in Appendix A – Congestion Analysis. The mean travel times and travel speeds, the Travel Time Index, and vehicle, person, and total throughput analyzed in Appendix A were used in the technology analysis. Third, WSDOT operator incident and dispatching logs were used to determine incident frequencies, durations, and severity. Fourth, as presented in Appendix F – Safety Analysis, the WSDOT Collision Data and Analysis Branch Reports database was used to examine changes in crashes on SR 520 and I-90. The final data source was the WSDOT-sponsored interviews of WSP troopers, IRT operators, and King County Metro Transit bus operators, which provides insight into their perceptions of the effectiveness of the ATM and travel time signs.

E.2 Operation of SR 520 and I-90 ATM and Travel Time Sign Systems

This section summarizes the elements of the SR 520 and I-90 ATM and travel time signs. The operation of the ATM system, or Smarter Highways as it is called by WSDOT, is presented first in Section E.2.1. The operation of the travel time signs to downtown Seattle via SR 520 and I-90 is discussed in Section E.2.2.

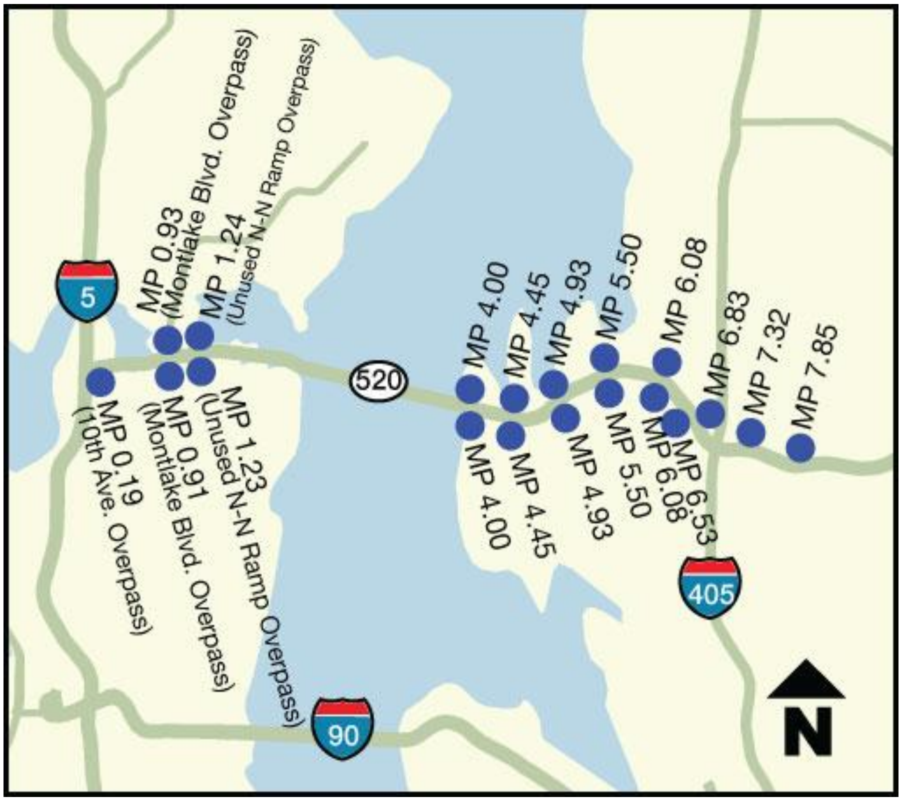
E.2.1 ATM System on SR 520 and I-90

The Smarter Highways system in the Seattle area was initiated on I-5 in 2010. The Smarter Highways system focuses on the use of advanced technologies to adapt to constantly changing highway conditions and to respond in the most effective manner. The ATM operations on SR 520 were implemented in November 2010. As illustrated Figure E-1, there are 19 ATM sign locations in the 8-mile corridor from I-5 to 130th Avenue, N.E. in Bellevue. There are 70 new signs at these 19 locations. There are no signs in the 2.75-mile section that includes the SR 520 bridge. Most of the ATM system on I-90 was implemented in June 2011, with remaining signage on eastbound I-90 becoming operational in May 2012. Figure E-2 illustrates the location of the 25 sign locations, which contain 129 new signs, along the 9-mile corridor from I-5 to 150th Avenue, S.E. in Bellevue.

The ATM system includes signs over every lane that can display variable speed limits (VSL), lane status, merge arrows, and HOV information. The system also includes DMS with posted messages on congestion and incidents. Figure E-3 illustrates the ATM system on I-5 displaying regulatory VSLs and a message to “reduce speed.” Figure E-4 presents the different lane status signs that can be used with ATM system. The possible lane status signs include a green arrow for lane open, a yellow arrow for caution, a yellow X for closed ahead, and a red X for closed.

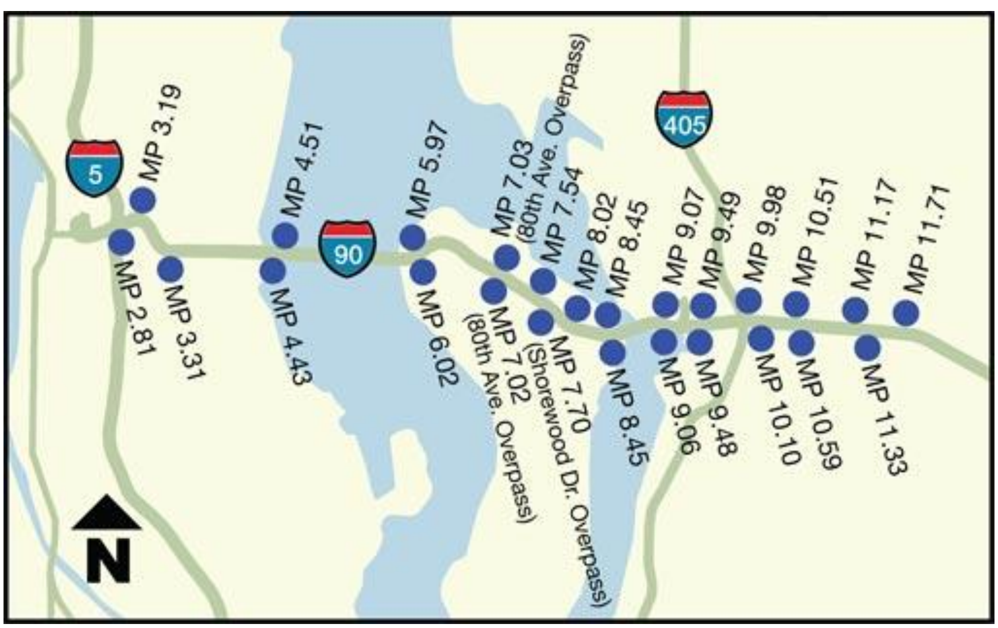
Some of these lane status signs are experimental and are not MUTCD compliant[1]. The VSL signs are automated and are activated by the system in advance of congested freeway segments. The posted speeds can range in 5 mph increments from 60 mph, the highest default speed, to 30 mph, the lowest speed. Message signs are also used to alert drivers of accidents and congestion ahead.

[1] The Merge with Diagonal Arrows are not MUTCD compliant, but have received MUTCD experimental approval by FHWA. The Yellow – Caution arrow and Yellow X – Closed Ahead signs are not MUTCD compliant and have not received experimental approval from FHWA.



Source: WSDOT Website, http://www.wsdot.wa.gov/Projects/LkWaMgt/LkWaATM/map.htm.

Figure E-1. Location of ATM Signs on SR 520

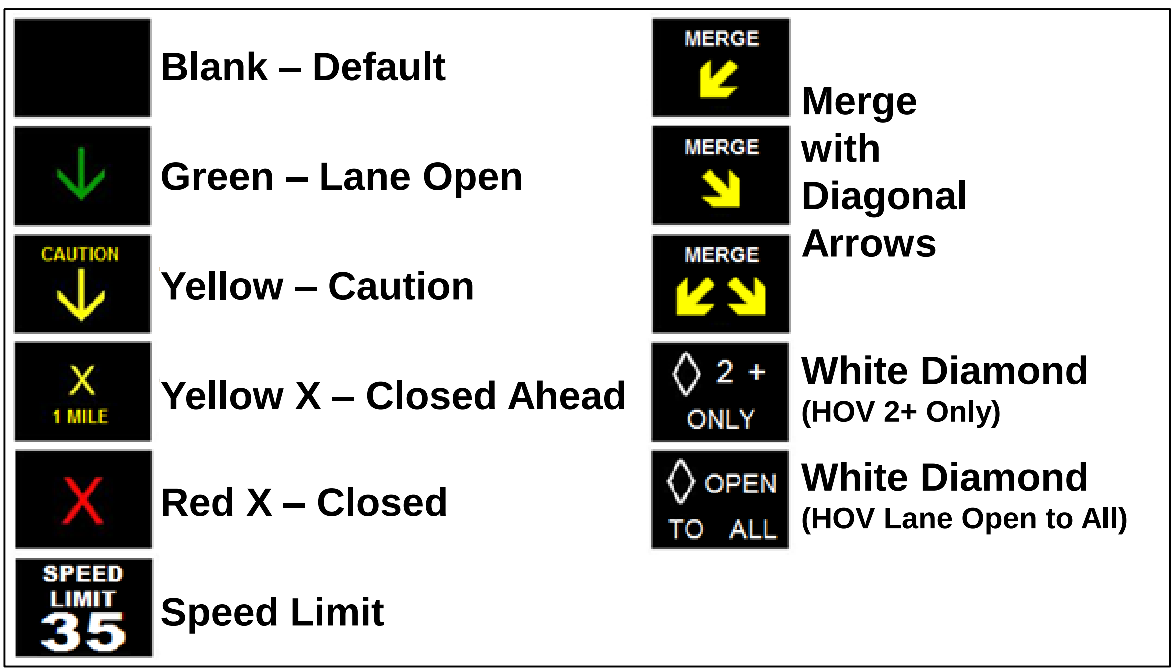


Source: WSDOT Website, http://www.wsdot.wa.gov/Projects/LkWaMgt/LkWaATM/map.htm.

Figure E-2. Location of ATM Signs on I-90

Source: WSDOT.

Figure E-3. ATM System on I-5 Displaying VSLs



Source: WSDOT (modified by Battelle).

Figure E-4. WSDOT ATM System Sign Options

The ATM system is in operation 24 hours a day, 7 days a week (24/7). The VSL signs are automated, with changes in speed activated by the system in advance of a congestion area. WSDOT operators can override the posted speed limit to better reflect actual speeds if needed. When an incident occurs, the operators uses WSDOT-developed software to select and post the appropriate message on the DMS.

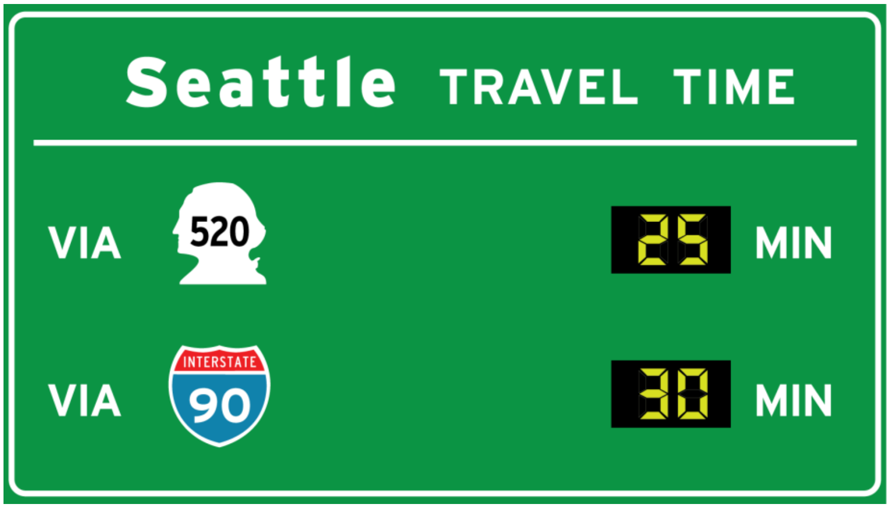
E.2.2 SR 520 Travel Time Signs

Three DMS were implemented as part of the Seattle/LWC UPA to display real-time travel times to downtown Seattle via SR 520 and I-90. As illustrated in Figure E-5 and noted below, these travel time signs are located on SR 522, SR 520, and I-405. The travel time signs on SR 520 and SR 522 became operational in April 2011 and the travel time sign on I-405 became operational in June 2011.

- Westbound SR 520 in Bellevue – one mile east of I-405;
- Southbound I-405 at NE 72nd Place in Kirkland (1.3 miles north of SR 520); and
- Westbound SR 522 at the SR 202 overpass in Woodinville (1 mile east of I-405).

Source: WSDOT Website, http://www.wsdot.wa.gov/Projects/LkWaMgt/LkWaATM/map.htm.

Figure E-5. Location of the Real-time Travel Time Signs



Source: WSDOT Website, http://www.wsdot.wa.gov/Projects/LkWaMgt/LkWaATM/map.htm.

Figure E-6. Example of SR 520 Real-Time Travel Time Sign

E.3 Impacts of the SR 520 and I-90 ATM and Travel Time Signs

This section examines the impacts of the SR 520 and I-90 ATM and travel time signs. Section E.3.1 analyzes the impact on VMT. Section E.3.2 explores the potential impacts of the ATM systems on SR 520 and I-90 and the real-time travel time signs on incidents. The number and type of incidents are examined, along with changes in the duration of incidents, travel times, and travel speeds. Section E.3.3 examines the impacts of the ATM and travel time signs on crashes on SR 520 and I-90. In an attempt to explore the impacts of the ATM and travel time signs before the changes resulting from tolling SR 520, the following three time-periods were examined in the various analyses.

1. 2010 – prior to implementation of the UPA improvements (January through December 2010),
2. 2011 – when only the ATM and travel time signs were active in the corridor (June 2011 through November 2011) and
3. 2012 – when tolling was implemented on the SR 520 bridge (January through December 2012).

E.3.1 Impact of the SR 520 and I-90 ATM and Travel Time Signs on VMT

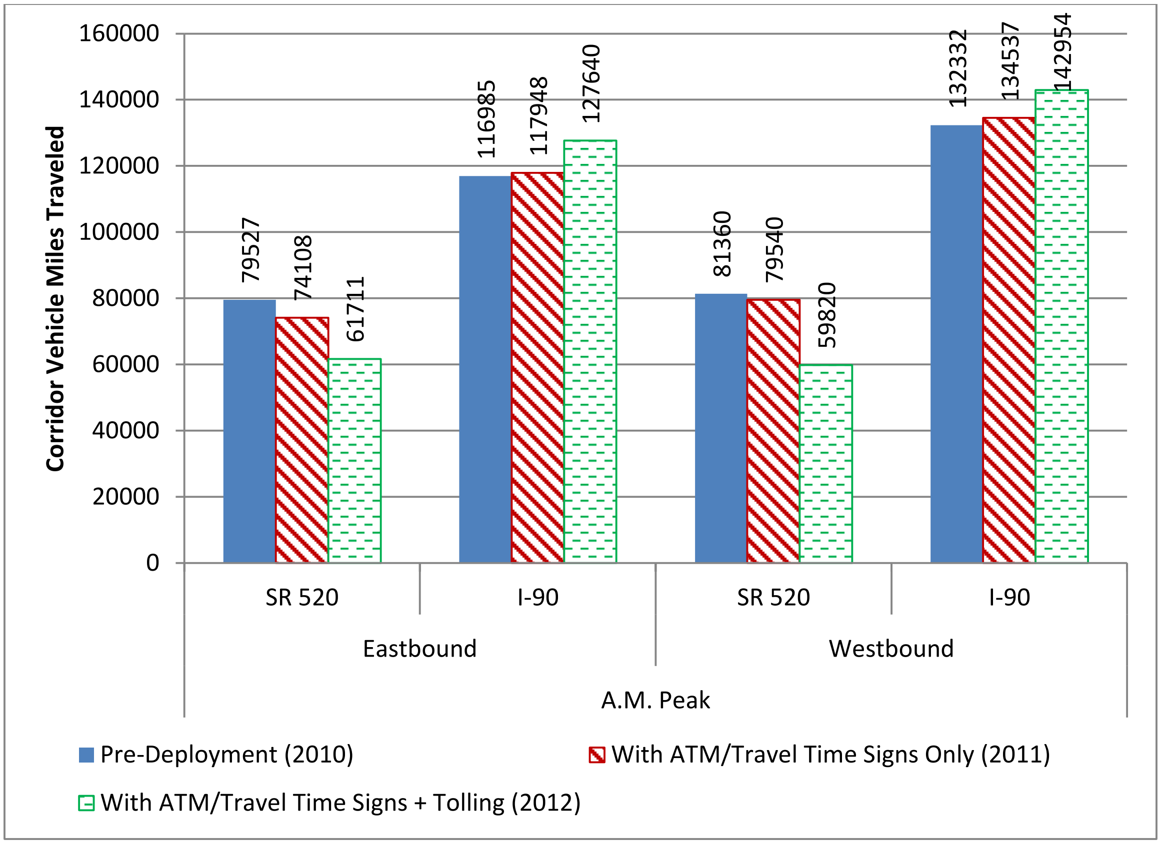
The national evaluation team examined the potential impact of the ATM and travel time signs on VMT. Table E-2 presents the corridor-level VMT recorded on SR 520 and I-90 in both directions of travel during the three evaluation periods noted previously – prior to implementing the systems, with the ATM and travel time signs in operation, and with the ATM and travel time signs and tolling the SR 520 bridge.

Figure E-7 provides a graphic comparison of the corridor VMT for the a.m. peak while Figure E-8 compares the corridor-level VMT for the p.m. peak. The tables and figure show that little change, if any, occurred in the VMT as a result of deploying the ATM and travel times signs solely. A much larger shift occurred after tolling was implemented on SR 520. These findings are expected as the travel time signs are about providing information to travelers to lessen driver frustration. This is not to say that individual drivers may elect to take change routes during any one particular trip because of the differences in travel times, but when taken on aggregate, drivers typically require additional motivation (such as tolling) to cause systematic shift in travel demands.

Table E-2. Pre- and Post-Deployment Corridor-Level VMT With and Without ATM/Travel Time Signing and Tolling in the LWC

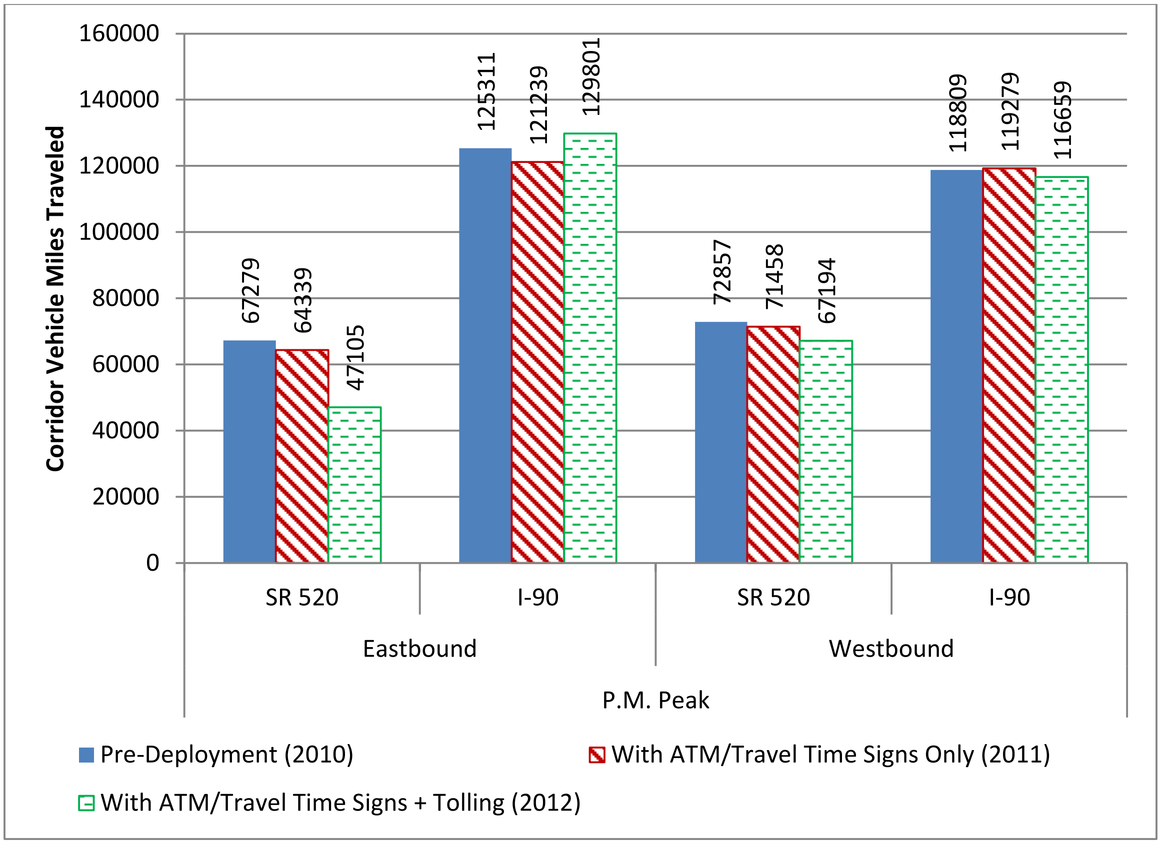
Facility	Direction	Lane Type	Period	Corridor VMT		
				Pre-Deployment	Post-Deployment	
				2010	2011	2012
SR 520	EB	General Purpose	A.M. Peak	79,527	79,533	61,711
			Off-Peak	103,193	97,845	60,071
			P.M. Peak	67,279	67,123	47,105
	WB	General Purpose	A.M. Peak	81,360	81,917	59,820
			Off-Peak	112,320	109,949	68,199
			P.M. Peak	72,857	74,080	67,194
I-90	EB	General Purpose	A.M. Peak	115,934	116,930	125,759
			Off-Peak	141,222	142,555	163,460
			P.M. Peak	120,180	116,766	125,760
		Express	A.M. Peak	1,052	1,018	1,881
			Off-Peak	2,158	1,975	2,982
			P.M. Peak	5,131	4,472	4,041
	WB	General Purpose	A.M. Peak	128,342	130,465	137,939
			Off-Peak	138,282	139,601	158,116
			P.M. Peak	113,233	113,315	110,247
		Express	A.M. Peak	3,990	4,072	5,015
			Off-Peak	3,347	3,291	4,284
			P.M. Peak	5,576	5,964	6,412

Source: Texas A&M Transportation Institute.



Source: Texas A&M Transportation Institute.

Figure E-7. Effects of Deploying ATM/Travel Time Signs with and without Tolling on A.M. Peak VMT in the LWC



Source: Texas A&M Transportation Institute.

Figure E-8. Effects of Deploying ATM/Travel Time Signs with and without Tolling on P.M. Peak VMT in the LWC

E.3.2 Impact of the SR 520 and I-90 ATM and Travel Time Signs on Incidents

Data from the operator logs from the Northwest Regional Traffic Management Center operated by WSDOT were examined in this analysis. These operator logs are computer generated logs which record all the action taken by WSDOT's central management software system. Included in these logs are information about when operators detected and cleared incidents within the system. These data were used to identify when incident conditions existed in the corridor. Log entries were used to determine the start time and end time of each incident situation as well as the roadway and milepoints impacted by each.

The national evaluation team then extracted traffic sensor data from the WSDOT's detector system to compute travel times, corridor speed, and 95th percentile travel times performance measures during the specified duration of each incident. The incident level values were then compared to the non-incident level conditions for each evaluation period.

One hypothesis in the technology analysis of the national evaluation is that deploying ATM in the LWC will reduce the duration of congestion-causing incidents on SR 520 and I-90. Table E-3 presents the total number of weekday incidents (collision, disabled vehicles, and others) logged by operators during the evaluation period. Note these represent the total number of incidents logged by operators throughout the entire year. There was an 88 percent increase in the total number of incidents logged by operators in the TMC from the pre-deployment period to the post-deployment period. One reason for the large increase in the number of incidents logged by operators is a change in the hours of operations of the TMC. During the pre-deployment period the TMC was staffed from 5:30 a.m. to 7:30 p.m. In the post-deployment period, the TMC began operating 24 hours per day, 7-days a week (24/7).

Table E-3. Change in the Number of Incident Logged by TMC Operators

		Number of Incidents Logged by TMC Operators				
		2010	**2011**	**2012**	**Percent Change 2010 – 2011**	**Percent Change 2010 – 2012**
SR 520	Eastbound	129	203	164	56%	27%
	Westbound	161	217	192	34%	19%
	Not specified	0	0	4	–	–
I-90	Eastbound	91	101	142	11%	56%
	Westbound	113	113	178	0%	58%
	Not specified	0	0	3	–	
Total		**494**	**634**	**927**	**28**%	**88%**

Source: Texas A&M Transportation Institute.

Table E-4 presents the distribution of incident types as recorded by the operators in the TMC. The majority of incidents reported by the operators were classified as either collisions or disabled vehicles. The distribution of these incidents by type remained relatively constant throughout the evaluation period.

Table E-4. Distribution of Reported Incidents on SR 520 and I-90 by Incident Type

Facility	**Evaluation Period**	Incident Type			
		Collision	**Disabled Vehicle**	**Incident**	**Other**
SR 520	2010	43%	54%	3%	0%
	2011	37%	57%	3%	0%
	2012	39%	54%	6%	1%
I-90	2010	60%	32%	5%	2%
	2011	51%	46%	3%	0%
	2012	58%	35%	6%	2%

Source: Texas A&M Transportation Institute.

Additionally in 2012, operators recorded that SR 520 was closed a total of 123 times for planned closures (typically lasting less than 30 minutes) to allow for boats to pass between sections of the lake. Information on total road closures for SR 520 was unavailable in the 2010 data. These data also do not include planned lane closures due to construction or roadway maintenance.

Table E-5 presents the distribution of durations for the logged incidents on SR 520 and I-90. The majority of logged incidents were under 30 minutes in duration. Few of the reported incidents logged had durations of over 90 minutes. The distribution of incident duration did not change significantly as a result of deploying the UPA improvements on either facility.

Table E-5. Distribution of Recorded Incidents by Incident Duration

Facility	Direction	Incident Duration	2010	2011	2012
SR 520	Eastbound	<30 Min	88%	87%	81%
		30-60 min	12%	9%	7%
		60-90-min	1%	2%	4%
		> 90 Min	0%	2%	8%
	Westbound	<30 Min	83%	81%	80%
		30-60 min	15%	15%	8%
		60-90-min	1%	3%	4%
		> 90 Min	1%	1%	8%
I-90	Eastbound	<30 Min	75%	70%	81%
		30-60 min	15%	19%	17%
		60-90-min	2%	5%	4%
		> 90 Min	8%	5%	4%
	Westbound	<30 Min	73%	79%	80%
		30-60 min	15%	16%	15%
		60-90-min	2%	10%	5%
		> 90 Min	5%	4%	3%

Source: Texas A&M Transportation Institute.

Table E-6 presents the change in the average incident duration between the periods when the specific strategies were deployed. Table E-7 shows how the average incident durations changed as a result of the different levels of deployment in the corridor. The tables show that average incident duration in the westbound direction of I-90 increased by 21 percent after the ATM and travel time signs became operational in June 2011, before dropping 5 percent in 2012 below pre-deployment levels after tolling commenced on SR 520. Average incident duration in the eastbound direction of I-90 dropped by 20 percent 2011 and by 25 percent once tolling was added to the corridor. This is significant because ATM was not fully deployed in the eastbound direction after tolling commenced on SR 520.

For SR 520, incident durations increased by approximately 3.5 minutes in 2011 and by 5 minutes in 2012 in the eastbound direction. Average incident durations also increased for the westbound direction of SR 520 between the pre-deployment period and both post-deployment periods. The reasons for these changes in incident duration could not be determined based on the information contained in the operator logs.

Table E-6. Pre- and Post-Deployment Average Incident Duration for I-90 and SR 520

Year	Facility	Direction	Incident Duration (mins)			
			Average	Median	Standard Deviation	Count
Pre-Deployment (2010)	I-90	EB	33.12	14.29	61.25	91
		WB	24.44	11.87	32.45	113
	SR 520	EB	13.58	9.54	13.39	129
		WB	17.01	10.90	17.88	162
ATM/Travel Time Signs (2011)	I-90	EB	26.22	13.87	31.58	67
		WB	29.57	17.53	38.10	95
	SR 520	EB	17:15	13.43	16.75	130
		WB	19.87	12.15	23.07	128
ATM/Travel Time Signs Plus Tolling (2012)	I-90	EB	24.83	14.79	32.27	142
		WB	23.12	13.45	32.61	178
	SR 520	EB	18.37	10.92	20.40	164
		WB	18.60	11.05	21.01	185

Source: Texas A&M Transportation Institute.

Table E-7. Comparison of Incident Durations on I-90 and SR 520 for Different Deployment Strategies

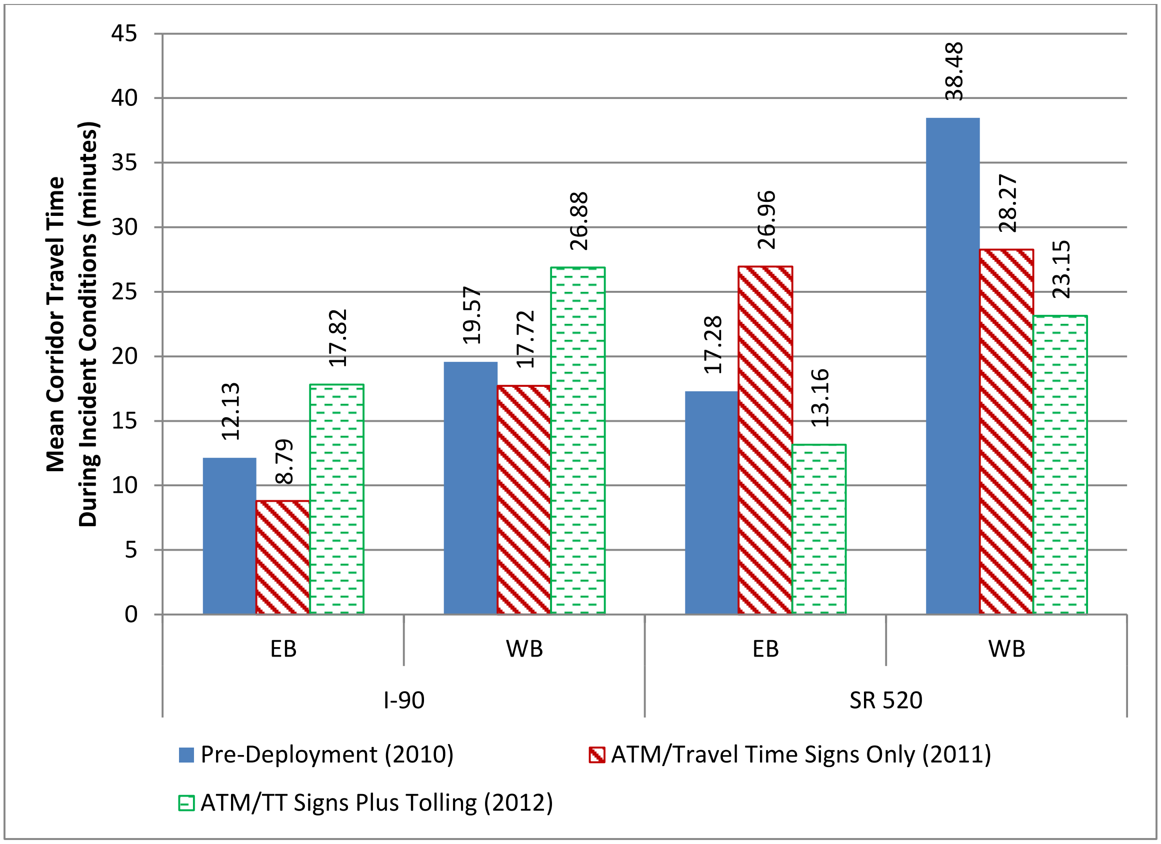
		Incident Duration (minutes)				
Facility	**Direction**	**Pre-Deployment (2010)**	**ATM/Travel Time Signs (2011)**	**ATM/Travel Time Signs Plus Tolling (2012)**	**Percent Change (2010 – 2011)**	**Percent Change (2010 – 2012)**
I-90	EB	33.12	26.22	24.83	-20%	-25%
	WB	24.44	29.57	23.12	21%	-5%
SR 520	EB	13.58	17.15	18.37	26%	35%
	WB	17.01	19.87	18.60	17%	9%

Source: Texas A&M Transportation Institute.

The national evaluation team also examined the mean travel times, average travel speed, and 95th percent travel times during incident conditions during the pre- and post-deployment periods. For this analysis, the national evaluation team focused only on incidents occurring between June and November, 2011 with durations between 15 minutes and 90 minutes in the incident logs. To increase the sample size, the analysis included incidents occurring on each facility from 5:00 a.m. to 7:00 p.m.

Figure E-9 compares the mean travel times during incident conditions on SR 520 and I-90 for the pre-deployment condition, during the time-period when only ATM and travel time signs were deployed in the corridor, and after tolling was implemented in the corridor. Travel times on I-90 during incident conditions improved slightly from 2.5 minutes in the eastbound direction and 1 minute in the westbound direction during the period in which the only the ATM and travel times signs were deployed in corridor. In contrast, average travel times during incident conditions on SR 520 improved only for the westbound direction after the ATM and travel time signs were deployed in the corridor, which is the direction of travel the travel time signs were deployed to influence. In the eastbound direction, average travel times on SR 520 during incident conditions increased by approximately 12 minutes during the time-period when only the ATM and travel time signs were deployed.

The mean travel times on I-90 during incident conditions increased substantially between the pre-deployment period (2010) and the post-deployment period when tolling was in effect. The mean travel times on I-90 during incident conditions increased by approximately 5 minutes in the eastbound direction and by approximately 7 minutes in the westbound direction in the post-deployment period. In comparison, mean travel times on SR 520 during incident conditions decreased by 4 minutes in the eastbound direction and by 15 minutes in the westbound direction. The shifting of traffic from SR 520 to I-90 as a result of implementing tolling likely influenced in the post-deployment period with tolling these changes.



Source: Texas A&M Transportation Institute.

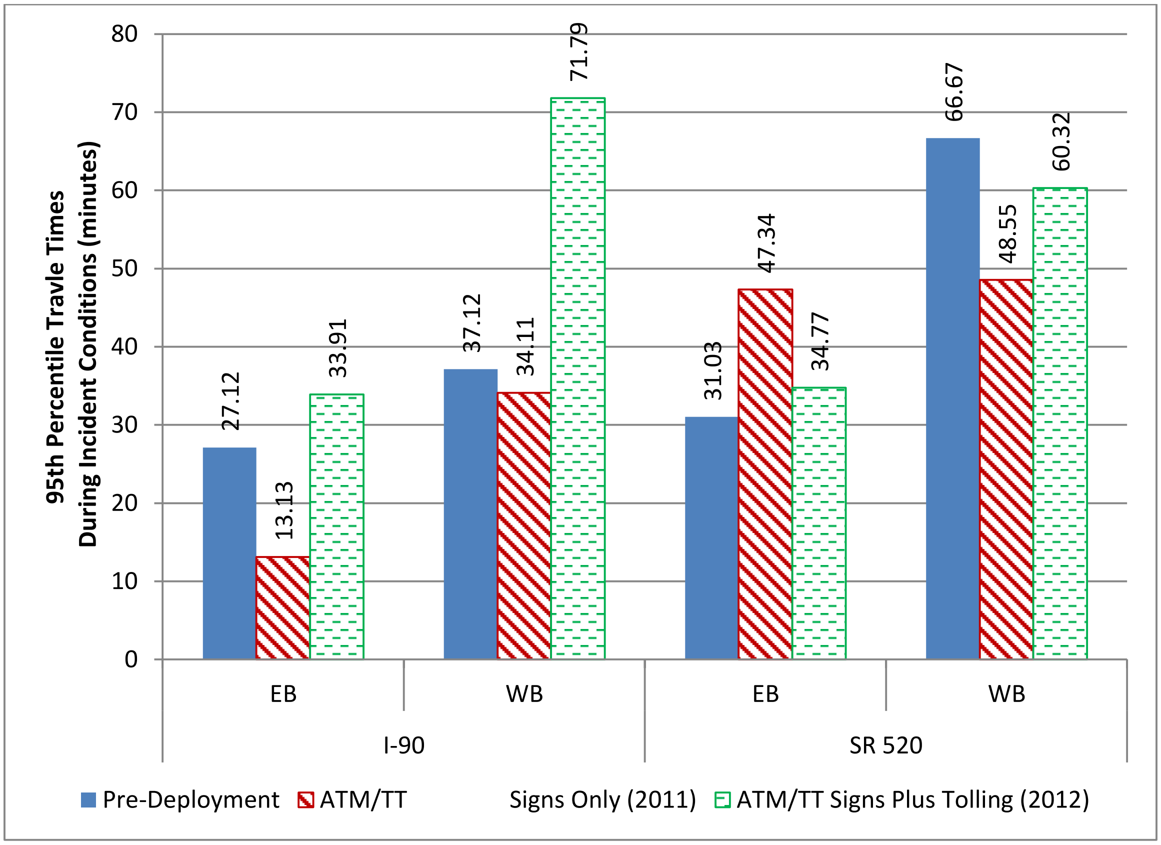
Figure E-9. Mean Corridor Travel Time on I-90 and SR 520 from I-5 to I-405 During Incident Conditions

Figure E-10 compares the average travel speeds on SR 520 and I-90, from I-5 to I-405, during incident conditions in each of the three evaluation periods. Average corridor speeds on I-90 during incident conditions declined by over 16 mph in the eastbound direction and by 4 mph in the westbound direction. Average corridor speeds on SR 520 during incident condition improved by over 15 mph in each direction in the post-deployment period after tolling was implemented. Again, the reason for this change in travel speeds during incident conditions is largely due to the shifting in demand from SR 520 to I-90 with the implementation of tolling on SR 520.

Source: Texas A&M Transportation Institute.

Figure E-10. Average Corridor Travel Speed on I-90 and SR 520 During Incident Conditions

Figure E-11 presents the change in the 95th percentile travel times during incident conditions on SR 520 and I-90. The 95th percentile travel times during incident conditions on I-90 were negatively impacted during the post-deployment period. Ninety-fifth percentile travel times for incident conditions in the westbound direction essentially doubled during the post-deployment period when tolling was in effect, increasing from 37 minutes to over 71 minutes. In contrast, the observed 95th percentile travel time on SR 520 remained relatively constant between the pre- and post-deployment periods, increasing by only 4 minutes in the eastbound direction and decreasing 6 minutes in the post-deployment period. These changes imply that travel times during incident conditions became less stable on I-90 in the post-deployment period compared to pre-deployment conditions. Again, the shifting of demand from SR 520 to I-90 as a result of the introduction of tolling on SR 520 was most likely to be source of the change in the 95th percentile travel times in the corridor.



Source: Texas A&M Transportation Institute.

Figure E-11. Comparison of 95th Percentile Travel Times on I-90 and SR 520 from I-5 to I-405 During Incident Conditions

Table E-8 provides a comparison of the average travel speed differential between the average speed during incident conditions and the average travel speed for the same time interval but under non-incident conditions. This table represents the difference in the incident and average non-incident travel for the same time-of-day in the corridor. Values in the table are computed by taking the difference between the corridor travel speed during incident conditions and the corridor the average corridor travel speed during non-incident conditions for the same 5-minute interval. The results indicate that the average difference between the corridor travel speeds during incident conditions and the average corridor speed during non-incident conditions for the same time of day is 11.82 mph on I-90 in the eastbound direction. This implies that speeds during incident condition average about 12 mph lower during incident conditions compared to non-incident conditions for the same time of day.

Table E-8. Average Speed Differential in Incident Conditions Compared to Non-Incident Conditions Pre- and Post-Deployment

Facility	Direction	Speed Differential (mph)		
		Pre-Deployment (2010)	ATM/Travel Time Signs Only (2011)	ATM/TT Signs Plus Tolling (2012)
I-90	EB	-11.82	-2.54	-24.87
	WB	-17.04	-29.23	-21.66
SR 520	EB	-18.31	-28.37	-16.64
	WB	-25.28	-17.32	-21.64

Source: Texas A&M Transportation Institute.

The results further indicate that the speed differential between incident and non-incident travel conditions on I-90 in the westbound were worse in the both post-deployment periods compared to the pre-deployment period. The average speed difference between incident and non-incident conditions decreased from 17 mph to 29 mph in both the post-deployment periods. In contrast, the average speed reduction during incident conditions improved slightly on SR 520 only after tolling was implemented in the corridor. The results indicate that when incidents occur, the average decline in travel speeds on SR 520 improved (by 2 mph in the eastbound direction and by 4 mph in the westbound direction) after tolling was implemented.

The national evaluation team also compared the ratio of incident to non-incident travel times in both the pre- and post-deployment conditions. Similar in concept to a travel time index, this ratio represents the extent to which travel times in the SR 520 and I-90 corridors were impacted by incident conditions. This ratio was computed for each direction of travel on SR 520 and I-90. Table E-9 shows that ratio of incident to non-incident travel times worsen on I-90 during the post-deployment period compared to the pre-deployment conditions. Travel times on I-90 during incident conditions are 2.1 and 2.6 times longer during incident conditions in the post-deployment period compared to 1.5 and 1.9 times longer in the pre-deployment period.

The ratio of the incident to non-incident conditions on SR 520 improved slightly in the post-deployment period. During the post-deployment periods, the ratio of incident to non-incident travel times for the eastbound direction of travel improved from 2.04 times in pre-deployment condition to 1.92 times in the post-deployment period. The impact of incidents on travels times in the westbound direction was not as substantial – changing from nearly 3 times to only 2.5 times worse – in the post-deployment period. The primary cause of this change in the extent to which incidents impacts travel times in these facilities is more likely the large shifting in travel demands in the corridor due to tolling, rather than any influence of the ATM and travel time signs.

Table E-9. Ratio of Incident to Non-Incident Travel Times

Facility	Direction	Ratio of Incident to Non-Incident Travel Times		
		Pre-Deployment (2010)	ATM/Travel Time Signs Only (2011)	ATM/TT Signs Plus Tolling (2012)
I-90	EB	1.47	1.05	2.07
	WB	1.87	2.26	2.62
SR 520	EB	2.04	2.91	1.92
	WB	3.17	2.15	2.47

Source: Texas A&M Transportation Institute.

E.3.3 Impacts of the SR 520 and I-90 ATM and Travel Time Signs on Crashes

Appendix F – Safety Analysis examined the safety implications of the Seattle/LWC UPA projects, including the ATM and travel time signs on SR 520 and I-90. This analysis is included in Section F.1.1.1. The WSDOT TRIPS database was used to analyze the changes in the number, type, severity, and location of crashes. In addition, the database includes information on lighting, road surface, and weather conditions. The analysis examined changes before-and-after the implementation of tolling on the SR 520 bridge. The analysis further examined changes in crashes before and after ATM was deployed on SR 520, prior to the implementation of tolling. The ATM system on I-90 was deployed in two stages, June 2011 and May 2012, making comparisons on that corridor more difficult due to the impacts of tolling. A full year of crash data on SR 520 was available between implementation of the ATM system in November 2010 and the beginning of tolling.

The analysis found that there were no statistically significant changes in crashes on SR 520 as a result of deploying the ATM system. The analysis did show a shift in crashes after tolling was implemented on the SR 520 bridge, however. A statistically significant increase in crashes occurred on I-90, accounting for changes in VMT, in the post-deployment period with tolling of the SR 520 bridge.

E.4 Perceptions of Washington State Patrol Troopers, IRT Operators, and King County Metro Transit Bus Operators

As part of the national evaluation, WSDOT sponsored interviews with WSP troopers, IRT operators, and King County Metro Transit bus operators. The primary purpose of the interviews was to obtain the perspective of individuals who travel the SR 520 and I-90 corridors on a regular basis and who are responsible for traffic enforcement, traffic safety, incident response, and bus operations. The three sets of interviews were conducted by the Jacobs Engineering Group in September, 2012. A total of 3 WSP troopers, 2 IRT members, and 3 King County Metro Transit bus operators were interviewed.

Questions in the interviews focused on a number of topics, including the ATM variable speed and lane controls on SR 520 and I-90, travel time signs, and perceptions related to congestion, safety, crashes, and incidents. Responses to interview questions related to the ATM and travel time signs, experiences and observations with the use of VSL and lane control signs, and the potential influence of ATM strategies on the operation of SR 520 and I-90 are summarized in this section.

Based on their observations and experiences, the two IRT operators indicated that from their perspective the use of the ATM VSLs and lane controls had limited effects. It was suggested that the Smarter Highways strategies were less effective on SR 520, which has 2-to-3 lanes in each direction of travel, and more effective on I-90 and I-5, which have 3 or more lanes in each direction. The IRT operators suggested that the changes in congestion levels and crashes on SR 520 and I-90 may be influenced by tolling the SR 520 bridge, in addition to implementation of the Smarter Highways elements.

The IRT operators also suggested that some motorists do not pay attention to the Smarter Highways signs due to information overload, even though the signs are easy to understand. The operators further suggested that some drivers think the VSL signs are not enforceable and ignore them. The IRT operators felt the real-time travel time signs are beneficial, but lacked specific experience with their use as there are no travel time signs in their patrol zone.

The three WSP troopers had a different perspective on the Smarter Highways signs, lane control systems, and DMS. The troopers suggested that the signs were valuable in informing motorists of upstream incidents. They further suggested that the VSL signs are located in areas with high levels of congestion, and that the signs help to proactively manage traffic. The troopers noted that congestion levels and the number of crashes have decreased on SR 520, but that congestion has increased on I-90. While the Smarter Highways system has contributed to these improvements, the troopers suggested that tolling the SR 520 bridge has had a larger impact. Travelers are using the bridge less to avoid paying a toll, resulting in lower levels of traffic congestion and fewer crashes.

The troopers noted that Smarter Highways signs and the DMS messages were clear to drivers. They suggested that the “Accident Ahead – Slow Down” message was effective slowing oncoming traffic and reducing secondary collisions. The signs provide an additional tool in managing traffic on SR 520 and I-90. The troopers suggested that effectively enforcing the VSL would require additional shoulder space to pull violators over. Additional shoulder space is also needed to accommodate disabled vehicles.

King County Metro Transit bus operators indicated that the messages displayed on the Smarter Highways system signs were very clear and that motorists understood the messages, but noted mixed reactions by motorists. The lower speed limit signs do appear to help slow traffic, but not all drivers slow down. The bus operators suggested that many drivers do not respond to the lane control signs. Overall, the bus operators suggested that the lower congestion levels on SR 520 and the increase congestion levels on I-90 were due to tolling the SR 520 bridge. While the ATM system and travel time signs are beneficial, the bus operators did not feel these elements had a major impact on changes in congestion levels.

E.5 Summary of Technology Impacts

This section provides a summary of the results of the technology analysis. Table E-10 summarizes the technology impacts for the five hypotheses. The implementation of signs with real-time travel times via SR 520 and I-90 to downtown Seattle did not influence a change in VMT on the two facilities. The change in VMT occurred after tolling on the SR 520 bridge was implemented.

The ATM and travel time signs on SR 520 and I-90 did not result in major changes in travel times or travel speeds on SR 520 and I-90. The major changes occurred after tolling was implemented on the SR 520 bridge.

As presented in Appendix F – Safety Analysis and summarized in this appendix, there were no statistically significant changes in crashes resulting from the implementation of the ATM and travel time signs on SR 520 and I-90. The analysis did indicate a statistically significant change in crashes after the SR 520 bridge tolling was implemented, however. A statistically significant increase in crashes occurred on I-90, even accounting for an increase in VMT, after tolling was implemented.

The impact of the ATM and travel time signs on the duration of congestion-causing incidents on SR 520 and I-90 was mixed. The duration of incidents increased with the implementation of the ATM and travel time signs, but declined after tolling on the SR 520 bridge was implemented. The analysis indicated that during the period when the ATM and travel time signs were in operation, but tolling on the SR 520 bridge had not been implemented, the ratio of incidents to non-incident travel times improved on I-90 in the eastbound direction and on SR 520 in the westbound direction. After tolling was initiated, the ratio of incident to non-incident travel times improved on SR 520, but were worse in I-90.

Table E-10. Summary of Impacts Across Congestion Hypotheses

Hypotheses/Questions	Result	Evidence
The travel time signs will promote a more even distribution of traffic between SR 520 and alternate routes (I-405 and SR 522)	Mixed	The results of the change in VMT between 2010 and 2011 showed that VMT on SR 520 and I-90 did not change after implementing the travel time signs. Changes in VMT on these facilities were not observed until tolling was implemented on SR 520.
Active Traffic Management will promote smoother traffic flow and better throughput on SR 520 and I-90 during non-incident conditions	Mixed	The results of the study on the effects of ATM to promote smoother flow and better throughput during incident conditions were inconclusive. The results show minor improvements in mean travel times in both directions on I-90 during incident conditions after deployment of the ATM/travel time signs. Mean travel speeds during incidents were reduced on SR 520 in the WB direction but increased in the EB direction.
Active Traffic Management will reduce the number of congestion-causing collisions on SR 520 and on I-90.	Mixed	The analysis found that there were no statistically significant changes in crashes on SR 520 as a result of deploying the ATM system. The analysis did show a shift in crashes after tolling was implemented on the SR 520 bridge, however. A statistically significant increase in crashes occurred on I-90, accounting for changes in VMT, in the post-deployment period with tolling of the SR 520 bridge.
Active Traffic Management in the Lake Washington Corridor will reduce the duration of congestion-causing incidents on SR 520 and I-90	Mixed	While incident durations increased after deployment of the ATM system, average incident duration declined after implementing tolling on SR 520. However, this may be a factor more the number of incidents than due to the implementation of the technology in the corridor.
Active Traffic Management will reduce the impact severity of congestion-causing incidents	Mixed	The analysis shows that during the time when only ATM was active in the corridor, the ratio of incident to non-incident travel times improved on I-90 in the EB direction and on SR 520 in the WB direction only. After tolling on SR 520 was initiated, the ratio of incident to non-incident travel times improved on SR 520 but became worse on I-90.

Source: Texas A&M Transportation Institute.

Appendix F. Safety Analysis

This appendix contains the safety-related analysis of the Seattle-Lake Washington Corridor (LWC) UPA projects. In general, safety implications associated with the Seattle UPA projects, in particular tolling, active traffic management (ATM), and traveler information systems were examined for the absence of an undesirable degradation in safety. The hypothesis being examined for the safety analysis is shown in Table F-1.

Table F-1. Safety Hypothesis

Hypothesis
• Tolling, ATM and traveler information (e.g., travel time sign) strategies that entail unfamiliar signage and which may alter existing traffic flows will not adversely affect highway safety.

Source: Battelle

The remainder of this appendix is divided into four sections. The data sources used in the safety analysis are presented next in Section F.1. The possible influences on safety from the UPA projects on SR 520 and I-90 are examined in Section F.2. Crash data for SR 520, I-90 and other relevant corridors in the region are examined and the perceptions of Washington State Patrol Officers, Incident Response Team Operators, and transit operators related to the safety implications of some UPA projects are discussed, as well as perceptions of safety given by SR 520 users in a WSDOT-sponsored telephone survey. The appendix concludes with a summary of the safety analysis in Section F.3.

F.1 Data Sources

The Washington State Department of Transportation (WSDOT) Collision Data and Analysis Branch Reports (TRIPS) database was used to examine the safety implications of the UPA projects on traffic for a selected set of relevant corridors in the region, including SR 520 and I-90, presented in Table F-2 below. The data available from the TRIPS Database is derived from collision reports completed by law enforcement personnel and from citizen reports. The major elements in the TRIPS Database include the severity of the crash, the crash type, the location, lighting, road surface, and weather conditions.

Table F-2. Collision Data Collection Locations

Highway	Start Point	End Point
SR 520	I-5	I-405
	SR 202 (Redmond)	I-405
I-90 (including general purpose and express lanes)	I-5	I-405
	I-405	SR 202
I-405	SR 522	SR 520
	I-90	SR 520
	I-90	SR 167
I-5	SR 522	SR 520
	SR 520	I-90
	I-90	SR 900
SR 522 (arterial)	I-405	I-5

Source: Battelle

Information from telephone surveys, interviews, and focus groups sponsored by WSDOT was also used in the safety analysis. As part of the national evaluation, WSDOT held separate group interviews with Washington State Patrol (WSP) Officers, Incident Response Team (IRT) operators, and transit operators. The interviews and focus groups were conducted in November 2012 by WSDOT representatives. Questions in the focus groups and interviews examined perceptions in changes in safety on SR 520 due to tolling and the ATM strategies implemented.

A series of three telephone surveys of travelers using SR 520 was sponsored by WSDOT and conducted by PRR, Inc. It included questions on perceptions of changes in safety on the SR 520 bridge, and in particular the ATM signage. Each survey was completed by a total of 800 individuals who travel the SR 520 Bridge.

F.2 Potential Safety Implications of the UPA Projects

This section presents the analysis of crash data and the perception of safety by users of SR 520, I-90, and other selected corridors in the region. The analysis using the TRIPS Crash Database is described in F.2.1. Safety-related information from the interviews with WSP Officers, IRT operators, and transit operators related to the safety implications of UPA projects are discussed, as well as perceptions of safety given by SR 520 users in a WSDOT-sponsored telephone survey presented in F.2.2.

F.2.1 Crash Data

The examination of crash data and the overall safety analysis was complicated by a number of exogenous factors, as reported in Appendix K. In particular, construction was occurring on SR 520 east of the bridge from Medina to SR 202 during much of the evaluation period beginning in January 2011, which may have impacted safety in the corridor.

The dates of analysis for the national evaluation are centered around the go-live date for tolling on the SR 520 Bridge on December 29, 2011. This safety evaluation includes 48 months of pre-deployment data from December 29, 2007 to December 28, 2011, and 12 months of post-deployment from December 29, 2011 to December 28, 2012. Because there is only 12 months of post-deployment data available for analysis, a more robust analysis including longer post-deployment time periods is needed to fully assess the potential safety impacts of the UPA projects and other improvements on the SR 520, I-90, and other Lake Washington corridors.

The national evaluation team used the before-after evaluation approach in the crash analysis. This approach has been used to evaluate various safety countermeasures on other projects. As presented in Table F-3, the number of crashes by accident severity for the two time periods was determined first for the selected corridors. The accident severity categories include fatal, injury, and property damage only (PDO). The fatality category includes incident types of dead at scene, dead on arrival, and died at hospital. The injury category includes serious injury, possible injury, and evident injury. The PDO category includes no injury and a limited number of unknown incident types.

Table F-3. Crashes by Severity for Pre- and Post-Deployment Periods on Select Corridors

Corridor	Segment	Crash Severity	Pre-Deployment 12/29/2007-12/28/2008 (1 year)	Pre-Deployment 12/29/2008-12/28/2009 (1 year)	Pre-Deployment 12/29/2009-12/28/2010 (1 year)	Pre-Deployment 12/29/2010-12/28/2011 (1 year)	Post-Deployment 12/29/2011-12/28/2012 (1 year)
SR 520	I-5 to I-405	Fatal	0	0	0	0	1
		Injury	102	79	88	92	67
		PDO	223	199	203	207	118
		Total	325	278	291	299	186
	I-405 to SR 202	Fatal	0	0	0	0	0
		Injury	37	40	37	47	54
		PDO	79	89	117	78	107
		Total	116	129	154	125	161
I-90 (general purpose and express lanes)	I-5 to I-405	Fatal	0	0	0	0	0
		Injury	74	61	65	106	119
		PDO	163	165	172	159	242
		Total	237	226	237	265	361
	I-405 to SR 202	Fatal	0	1	2	1	0
		Injury	111	80	106	108	110
		PDO	183	181	187	190	181
		Total	294	262	295	299	291
I-405	SR 522 to SR 520	Fatal	1	0	1	0	1
		Injury	117	111	110	96	124
		PDO	235	229	201	225	247
		Total	353	340	312	321	372
	SR 520 to I-90	Fatal	2	0	0	1	0
		Injury	87	128	126	113	111
		PDO	199	255	260	259	201
		Total	288	383	386	373	312
	I-90 to SR 167	Fatal	0	0	0	0	0
		Injury	219	190	202	172	194
		PDO	417	393	381	365	383
		Total	636	583	583	537	577

Table F-3. Crashes by Severity for Pre- and Post-Deployment Periods on Select Corridors (Continued)

Corridor	Segment	Crash Severity	Pre-Deployment				Post-Deployment
			12/29/2007-12/28/2008 (1 year)	12/29/2008-12/28/2009 (1 year)	12/29/2009-12/28/2010 (1 year)	12/29/2010-12/28/2011 (1 year)	12/29/2011-12/28/2012 (1 year)
I-5	SR 522 to SR 520	Fatal	0	0	0	0	0
		Injury	113	105	107	120	111
		PDO	275	245	242	232	221
		Total	388	350	349	352	332
	SR 520 to I-90	Fatal	2	0	1	1	0
		Injury	220	193	150	167	185
		PDO	440	451	384	410	397
		Total	662	644	535	578	582
	I-90 to SR 900	Fatal	0	3	3	3	1
		Injury	175	179	182	173	196
		PDO	365	393	366	331	359
		Total	540	575	551	507	556
SR 522	I-5 to I-405	Fatal	0	1	0	1	3
		Injury	150	118	106	89	135
		PDO	221	187	198	198	226
		Total	371	306	304	288	364
Total for All Selected Corridors		Fatal	5	5	7	7	6
		Injury	1405	1284	1279	1283	1406
		PDO	2800	2787	2711	2654	2682
		Total	4210	4076	3997	3944	4094

Source: Battelle

Originally, the team considered fatal, injury, and PDO. However, the sample sizes were too small for individual crash type estimation. As a result, the fatal and injury categories were further merged into one category – named fatal plus injury – to provide a sufficient sample size. The merging of subcategories of injury crashes into one is typically done in crash analysis. The percent changes in crashes were calculated in two ways: without accounting for changes in VMT and accounting for changes in VMT from the pre-deployment to the post-deployment periods.

The percent changes in crashes from before to after periods were computed following the procedure described in Hauer (1997).[1] The steps are summarized below.

Let *K* be the observed crash count of a road segment during the before period and *L* be the observed crash count during the after period. Let π be the expected number of crashes of a road segment in the after period had it not been treated and λ be the expected number of crashes of a road segment in the after period. Define the ratio of durations, r_d, by

r_d = (# of after crash data months) / (# of before crash data months).

The effect of the treatment on safety can be assessed by estimating the index of effectiveness, θ (= λ/π).

The naïve before-after evaluation method without accounting for changes in traffic volumes described in Hauer (1997) estimates the index of effectiveness θ by

$$\hat{\theta} = \frac{\hat{\lambda}/\hat{\pi}}{1+V\hat{a}r\left(\hat{\pi}\right)/\hat{\pi}^2}$$

where $\hat{\pi}$ and $\hat{\lambda}$ are the estimates of π and λ, respectively, given by $\hat{\lambda} = L$ and $\hat{\pi} = r_d K$, and $V\hat{a}r\left(\hat{\pi}\right) = r_d{}^2 K$. The standard error of $\hat{\theta}$ is given by:

$$SE\left(\hat{\theta}\right) = \sqrt{\hat{\theta}^2\left[\left(1/\hat{\lambda}\right)+\left(V\hat{a}r\left(\hat{\pi}\right)/\hat{\pi}^2\right)\right]\Big/\left[1+V\hat{a}r\left(\hat{\pi}\right)/\hat{\pi}^2\right]^2}$$

and the approximate 95 percent confidence interval for θ is given by:

$\hat{\theta} \pm 1.96 \cdot SE\left(\hat{\theta}\right)$.

The estimate for the percent change in crashes and the associated standard errors (SE) can then be obtained as follows:

Percent change = $\left(\hat{\theta}-1\right)\times 100$,

$SE = SE\left(\hat{\theta}\right)\times 100$.

[1] Hauer, E. 1997. Observational Before-After Studies in Road Safety: Estimating the Effect of Highway and Traffic Engineering Measures on Road Safety. Pergamon Press, Elsevier Science, Ltd., Oxford, United Kingdom.

As a matter of fact, the assumption that there have been no changes from before to after periods other than the treatment is often violated. There will almost always be changes over time in traffic volumes, vehicle mix, weather, and so on. Because the naïve before-after evaluation does not control for those changes, the effect of treatment cannot be separated from those changes. Among several potential changes between before and after periods the changes in traffic volumes are often non-ignorable, and almost always need to be incorporated into the analysis. To incorporate traffic volume changes in the before-after analysis, the before crash count, *K*, can be replaced by $K \times \frac{VMT^{AT}}{VMT^{BT}}$ where VMT^{BT} and VMT^{AT} are the *VMT* during the before period and the *VMT* during the after period, respectively. The percent change in crashes with incorporating changes in VMT can be estimated by substituting $K \times \frac{VMT^{AT}}{VMT^{BT}}$ for K in the above steps.

The location of the crashes by various segments of corridors throughout the region were examined in the pre- and post-deployment periods. In particular, tolling and ATM signage strategies were implemented on SR 520 between I-5 and I-405, and ATM signage was also deployed on I-90 between I-5 and I-405.

Table F-4 presents the results for total crashes, not accounting for changes in VMT. The estimates for changes in VMT at individual locations were not available at the time of the analysis. The results show a statistically significant decline in fatal plus injury, PDO, and total crashes for the section of SR 520 from I-5 to I-405, and statistically significant increases in fatal plus injury, PDO, and total crashes for the segment of I-90 from I-5 to I-405 (including both general purpose and express lanes). The results also show an increase in total crashes for SR 522 from I-5 to I-405. Given the small sample size and short time periods, however, more detailed analysis along with accounting for changes in VMT is needed to better assess possible changes in crash locations, particularly because traffic shifts from SR 520 to I-90 and SR 522 between I-5 and I-405 may have caused these shifts in crashes.

Table F-4. Crash Data by Freeway Segment Pre- and Post-Deployment

Corridor	Segment	Crash Severity	Pre-Deployment Period 12/29/2007-12/28/2011 (Annual Average)	Post-Deployment Period 12/29/2011-12/28/2012 (1 year)	Actual Difference	Percent Change in Crashes from Before to After Period (without accounting for VMT change)[2]
SR 520	I-5 to I-405 (Tolling+ATM)	F+I[1]	90	68	-22	**-24.9** (9.91)
		PDO	208	118	-90	**-43.3** (5.57)
		Total	298	186	-112	**-37.7** (4.91)
	I-405 to SR 202	F+I[1]	40	54	14	33.3 (20.84)
		PDO	91	107	16	17.6 (12.90)
		Total	131	161	30	22.7 (11.03)
I-90 (general purpose and express lanes)	I-5 to I-405 (ATM)	F+I[1]	77	119	42	**55.0** (16.70)
		PDO	165	242	77	**46.7** (11.01)
		Total	241	361	120	**49.5** (9.21)
	I-405 to SR 202	F+I[1]	102	110	8	7.3 (11.50)
		PDO	185	181	-4	-2.4 (8.08)
		Total	288	291	3	1.1 (6.63)
I-405	SR 522 to SR 520	F+I[1]	109	125	16	14.4 (11.58)
		PDO	223	247	24	10.9 (7.97)
		Total	332	372	40	12.1 (6.57)
	SR 520 to I-90	F+I[1]	114	111	-3	-3.1 (10.24)
		PDO	243	201	-42	**-17.5** (6.39)
		Total	358	312	-46	**-12.8** (5.45)
	I-90 to SR 167	F+I[1]	196	194	-2	-1.0 (7.93)
		PDO	389	383	-6	-1.6 (5.61)
		Total	585	577	-8	-1.4 (4.58)

Table F-4. Crash Data by Freeway Segment Pre- and Post-Deployment (Continued)

Corridor	Segment	Crash Severity	Pre-Deployment Period 12/29/2007-12/28/2011 (Annual Average)	Post-Deployment Period 12/29/2011-12/28/2012 (1 year)	Actual Difference	Percent Change in Crashes from Before to After Period (without accounting for VMT change)[2]
I-5	SR 522 to SR 520	F+I[1]	111	111	0	-0.4 (10.54)
		PDO	249	221	-28	-11.2 (6.60)
		Total	360	332	-28	-7.8 (5.61)
	SR 520 to I-90	F+I[1]	184	185	1	0.7 (8.27)
		PDO	421	397	-24	-5.8 (5.25)
		Total	605	582	-23	-3.8 (4.44)
	I-90 to SR 900	F+I[1]	180	197	17	9.6 (8.80)
		PDO	364	359	-5	-1.4 (5.81)
		Total	543	556	13	2.3 (4.86)
SR 522	I-5 to I-405	F+I[1]	116	138	22	18.5(11.46)
		PDO	201	226	25	12.3 (8.44)
		Total	317	364	47	**14.6** (6.81)
Total for All Selected Corridors		F+I[1]	1319	1412	93	7.1 (3.21)
		PDO	2738	2682	-56	-2.1 (2.11)
		Total	4057	4094	37	0.9 (1.76)

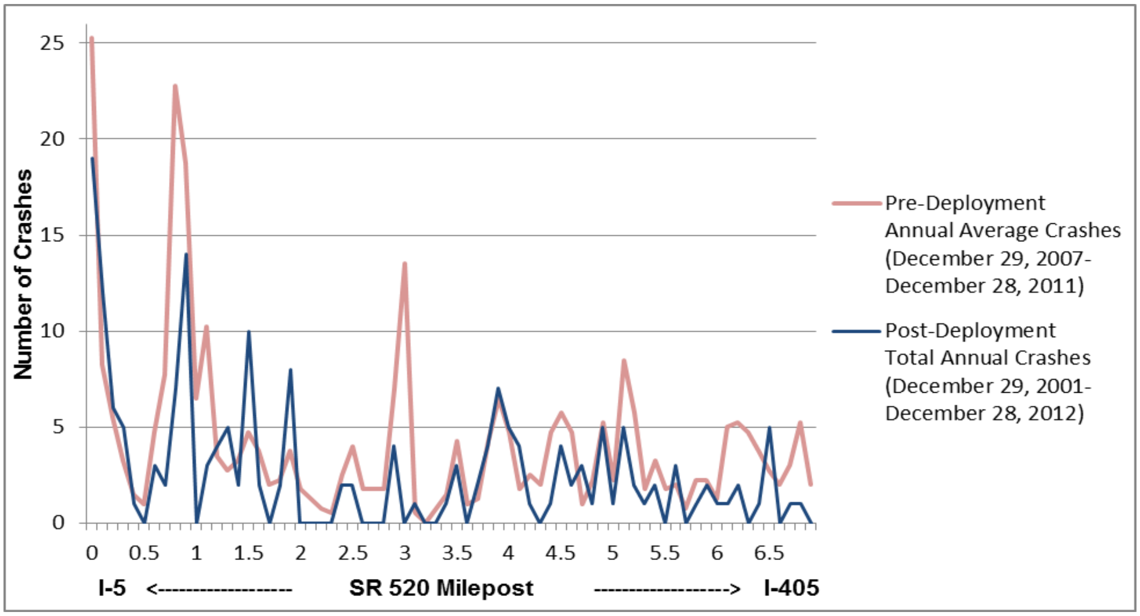
Source: Battelle

[1] Combines all fatal and injury crashes.

[2] Standard errors are given in parentheses.

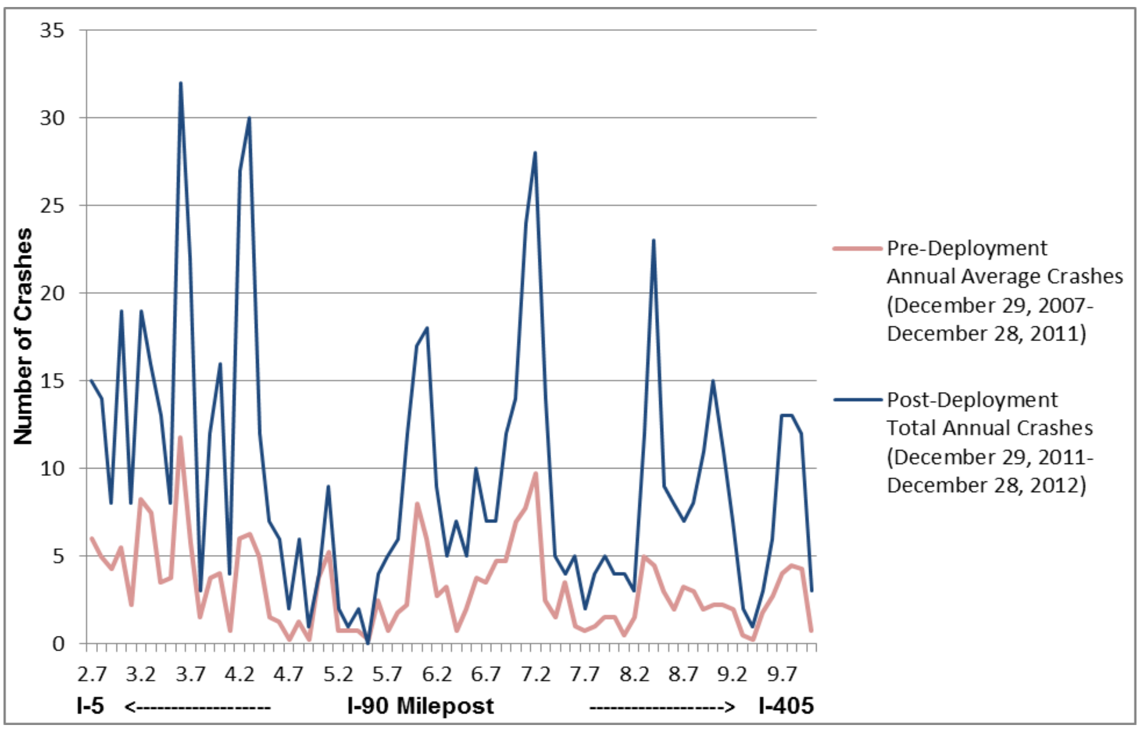
* Statistically significant results at 95 percent are presented in bold.

The spatial configuration of these crashes on both SR 520 and I-90 between I-5 and I-405 were also examined for the pre- and post-deployment periods and are presented in Figure F-1 and Figure F-2. These figures illustrate the decreases in annual crashes on SR 520 and increases in annual crashes on I-90 from the pre-deployment period to the post-deployment period for crashes by milepost.



Source: Battelle

Figure F-1. Spatial Configuration of Crashes on SR 520 by Milepost Pre- and Post-Deployment of Tolling



Source: Battelle

Figure F-2. Spatial Configuration of Crashes on I-90 by Milepost Pre- and Post-Deployment of Tolling on the SR 520 Bridge

Mean VMT data were obtained from the congestion analysis for select corridors for one full year in both the pre-deployment period (2010) and post-deployment period (2012). This mean VMT includes the time period from 6:00 a.m. to 7:00 p.m. The total numbers of crashes occurring during these pre- and post-deployment periods for corridors with available VMT data are presented in Table F-5 alongside the percent changes in crashes, with and without accounting for changes in VMT. Approximately 16 percent of crashes in these corridors that occurred from 7:00 p.m. to 6:00 a.m. are included, but not represented by the VMT data in the analysis below; despite the lack of VMT data from 7:00 p.m. to 6:00 a.m., the effects on the results should be negligible.

As presented in Table F-4 and Table F-5, the results show statistically significant increases in crashes for all categories of crash severity on I-90 between I-5 and I-405 both with and without accounting for VMT. Statistically significant decreases in crashes for all categories of crash severity are seen on SR 520 between I-5 and I-405 only when VMT is not considered from pre-deployment (December 29, 2007-December 28, 2011) to post-deployment (December 29, 2011-December 28, 2012). Given the large fluctuations of VMT from the pre-deployment period (2010) to the post-deployment period (2012) between I-5 and I-405 on SR 520 (28.9 percent decrease) and I-90 (8.8 percent increase) these results seem to indicate a similar shift of crashes from SR 520 to I-90 after the start of tolling. Although VMT data were unavailable for the arterial corridor SR 522 that is an alternate route for the SR 520 Bridge, Table F-4 shows a statistically significant increase in total crashes for this corridor between I-5 and I-405.

Finally, Appendix E – Technology Analysis, reports on the changes in average incident duration over the course of the UPA project: the pre-deployment period in 2010, after the deployment of ATM and travel time signage in mid-2011, and after tolling became operational on SR 520 in December 2011. Average incident duration dropped on I-90 by 25 percent in the eastbound direction and by 5 percent in the westbound direction when averaged across all time-periods as shown in Table F-6. This change is equivalent to a 9 minute and 1 minute reduction in incident duration on I-90, respectively. Incident durations increased by approximately 5 minutes on SR 520 between the pre-deployment period in 2010 and the post-deployment period in 2012. The reasons for these changes in incident duration could not be determined based on the information contained in the operator logs.

Table F-5. Crash and VMT Data for Pre- and Post-Deployment Periods for Selected Corridors by Crash Severity

Corridor	Segment	Crash Severity	Pre-Deployment Period 12/29/2009-12/28/2010	Post-Deployment Period 12/29/2011-12/28/2012	Actual Difference	Percent Change from Before to After Period (without accounting for VMT change)[2]	Percent Change from Before to After Period (accounting for VMT change)[2]
SR 520	I-5 to I-405 (Tolling+ATM)	F+I[1]	88	68	-20	**-23.6** (12.20)	7.0 (18.45)
		PDO	203	118	-85	**-42.2** (6.66)	-18.8 (10.01)
		Total	291	186	-105	**-36.3** (5.96)	-10.5 (9.00)
		Mean Daily VMT[3]	510,557	362,919	-147638	-28.9	
I-90 (GP and express lanes)	I-5 to I-405 (ATM)	F+I[1]	65	119	54	**80.3** (27.39)	**65.9** (24.57)
		PDO	172	242	70	**39.9** (13.87)	**28.6** (12.46)
		Total	237	361	124	**51.7** (12.63)	**39.5** (11.33)
		Mean Daily VMT[3]	786,212	855,365	69153	8.8	
I-405	SR 522 to SR 520	F+I[1]	111	125	14	11.6 (14.43)	16.1 (15.16)
		PDO	201	247	46	22.3 (11.56)	**27.2** (12.15)
		Total	312	372	60	18.8 (9.09)	**23.6** (9.56)
		Mean Daily VMT[3]	1,190,468	1,144,264	-46204	-3.9	
	SR 520 to I-90	F+I[1]	126	111	-15	-12.6 (11.29)	-16.4 (10.69)
		PDO	260	201	-59	**-23.0** (7.21)	**-26.3** (6.83)
		Total	386	312	-74	**-19.4** (6.12)	**-22.9** (5.80)
		Mean Daily VMT[3]	496,566	519,290	22724	4.6	
I-5	SR 520 to I-90	F+I[1]	151	185	34	21.7 (13.26)	21.1 (13.18)
		PDO	384	397	13	3.1 (7.36)	2.6 (7.31)
		Total	535	582	47	8.6 (6.49)	8.0 (6.45)
		Mean Daily VMT[3]	525,567	528,247	2680	0.5	

Source: Battelle

[1] Combines all fatal and injury crashes.

[2] Standard errors are given in parentheses.

[3] Given mean daily VMT only accounts for 6:00 a.m. to 7:00 p.m.

* Statistically significant results at 95 percent are presented in bold.

Table F-6. Pre- and Post-Deployment Average Incident Duration for I-90 and SR 520

Facility	Direction	Incident Duration (minutes)				
		Pre-Deployment (2010)	ATM/Travel Time Signs (2011)	ATM/Travel Time Signs Plus Tolling (2012)	Percent Change (2010 – 2011)	Percent Change (2010 –2012)
I-90	EB	33.12	26.22	24.83	-20%	-25%
	WB	24.44	29.57	23.12	21%	-5%
SR 520	EB	13.58	17.15	18.37	26%	35%
	WB	17.01	19.87	18.60	17%	9%

Source: Texas A&M Transportation Institute

F.2.1.1 Crash Data Analysis for ATM Signage

A separate analysis was also desired to determine the potential effects of the ATM signage that was deployed in the region, specifically on SR 520 and I-90. It was concluded to conduct a before-after analysis only on the SR 520 ATM signage for two reasons. First, the I-90 ATM signage was deployed in two stages (June 8, 2011 and May 1, 2012), making a conclusive before-after analysis difficult, particularly since data is only available through December 2012. Second, results above indicate significant changes in crashes and VMT on both SR 520 and I-90 following the initiation of tolling on the SR 520 Bridge in December 2011. This is a major exogenous factor that would likely significantly influence findings regarding the safety analysis for the I-90 ATM signage, which was deployed approximately 6 months before and 5 months following the initiation of tolling. Because the SR 520 ATM signage was deployed on November 16, 2010, a full year of crash data after the deployment was available that did not include any effects resulting from the initiation of tolling. As shown in Table F-7, there were no statistically significant changes in crashes on the SR 520 corridor as a result of the ATM signage deployment.

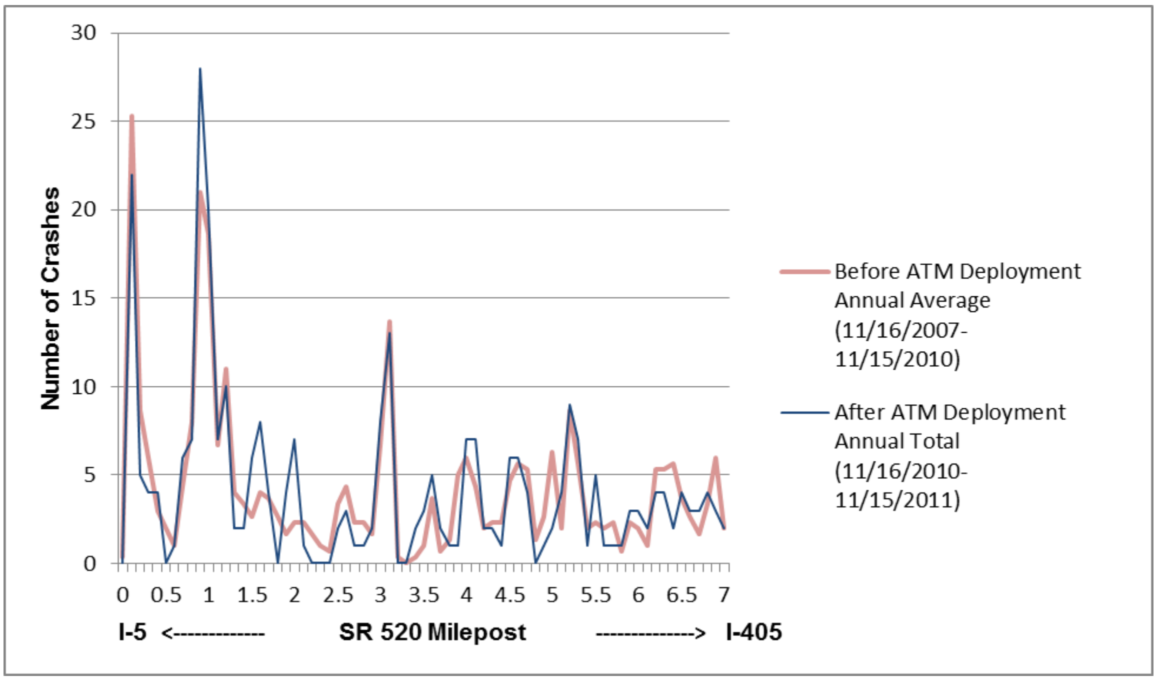
Table F-7. Crash Data on SR 520 from I-5 to I-405 Before and After Deployment of ATM Signage

Crash Severity	Before ATM Deployment				After ATM Deployment	Percent Change in Crashes from Before to After Period[1]
	11/16/2007-11/15/2008	11/16/2008-11/15/2009	11/16/2009-11/15/2010	Annual Average	11/16/2010-11/15/2011	
Injury	101	81	91	91	97	6.5
PDO	234	193	207	211	199	-5.9
Total	**335**	**274**	**298**	**302**	**296**	**-2.1**

Source: Battelle

[1] Not statistically significant at the 95 percent confidence level; does not account for changes in VMT

*No fatal crashes occurred in this corridor during these time periods



Source: Battelle

Figure F-3. Spatial Configuration of Crashes along SR 520 by Milepost Before and After ATM Deployment

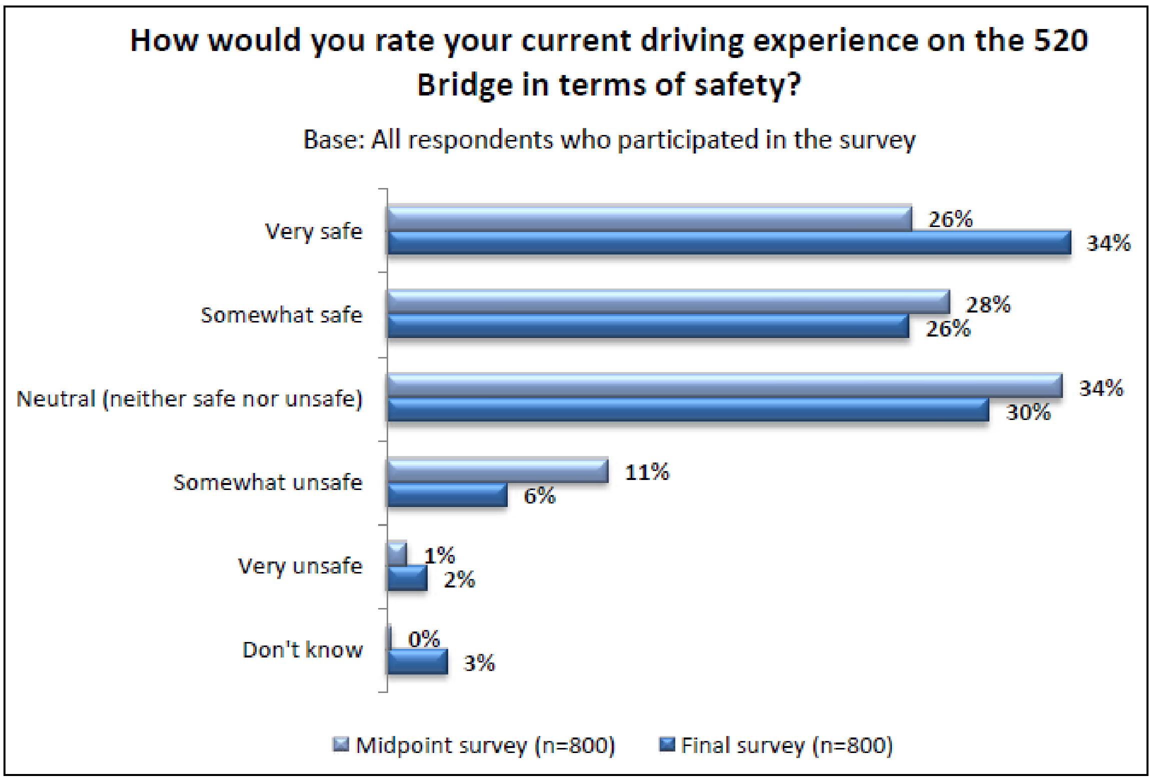
This analysis indicates that the UPA project, specifically due to the shift in traffic as a result of tolling on the SR 520 bridge, may have adversely affected safety. This finding is based on a limited time period and limited data examined. As noted previously, a longer period of time is needed to fully assess the potential safety impacts.

F.2.2 Safety Perceptions of SR 520 Users

Several surveys and interviews were conducted that asked various users their perception of safety in regards to the SR 520 bridge tolling, as well as the ATM signage that was deployed as part of the UPA demonstration. WSDOT conducted a series of surveys that asked 800 area drivers their perception of safety of the SR 520 bridge and ATM signage. WSDOT also led a number of focus groups to gather the perceptions of transit operators, IRT operators, and WSP officers.

F.2.2.1 WSDOT Driver Survey

A series of telephone surveys was conducted for WSDOT by PRR, Inc. in the pre- and post-deployment periods. All 800 respondents in the surveys were users of the SR 520 bridge. In both October 2010 (pre-deployment) and December 2012 (post-deployment), survey respondents were asked their perception of safety in regards to the SR 520 bridge, as well as the new ATM signage.[2] (Note that an earlier survey that was conducted did not ask any questions on safety.) More respondents felt that their driving experience on the SR 520 bridge was very safe in the post-deployment period (34 percent) than in the pre-deployment period (26 percent). The survey question and results are shown in Figure F-4.



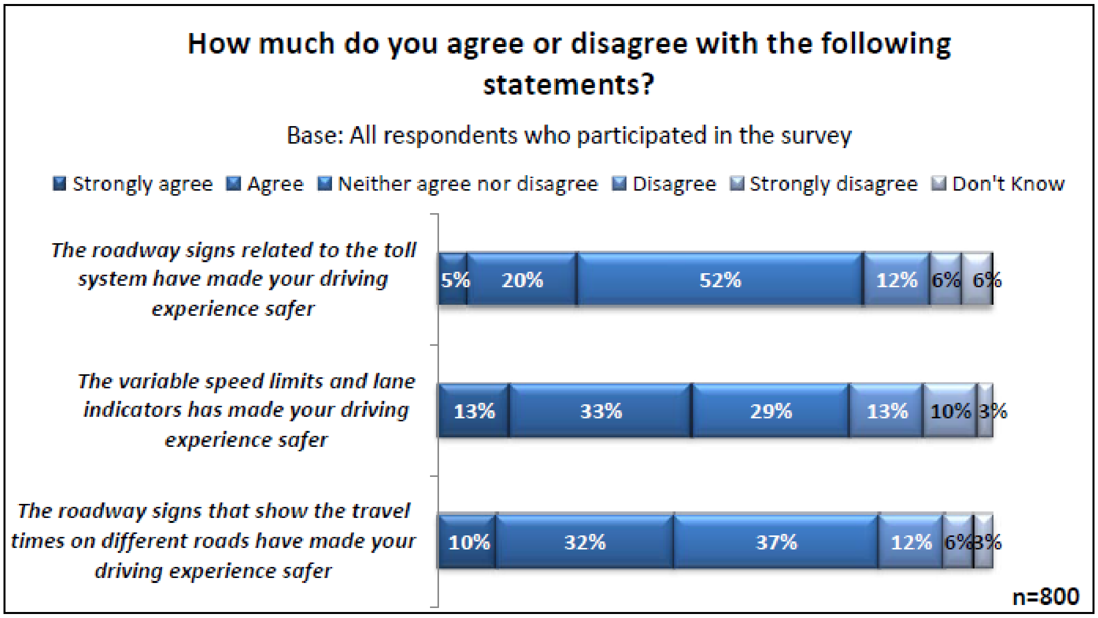
Source: WSDOT

Figure F-4. Pre- and Post-deployment Comparison of SR 520 Bridge Users' Perception of Safety

---

[2] SR 520 Tolling Final Evaluation Survey. Washington State Department of Transportation. Conducted by PRR, Inc. 12/28/2012.

The final WSDOT survey in this series in December 2012 (post-deployment) also asked the 800 respondents their perception of the roadway signage in regards to safety. The full results of these survey questions are shown in Figure F-5. Roughly 25 percent either agreed or strongly agreed that roadway signs related to the toll system made their driving experience safer. Regarding the ATM signage, almost half (46 percent) agreed or strongly agreed that variable speed limits and lane indicators made for a safer driving experience, while 42 percent agreed or strongly agreed that roadways signs showing travel times on various corridors have made their driving experience safer.



Source: WSDOT

Figure F-5. Survey Results on SR 520 Users' Perception of Safety Regarding New Roadway Signs and Variable Speed Limits

F.2.2.2 Focus Groups

In November 2012, toward the end of the post-deployment period, WSDOT sponsored a series of three focus groups with Washington State Patrol (WSP) Officers, Incident Response Team (IRT) operators, and transit operators to gather their perceptions of the UPA projects as part of the national evaluation. These were conducted by Jacobs Engineering Group. A total of 3 WSP officers, 2 IRT operators, and 3 King County Metro Transit bus operators participated in these focus groups.

The primary purpose of these focus groups was to obtain the perspective of individuals who travel the SR 520 and I-90 corridors on a regular basis and who are responsible for traffic enforcement, traffic safety, and incident response. Questions in the interviews focused on perceived changes in safety, the number and severity of crashes, congestion levels, incident response and clearance times due to the travel time signs, the ATM variable speed and lane controls on SR 520 and I-90, and the SR 520 toll system and toll signage. Participants presented sometimes differing perceptions of how tolling the SR 520 bridge and deploying ATM signage has affected safety in the LWC.

Regarding changes in crashes, both WSP officers and IRT operators noted an increase in crashes on I-90 since SR 520 tolling operations began. WSP officers noted that this is documented in crash reports, and felt that crashes had particularly increased during sporting events. Both the WSP officers and IRT operators felt that this could be caused by an increased number of drivers on I-90 who are unfamiliar with commuting on that route, but avoiding tolls on SR 520. The IRT operators had not noticed any change in the location of incidents or crashes on SR 520 since tolling operations began.

Transit operators feel that driving a bus on SR 520 is easier in the post-deployment period because of less traffic on that roadway as a result of tolling. However, they noted that the corridor is less safe now, but that is likely due to construction in the vicinity of the SR 520 bridge.

WSP officers were generally positive about the ATM signage in the LWC. While the WSP respondents were personally skeptical of the ATM signage, they noted their value in reducing rear end collisions and informing drivers of incidents downstream. Regarding enforcement of the variable speed limits, the officers feel additional shoulder space is necessary; they noted that wider shoulders could also help to clear an incident from the roadway for faster clearance times. Instead of distracting drivers through enforcement, they feel that the variable speed limits serve as an additional tool to drivers to indicate congestion ahead.

In contrast, IRT operators did not feel that variable speed limits and lane control were very effective on the ATM signage and have noticed no changes in congestion levels or crashes because of their use. They felt this is due to the public's perception that the variable speed limits cannot be enforced. IRT operators feel that there is an overload of signage and information for the public and so the messages are ignored.

Transit operators have noticed a decrease in the number and severity of crashes on SR 520 and I-90, which they believe may be attributable to the ATM signage. However, they have observed drivers that do not follow the variable speed limits or lane control messages that are displayed on the ATM signage. Ultimately, transit operators feel that drivers slow down when a variable speed limit is posted, but do not obey the lane control messages as much.

All three focus groups felt that the messages displayed on the ATM signage, including variable speed limits and lane closure signs, are very clear and generic for easy understanding by the general public.

F.3 Summary of Safety Impacts

Table F-8 summarizes the safety impacts for the safety hypothesis. The analysis presented in this appendix indicates that the UPA projects did not change safety on SR 520 and I-90. Instead, it appears that a shift of traffic from SR 520 to I-90 following the initiation of tolling on the SR 520 bridge caused a similar shift of crashes; findings show a statistically significant decrease in the number of crashes on SR 520 and statistically significant increase in the number of crashes on I-90 between I-5 and I-405. A separate analysis of crash data showed no statistically significant effect on the number of crashes after the ATM signage was installed on SR 520. As discussed, however, more extensive analysis over a longer time period is needed to fully assess the potential impacts of the various UPA projects and other improvements on crashes and safety on SR 520, I-90, and other relevant corridors in the region.

The analysis presented in this appendix indicates that there were statistically significant crash increases of 66 percent for fatal plus injury crashes and 29 percent for PDO crashes when the change in VMT was accounted for on I-90 in the post-deployment period, while SR 520 saw a 7 percent increase in fatal plus injury crashes and 19 percent decrease for PDO crashes when accounting for VMT during the same period (note that the actual number of fatal plus injury crashes decreased on SR 520). The analysis indicates that the SR 520 tolling system itself did not improve safety on SR 520, but that the resultant shift of VMT from SR 520 to I-90, and consequent increases in crashes on I-90 neutralized any safety impacts. Further analysis of data over a longer time period than available for this evaluation is needed to fully assess the safety impacts of the UPA projects.

The ATM strategies appear to have a neutral impact on crash rates, although improved perceptions of safety are reported by SR 520 travelers, WSP officers, and transit operators. Almost half (46 percent) of SR 520 users agreed or strongly agreed that variable speed limits and lane indicators made for a safer driving experience, while 42 percent agreed or strongly agreed that roadways signs showing travel times on various corridors have made their driving experience safer. The WSP officers and transit operators noted benefits that the ATM signage provided by informing drivers and potentially reducing the number of crashes and crash severity. On the other hand, the IRT operators did not feel the ATM signage was very effective.

Table F-8. Summary of Impacts for Safety Hypothesis

Hypotheses/Questions	Result	Evidence
Tolling, ATM and traveler information (e.g., travel time sign) strategies that entail unfamiliar signage and which may alter existing traffic flows will not adversely affect highway safety.	Approximately neutral, but more analysis needed	Total crashes decreased by 11% on SR 520 and increased by 40% on I-90, from 2010 to 2012 when accounting for VMT. The ATM signs had no statistically significant effect on the number of crash rates. However, more extensive analysis over a longer period is needed. Generally positive reactions on improved safety were received from the SR 520 travelers, transit operators, and WSP officers, but IRT operators did not feel the ATM signs were effective.

Source: Battelle

Appendix G. Environmental and Energy Analysis

This environmental and energy analysis of the Seattle/Lake Washington Corridor (LWC) Urban Partnership Agreement (UPA) focuses on the impacts of the project on air quality and energy consumption in the SR 520 corridor between Interstate 405 and Interstate 5. This heavily traveled east-west commuter route across Lake Washington separates downtown Seattle and coastal points to the south from eastside communities like Redmond and Bellevue.

The environmental analysis assesses the impacts of mode shift, vehicle and person throughput, increased speeds, reductions in idling, increases in transit ridership, and new telecommuters on the environment. These impacts were quantified using sensor-based measurements of vehicle traffic and speeds collected by the Washington State Department of Transportation (WSDOT) Northwest Region Traffic Management Center (NRTMC). Supplemental insight, especially in connection with mode choice, was derived from household travel surveys conducted by the Volpe National Transportation Systems Center and biannual Commute Trip Reduction (CTR) surveys conducted by worksites subject to the CTR law and submitted to WSDOT.

Table G-1 lists the questions included in the environmental analysis. The first question addresses the air quality impacts of the Seattle/LWC UPA projects. The second question explores the potential impacts of the UPA projects on energy consumption.

Table G-1. Environmental and Energy Analysis Questions

Questions
• What are the impacts of the UPA strategies in the SR 520 corridor on air quality?
• What are the impacts on energy consumption?

Source: Battelle

The questions are addressed by quantifying the change in ozone precursors – Volatile Organic Compounds (VOC), Nitrogen Oxides (NOx), Carbon Monoxide (CO), Particulate Matter less than 2.5 microns ($PM_{2.5}$), Particulate Matter less than 10 microns (PM_{10}), and Equivalent Carbon Dioxide (CO_2e) – as an indicator of greenhouse gas potential and energy use, expressed in gallons of fuel use. It should be noted that CO is no longer monitored in the Central Puget Sound region, but is included here for consistency with other UPA/CRD sites.

The Seattle region was formerly classified as nonattainment for ozone, CO, and PM_{10} and is currently designated as maintenance for all three, meaning they have attained the standard and are both monitoring and continuing control efforts to ensure continued attainment.

The remainder of this appendix is divided into four sections. The data sources used in the analysis are presented in Section G.1. The analysis methods used in the air quality and energy assessment are discussed in Section G.2. The results of the analysis of the air quality and energy impacts are summarized in Section G.3. Section G.4 highlights information from the stakeholder interviews and the content analysis of print media related to environmental perceptions. The appendix concludes with a summary of the environmental, energy, and stakeholder analyses in Section G.4.

G.1 Data Sources

The air quality emissions and energy analysis is based on the emissions rates of vehicles utilizing the freeway facilities in the Seattle area (including trucks or heavy duty vehicles [HDVs]), and the volumes and speed of those vehicles. Emission rates were provided by the Puget Sound Regional Council (PSRC), the metropolitan planning organization (MPO) for the region. The amount (volumes) and speed of the vehicles using SR 520, its alternate I-90, and the direct accesses from I-5 and I-405 in the pre- and post-deployment periods was measured by WSDOT freeway sensor data processed and analyzed by the national evaluation team.

G.1.1 Motor Vehicle Emission Rates

Motor vehicle emission rates are modeled with Environmental Protection Agency (EPA) mobile source emissions factor models and are expressed in terms of grams of pollutant per mile of travel and gallons of fuel per mile of travel. In the Seattle area, based on applicable regulatory requirements, PSRC used the EPA Motor Vehicle Emissions Simulator (MOVES) model for emissions modeling.

The latest version of EPA's MOVES, MOVES2010b, was used for this analysis. MOVES is the recommended EPA on-road emissions model, and it incorporates the latest emission test data, regulations, and technology. MOVES is currently used to estimate national, state, and county level inventories of criteria air pollutants, greenhouse gas emissions, and some mobile source air toxics from highway vehicles. Additionally, MOVES can make projections for energy consumption (total, petroleum-based, and fossil-based). MOVES can be run in "Emission Rates" mode to generate a set of emission factors by road type and vehicle speed, which was the method chosen for this analysis.

The national evaluation team originally requested emission factors for 2010 and 2011, representing the years in which travel data would be collected, which was later updated to 2010 and 2012. It was agreed that use of one set of 2012 emission factors would be a more consistent approach allowing comparison of changes in traffic patterns without obscuring those changes by use of differing emission factors.

Pollutants Emission Factors were developed for CO, $PM_{2.5}$, PM_{10}, NOx, VOCs, carbon dioxide equivalent (CO_2e), and total energy consumption (TEC). Emissions from running exhaust, crankcase exhaust, brake wear, and tire wear were considered. Final pollutant emission rates include the total of these four processes.

The input data was provided by the Washington State Department of Ecology (Ecology) and includes data on the local vehicle fleet and age distribution as well as the mix of vehicles on various transportation facilities in the region and local vehicle programs such as Inspection and Maintenance. Ecology also provided data that describes the model years subject to California LEV II standards.

Additional details on the MOVES model runs, inputs, and assumptions for the Seattle UPA analysis are provided in a memo from PSRC to the WSDOT Toll Division Office dated February 7, 2013.

G.1.2 Traffic Data

Changes in the amount and speed of travel drive changes to air quality and energy use. WSDOT NRTMC traffic sensors, which provide good coverage on most of the freeway segments, are the primary source for the traffic volume and travel speed evaluation data elements. Data are collected continuously from these sensors, reporting traffic volumes and speeds in approximately ¼ mile segments at a minimum of every 20 seconds.

These traffic sensors are generally located in each lane, the HOV lanes, and entrance and exit ramps of measured facilities. WSDOT archives the traffic sensor data for research and evaluation purposes. These archives contain 5-minute aggregation of the raw traffic sensor data.

Summaries of the traffic data prepared for and used in the environmental and energy analysis are presented in Sections G.2 and G.3. The analysis presented in Appendix A – Congestion Analysis, provides a comprehensive description and analysis of the data. This appendix provides summaries of the traffic data created expressly for the purpose of the environmental analysis which are not presented in Appendix A.

The traffic data used for the environmental and energy analysis are non-holiday weekdays for the a.m. and p.m. peaks (6:00 a.m. to 10:00 a.m. and 3:30 p.m. to 7:00 p.m.), as well as the daytime off-peak period. The pre-deployment data covered the period from January through December of 2010 and the post-deployment period covered the data from January through December of 2012. The data extractor for Seattle provides a field with percentage of data validity. Only those intervals with 50 percent or greater were retained for the analysis. FHWA data quality checks were also applied to filter out any invalid data.

Data are provided for 6 different freeway segments for both 2010 and 2012:

1. SR 520 between I-5 and I-405;
2. I-405 between SR 520 and 522;
3. I-405 between SR 520and I-90;
4. I-5 between SR 520 and I90;
5. I-90 between I-5 and I-405; and
6. SR 522 (however no 2010 data representing pre-deployment is available).

While the main interest for this analysis are the changes on SR 520 resulting after the tolling was implemented, the picture is more complete when considered along with changes on the alternate route I-90 and access routes between the two on I-5 and I-405. The analysis presented in Section G.3 focuses on changes in use of SR 520, I-90, I-405 and I-5.

More specifically, the following were utilized for each freeway segment listed above to support the environmental and energy analysis:

- The number of 5-minute intervals with valid station data by month. Stations with invalid data for the entirety were excluded from the table.
- Mean Volume – The volume is reported as mean flow rates in vehicles per hour per lane (vphpl). The numbers can be aggregated for larger intervals if necessary. The top and bottom 10 percent of data in each cell were removed by the national evaluation team before calculating the means.
- Mean Speed – The weighted mean speed at each station (mph). The top and bottom 10 percent of data in each cell were removed before calculating the means.
- Mean VMT – The mean VMT (vehicle miles traveled) for each station. The top and bottom 10 percent of data in each cell were removed before calculating the means.
- Mean Throughput – The mean throughput (vehicles/unit time) for each station. For a 5-minute aggregation interval, the throughput value is the average number of vehicles passing through a cross section (all lanes combined) within the specified 5-minute period. The top and bottom 10 percent of data in each cell were removed before calculating the means.
- Total Throughput – Total number of vehicles passing through a cross section (station) during AM Peak, PM Peak, and Off Peak as defined earlier.

G.1.3 Survey Data

Travel surveys were conducted as part of the UPA study by the Volpe Center. In addition, CTR Surveys are conducted biannually by larger area employers. These two data sources are used to provide additional context and depth to the freeway sensor data.

The Volpe Center conducted a household travel survey in the form of a two-stage panel study of Seattle-area households. The panel consisted of 2,063 households with a total of 3,698 adults. Surveys were conducted in November 2010 to represent pre-deployment travel patterns, and in May 2012 for post-deployment patterns. The survey addressed the impacts of tolling on (1) route and mode choice; (2) trip departure times; (3) origin-destination patterns; (4) overall VMT and daily travel time budgets; (5) carpooling; and (6) transit use.

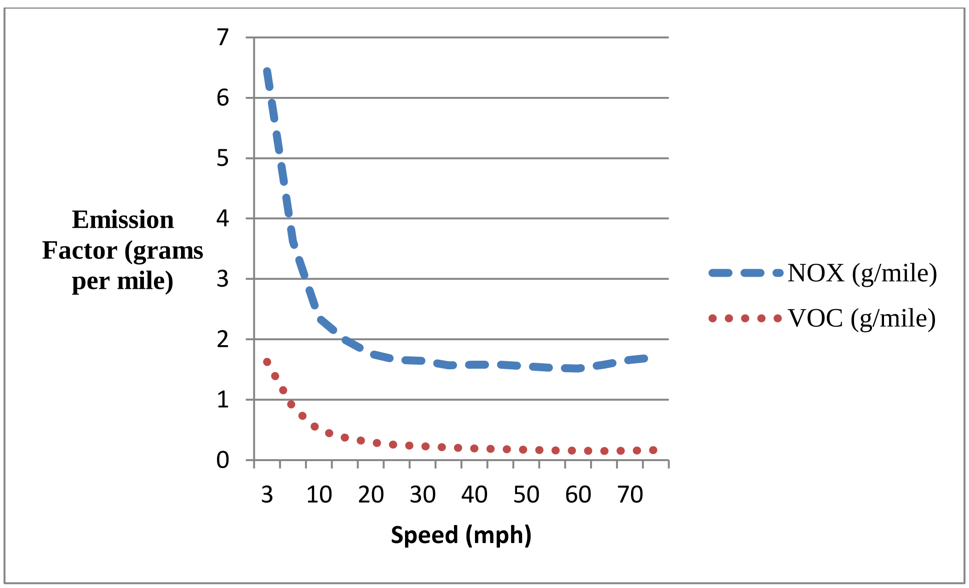
CTR Survey Data. The Washington State Commute Trip Reduction (CTR) Law was passed in 1991 and requires worksites with 100 or more employees (about 1,100 of them) to plan and implement programs to reduce vehicle trips and VMT by promoting commute alternatives. The law applies to all populous counties in the state, including those in the LWC. The law also requires affected worksites to survey employees and submit survey data to WSDOT. These data are available for 2010 and 2012.

G.2 Air Quality and Energy Analysis Methodology

The Seattle UPA projects change congestion levels, travel speeds, and traffic volumes in the LWC. These impacts result in changes in air quality and energy use. The speed, volume and congestion impacts on air quality and energy use were evaluated using the MOVES emissions model factors for the speeds available from the WSDOT sensor data described above in Section G.1.

Conceptually the environmental analysis is very simple. It involves multiplying the miles of travel by the rate of emissions per mile for each pollutant of interest. The energy analysis is the same except that it uses fuel use rates for travel. The rate of emissions and fuel use depends on the speed of travel; therefore a set of emission and fuel rates tied to travel speeds ranging from 0 to 75 mph is used. Both the rates and the speeds are specific to the LWC in 2012. The actual speeds used in this analysis are those measured by the WSDOT sensors on the freeway facilities studied.

As illustrated in Figure G-1, emission factors in the region change significantly at different speeds. Figure G-1 displays the particular relationship between VOC and NOx (precursors to ozone) and travel speed in the Seattle area[1]. The relationships between travel speed and emission rates for all other pollutants covered in this report are very similar: the lower the speed the higher the emission rate. At very high speeds, emissions begin to rise slightly. In general this means that improvements in congestion levels (if the speeds are lower than about 60 mph) will also improve air quality, even if traffic volumes do not decrease.



Source: Earth Matters, Inc. based on emission factors provided by PSRC for the Seattle region.

Figure G-1. Seattle Area Vehicle Emission Factors of Ozone Precursors as a Function of Travel Speed

[1] The emission factor-to-speed relationship displayed here is specific to the Seattle region. It is based on MOVES emission factors developed by PSRC using regional fleet and other characteristics.

As noted in Section G.1, traffic volumes and speeds for the Seattle UPA pre- and post-deployment periods were obtained from WSDOT freeway sensor data.

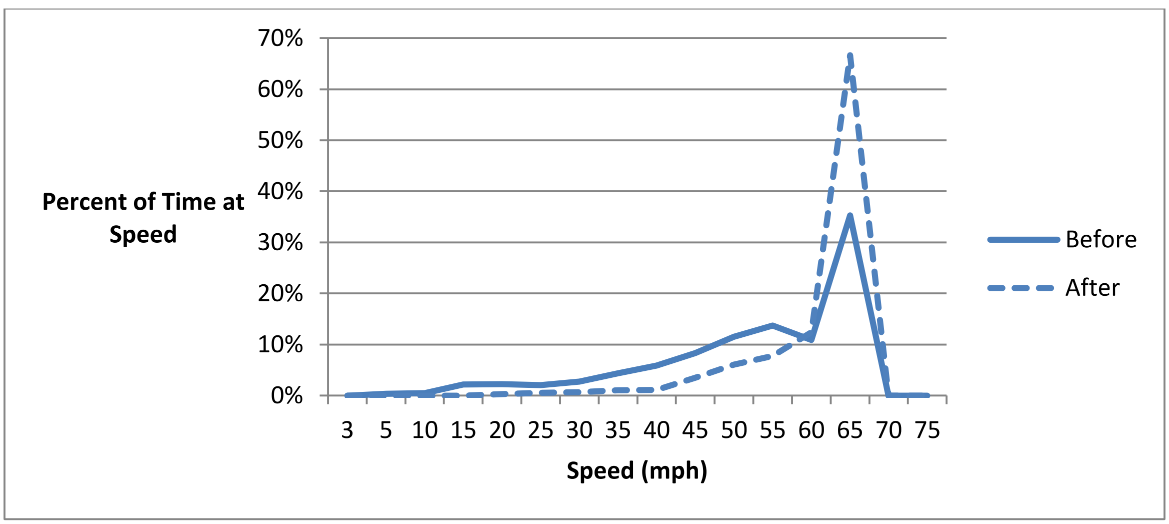
Data for the morning peak (6:00 a.m. to 10:00 a.m.), the daytime off-peak (10:00 a.m. to 3:30 p.m.) and the afternoon peak (3:30 p.m. to 7:00 p.m.) in both directions of traffic flow were used in the environmental analysis. Traditional commute flows on SR 520 were suburb-to-city, westbound in the morning and eastbound in the evening, but there is now a “reverse” commuter flow to the many employment centers on the Eastside, such as downtown Bellevue and the Microsoft campus in Redmond. The analysis therefore combines the two directions in most cases.

For the environmental analysis, traffic volumes and speeds were provided in 5-minute intervals for the general-purpose freeway lanes and HOV lane traffic data were analyzed only for the LWC. Sufficient data were not available on other freeway facilities or arterials adjacent to the corridor.

VMT was estimated by multiplying traffic volume (throughput) in a given freeway segment by the length of that segment. VMT estimates were prepared by doing this for each 5-minute period for each freeway, summing the 5 minute periods appropriate to each time period (e.g., 6:00 a.m. plus 6:05 a.m. and so on to 9:55 a.m. for the morning peak).

Because of the primary role played by travel speeds in the environmental and energy analysis, along with the need to adequately represent the changes in stop-and-go traffic, frequency distributions were prepared. These distributions show the percent of time vehicles spent at each speed between 1 mph and 75 mph in the pre-and post-deployment periods for all lanes of SR 520, I-405, I-90, and I-5 in the study area shown in Figure G-2.

The resulting frequency distributions were used in the environmental analysis to weight the emissions by frequency of speed. Figure G-2 below displays the before and after frequency distributions of speed on SR 520.



Source: Earth Matters, Inc. based on WSDOT Traffic Sensor Data.

Figure G-2. Percent of Time at Various Travel Speeds (SR-520 between I-5 and I-405)

Using the above figure as an example for calculating emissions on eastbound SR 520 in the pre-deployment period, morning peak VMT was approximately 80,000. The figure shows that in the pre-deployment period, travelers were able to drive at speeds of 65 mph about 35 percent of the time while in the post-deployment period they were able to do so over 65 percent of the time. By taking this distribution and multiplying the amount of travel (80,000 miles) by the emission factor appropriate to a given speed[2] and the percentage of time at that speed and then summing the results, it is possible to estimate total emissions in the morning peak period in a way that considers all the measured travel speeds on a given roadway and time period.

The above method was used to estimate emissions for each of the three time periods on each of the four freeway facilities in the pre- and post-deployment cases. These emission estimates and associated changes in traffic volumes are discussed in connection with the household and commute surveys for additional insight.

Fuel consumption is estimated in a two-step process. The PSRC provided energy use rates in the form of MMBtu[3] per mile driven. A set of these energy rates based on travel speeds of 1-75 mph was developed. The set is based on the particular distribution of vehicles in the Seattle area: for example, the mix of ages, car types (line haul trucks to motorcycles), and fuels used. The energy rates therefore contain a mix of fuels ranging from standard gasoline, reformulated gasoline, diesel, and other motor fuels. For simplicity, the energy content of standard gasoline (114,000 btu/gallon) was used to convert miles of travel by speed to gallons of fuel used.

G.3 Air Quality and Energy Analysis

A discussion of the effects of the Seattle/LWC UPA projects on air quality and energy use is presented in this section. Air quality is evaluated by quantifying pre- and post-deployment emissions of VOCs and NOx, which are the principle components of ozone (the kind that we breathe and that affects our respiratory health; not the kind in the upper atmosphere that protects us from solar particles). Other air pollutants are Carbon Monoxide, an odorless, poisonous gas, $PM_{2.5}$ which has a host of health effects, and CO_2, a major greenhouse gas (in this case, CO_2e).

There exist federal health standards for concentrations of all but CO_2, and the Seattle area has been designated as nonattainment for them in the past. Currently the area is considered in attainment with requirements to continue efforts to meet the federal standards.

The energy analysis uses fuel consumption in gallons of gasoline as a metric to quantify the effects of the UPA projects.

The combined effect of the SR 520 tolls considering all four freeway facilities and each direction (east/west for SR 520 and I-90, and north/south for I-5 and I-405) is shown below in Table G-2. Overall, traffic, emissions, and fuel consumption decreased by between 2.5 and 5.8 percent. As noted in Section G.2, because the relationship between pollutant emission rates and travel speeds is not linear and differs for different pollutants, the percentage changes are not the same for each parameter although they all trend in the same direction.

[2] Figure G-2 provided an example for VOC and NOx.

[3] Million British Thermal Units (the MM means thousand thousand). A BTU is the amount of energy it takes to heat or cool a pound of water by one degree Fahrenheit.

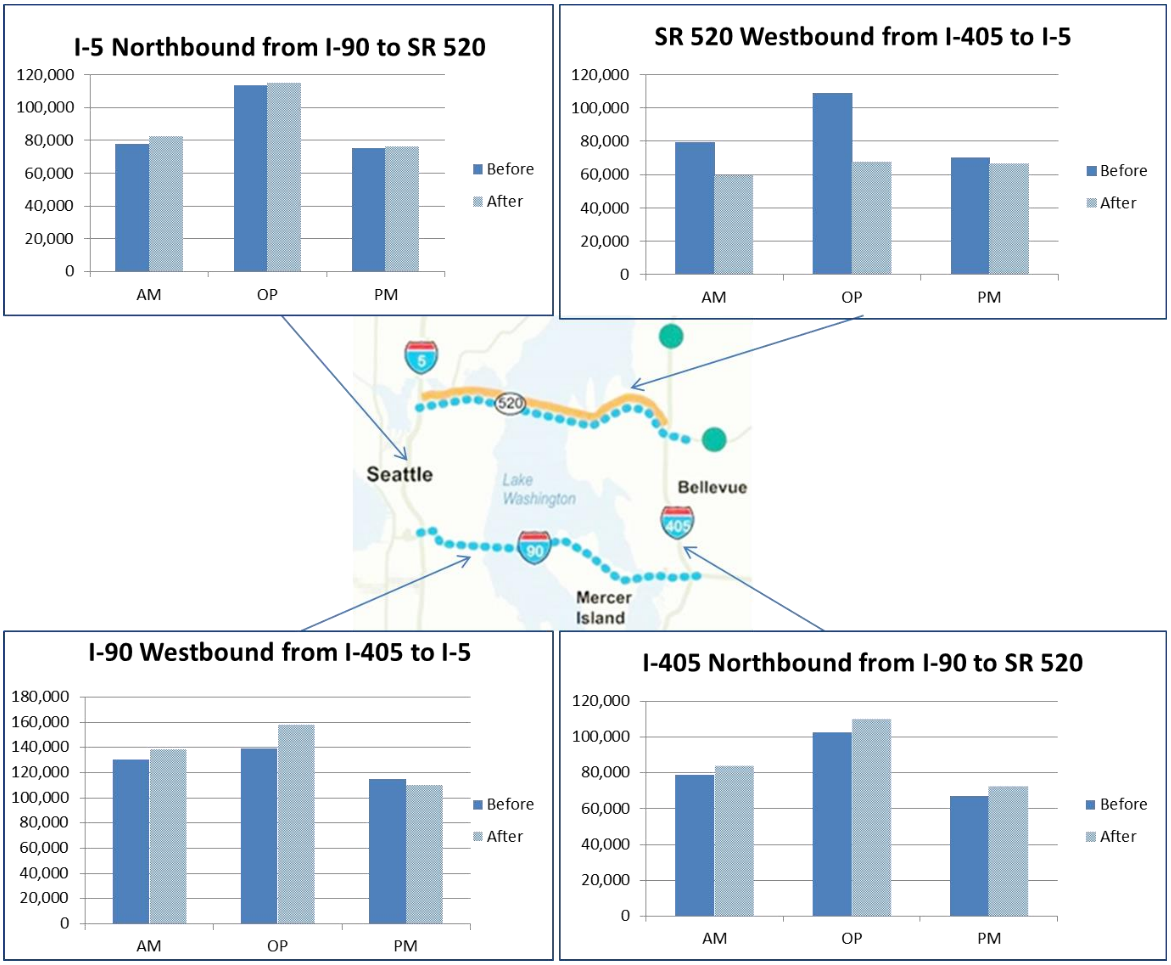
Table G-2. Combined Volume, Emission, and Fuel Consumption Changes for All Four Freeway Facilities in the LWC

Time Period	Deployment Period	VMT	VOC (lbs)	NOx (lbs)	$PM_{2.5}$ (lbs)	CO (tons)	CO_2e (tons)	Fuel Use (gal)
AM Peak (6 - 10 am)	Pre	722,629	265	2,501	120	6,926	381	39,747
	Post	714,750	258	2,477	119	6,636	376	39,208
Off Peak (10 am - 3:30 pm)	Pre	931,779	343	3,225	162	8,811	492	51,310
	Post	891,290	323	3,090	153	8,072	469	48,949
PM Peak (3:30 - 7 pm)	Pre	648,032	237	2,242	109	6,237	342	35,630
	Post	634,759	229	2,200	105	5,985	334	34,803
Combined	Pre	2,302,440	845	7,968	390	21,975	1,215	126,687
	Post	2,240,799	811	7,767	377	20,694	1,179	122,960
Net Change	Amount	-61,640	-35	-200	-13	-1,281	-36	-3,726
	Percent	-2.7%	-4.1%	-2.5%	-3.4%	-5.8%	-3.0%	-2.9%

Source: Earth Matters, Inc.

An alternative perspective is gained by examining pre- and post-deployment VMT along SR 520 and the other three freeway facilities. Because VMT is a primary driver for emissions and energy consumption, viewing changes in VMT is a way to gain additional insight prior to the presentation of detailed results later in this Appendix.

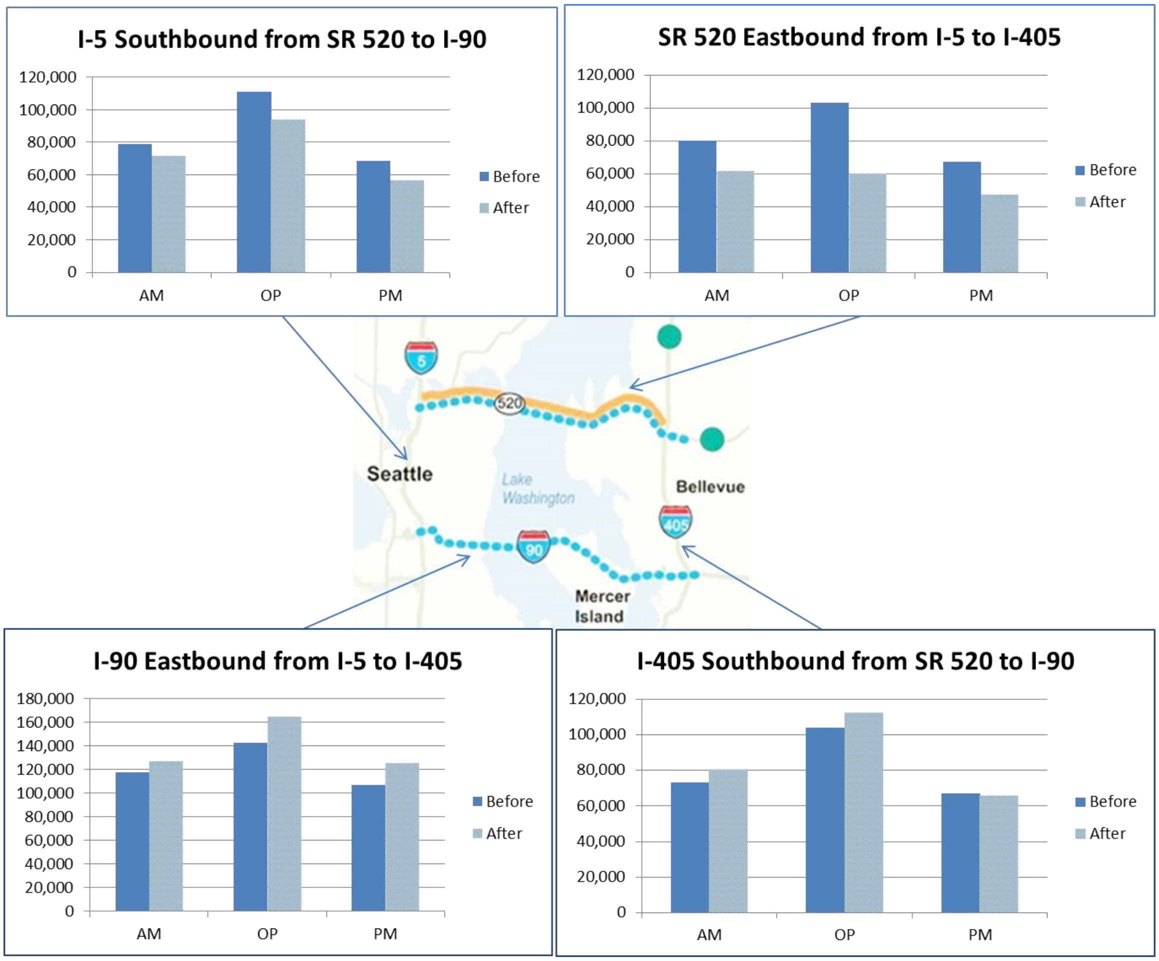
Figure G-3 and Figure G-4 display pre- and post-deployment VMT by time period alongside each of the four freeway facilities in the LWC.



Source: Earth Matters, Inc.

Figure G-3. VMT by Time Period[4] in the Pre- and Post-Deployment Periods for the WB and NB Directions

[4] AM refers to a.m. peak between 6:00 a.m. and 10:00 a.m.; OP is Off Peak between 10:00 a.m. and 3:30 p.m., and PM is the p.m. peak between 3:30 p.m. and 7:00 p.m.



Source: Earth Matters, Inc.

Figure G-4. VMT by Time Period in the Pre- and Post-Deployment Periods for the EB and SB Directions

These figures show that in the eastbound and northbound directions, VMT mostly increases on I-90, I-5, and I-405 while decreasing sharply on SR 520 for all periods of the day. On I-5 there are small increases in each time period; with larger (proportionally) increases along I-405 and I-90, also during all three time periods.

Changes in VMT for the westbound and southbound directions are more pronounced during the off-peak periods than in the peak periods, and the pattern is different than the pattern in the other directions. Travel on I-5 decreases (it increases in the other direction). Also, overall travel along I-90 increases but there is a decrease in afternoon peak travel along that facility in the westbound direction.

These figures provide a reasonable overview of the more detailed and facility-specific emission and fuel consumption changes presented in the following several pages. Changes on SR 520 are presented first, in Table G-3, followed by I-90, I-5, and I-405 in Table G-4 through Table G-7, with Table G-7 providing a more detailed look at travel patterns on I-5 and I-405.

The effect of the tolling on SR 520 is a marked decrease in traffic volumes, emissions, and fuel consumption along SR 520, shown in Table G-3.

Table G-3. Volume, Emission, and Fuel Consumption Changes for SR-520

Time Period	Deployment Period	VMT	VOC (lbs)	NOx (lbs)	PM2.5 (lbs)	CO (tons)	CO_2e (tons)	Fuel Use (gal)
AM Peak (6 - 10 am)	Pre	159,868	63.4	560	18.5	1,970	87.0	9,065
	Post	121,414	42.0	419	12.5	1,460	63.0	6,565
Off Peak (10 am - 3:30 pm)	Pre	212,857	84.4	746	24.7	2,624	115.8	12,070
	Post	127,595	44.2	440	13.1	1,534	66.0	6,899
PM Peak (3:30 - 7 pm)	Pre	137,833	54.6	483	16.0	1,699	75.0	7,816
	Post	113,911	39.4	393	11.7	1,370	59.0	6,159
Combined	Pre	510,557	202.4	1,788	59.2	6,293	277.8	28,951
	Post	362,919	125.6	1,252	37.4	4,364	188.0	19,623
Net Change	Amount	-147,638	-76.8	-536	-21.9	-1,929	-90	-9,328
	Percent	-28.9%	-37.9%	-30.0%	-36.9%	-30.6%	-32.3%	-32.2%

Source: Earth Matters, Inc.

Emissions and fuel consumption decrease by slightly more than VMT: from 30 to 37 percent depending on the pollutant. Again, differences in the amount and proportion of emission change is dependent on the speed-to-emission-rate differences in addition to the changes in travel miles.

The Volpe household travel survey corroborates the travel results. The travel diaries showed a decrease in travel along SR 520 of 42 percent. The freeway sensor data measured 29 percent, as shown above. However, the Volpe household travel survey also found post-deployment auto occupancies of 1.61. If the measured change in VMT (miles travelled by vehicles as opposed to people) is multiplied by 1.61 we get a 46 percent reduction in people miles, which is very close to the surveyed responses.

The decrease in travel and associated emissions and fuel consumption along SR 520 is accompanied by a large increase in travel on the alternate route I-90, as shown in Table G-4 below.

Table G-4. Volume, Emission, and Fuel Consumption Changes for Interstate 90

Time Period	Deployment Period	VMT	VOC (lbs)	NOx (lbs)	PM2.5 (lbs)	CO (tons)	CO_2e (tons)	Fuel Use (gal)
AM Peak (6 - 10 am)	Pre	253,507	87	875	26	3,041	131	13,656
	Post	274,385	95	949	28	3,292	142	14,859
Off Peak (10 am - 3:30 pm)	Pre	287,146	98	991	29	3,445	148	15,469
	Post	332,165	115	1,148	34	3,986	172	17,987
PM Peak (3:30 - 7 pm)	Pre	232,193	79	801	24	2,785	120	12,508
	Post	248,815	86	860	26	2,986	129	13,474
Combined	Pre	772,846	264	2,667	78	9,271	399	41,633
	Post	855,365	296	2,957	88	10,263	444	46,320
Net Change	Amount	82,519	33	290	9	993	45	4,686
	Percent	10.7%	12.4%	10.9%	12.0%	10.7%	11.3%	11.3%

Source: Earth Matters, Inc.

Over the course of the day, travel along I-90 increased by almost 11 percent, representing 82,519 additional miles of vehicle travel. On SR 520, travel decreased by 147,638 miles. This means that increases in travel and associated emissions and fuel use along alternate route I-90 offset the decreases along SR 520 by over 56 percent. Or, put another way, the decrease in travel and emissions along SR 520 was offset by only about half because of the increase in travel and emissions along I-90.

The Volpe household travel survey for the LWC recorded a 13 percent decrease in person trips along I-90. This is different than the measured 10.7 percent increase in vehicle miles. If the vehicle miles are adjusted by the 1.48 average vehicle occupancy in the corridor, the increase would be reduced to 7.2 percent The remainder of the difference could be a combination of survey response errors (or survey fatigue) and the fact that the sensor measurement data used in the analysis reported here covers daytime travel only. Additionally, the Volpe household travel survey discusses trips as opposed to miles of travel.

The picture may be more complete when consideration is given to changes along the access freeways between I-90 and SR 520. Table G-5 and Table G-6 present these values.

Table G-5. Volume, Emission, and Fuel Consumption Changes for I-5

Time Period	Deployment Period	VMT	VOC (lbs)	Nox (lbs)	PM2.5 (lbs)	CO (tons)	CO_2e (tons)	Fuel Use (gal)
AM Peak (6 - 10 am)	Pre	156,966	60	537	60	1,914	83	8,652
	Post	154,539	61	534	61	1,883	83	8,665
Off Peak (10 am - 3:30 pm)	Pre	224,883	86	770	86	2,742	119	12,395
	Post	209,366	82	724	82	2,551	113	11,739
PM Peak (3:30 - 7 pm)	Pre	143,717	55	492	55	1,752	76	7,921
	Post	133,668	53	462	53	1,629	72	7,495
Combined	Pre	525,566	200	1,799	200	6,408	278	28,968
	Post	497,573	196	1,720	196	6,063	268	27,900
Net Change	Amount	-27,993	-4	-79	-4	-345	-10	-1,068
	Percent	-5.3%	-2.0%	-4.4%	-2.0%	-5.4%	-3.7%	-3.7%

Source: Earth Matters, Inc.

Table G-6. Volume, Emission, and Fuel Consumption Changes for I-405

Time Period	Deployment Period	Volumes	VOC (lbs)	NOx	PM2.5	CO (tons)	CO_2e (tons)	Fuel Use (gal)
AM Peak (6 - 10 am)	Pre	152,288	55	529	16.32	0.9	80	8,374
	Post	164,412	60	575	17.59	1.0	87	9,120
Off Peak (10 am - 3:30 pm)	Pre	206,893	75	718	22.17	1.2	109	11,376
	Post	222,165	82	778	23.77	1.3	118	12,323
PM Peak (3:30 - 7 pm)	Pre	134,289	49	466	14.39	0.8	71	7,384
	Post	138,366	51	484	14.81	0.8	74	7,675
Combined	Pre	493,471	179	1,713	52.88	3.0	260	27,135
	Post	524,942	193	1,837	56.17	3.2	279	29,118
Net Change	Amount	31,472	13.4	124	3.29	0.2	19	1,983
	Percent	6.4%	7.5%	7.2%	6.2%	6.8%	7.3%	7.3%

Source: Earth Matters, Inc.

The changes in travel along I-90 and I-405 are associated with changes along SR 520 and I-90 but the extent to which they are connected is not known. This issue is discussed in more detail in the congestion analysis presented in Appendix A. One could theorize that increases in travel in the southbound direction could be explained by increases in travel to I-90 that had bypassed what had been the normal route to use SR 520.

In order to explore this possibility, an analysis was made of changes in I-5 and I-405 VMT. This analysis is shown in Table G-7 below.

Table G-7. Changes in VMT along Southbound I-5 and I-405

Route	Time Period	VMT Pre-Deployment	VMT Post-Deployment	Change	Percent Change
I-405 Southbound	AM	64,734	71,291	6,557	10.1%
	OP	91,138	97,209	6,071	6.7%
	PM	52,969	49,981	-2,988	-5.6%
	Total	208,841	218,480	9,640	4.6%
I-5 Southbound	AM	78,995	71,925	-7,069	-8.9%
	OP	111,154	94,231	-16,923	-15.2%
	PM	68,231	56,996	-11,235	-16.5%
	Total	258,379	223,152	-35,228	-13.6%

Source: Earth Matters, Inc.

The changes shown in Table G-7 do not support the concept that possible increases in travel along I-90 as an alternate route for SR 520 are accompanied by similar increases in travel between SR 520 and I-90. In actuality, travel along I-5 decreased substantially and there were minor (about 11 percent of the increase on I-90) increases in travel on southbound I-405.

No data are available for arterial routes to access I-90, nor are pre-deployment data available for the northern alternative on SR 522. Therefore the data available support the measured fact (see Table G-2 for example) that traffic and emissions in the corridor all declined in the post-deployment period.

G.4 Summary of Environmental Analysis

Table G-8 presents a summary of the questions examined in the environmental and energy analysis of the Seattle/LWC UPA projects. As discussed in this appendix, the projects had positive impacts on air quality and energy consumption. The analysis indicated positive impacts on air quality overall. Over the combined effects on all four freeway facilities, reductions of between 2.5 percent to 5.8 percent in emissions, and a 2.9 percent reduction in fuel use were calculated. On SR 520, emissions decreased by 30-37.9 percent and fuel use declined by 32.2 percent. These decreases were offset somewhat by increases along I-90 and I-405 of 6-12 percent and enhanced somewhat by decreases in emissions and fuel use on I-5.

Table G-8. Summary of Impacts Across Questions

Questions	Result	Evidence
What are the impacts of the Seattle UPA strategies on air quality?	Positive impacts.	Emission reductions of over 30 percent for all pollutants on SR 520. Emission reductions between 2.5-5.8 percent when considering the difference between pre- and post-deployment combined effects of SR 520, I-90, I-5, and I-405.
What are the impacts on energy consumption?	Positive impacts.	Fuel use reduction of 32.2 percent on SR 520. Combined fuel use reduction of 11.3 percent when considering the difference between pre- and post-deployment combined effects of SR 520, I-90, I-5, and I-405.

Source: Earth Matters, Inc.

This page intentionally left blank

Appendix H. Equity Analysis

This analysis examines potential equity issues associated with the various Seattle/LWC UPA projects. Experience with the SR 167 HOT lanes in the Seattle region and with other HOT and toll facilities throughout the country indicate that perceptions of fairness, or equity, may be a factor in the acceptance of proposed pricing projects. Equity may also be a concern in the spatial distribution of services and infrastructure. Equity issues are important to assess because the impacts – both positive and negative – may contribute to public opinion and the effects upon various population groups.

The Seattle/LWC UPA partner agencies are taking a number of actions to mitigate any potential equity concerns. For example, although many travelers are expected to use the SR 520 *Good to Go!* pre-paid, transponder-based account, several other payment options are being offered. These options include pre- or post-payment for each toll transaction by mail, over the Internet, by telephone, and in person at a customer service store. Outreach efforts, including those focused on limited-English-speaking populations, are also planned.

Table H-1 presents the questions in the equity analysis. First, the direct social effects from the Seattle/LWC UPA projects, including tolling SR 520, on various user groups is examined. These social effects may include tolls paid, travel-time savings, and adaptation costs. The second question addresses the spatial distribution of aggregate out-of-pocket and inconvenience costs, and travel time and mobility benefits. Third, possible differential environmental impacts on certain socio-economic groups is examined. This question addresses possible environmental justice issues. Finally, the reinvestment of revenues from tolling the SR 520 bridge and how this reinvestment impacts various user groups will be examined.

Table H-1. Equity Analysis Questions

Questions
• What are the direct social effects (tolls paid, travel times, adaptation costs) for various transportation system user groups from tolling the SR 520 bridge, transit, and other UPA strategies?
• What is the spatial distribution of aggregate out-of-pocket and inconvenience costs, and travel time and mobility benefits?
• Are there any differential environmental impacts on certain socio-economic groups?
• How does reinvestment of revenues from tolling SR 520 impact various transportation system users?

Source: Battelle

The remainder of the appendix is divided into six sections. Section H.1 describes the data sources used in the equity analysis. Section H.2 presents the analysis of potential equity impacts to the different transportation system user groups. Analysis of geographic equity is presented in Section H.3. Section H.4 examines the air quality impacts from the UPA projects across geographic and socio-economic groups. Section H.5 discusses the planned reinvestment of potential revenues from the SR 520 tolls. The appendix concludes with a summary of the potential equity impacts in Section H.6.

H.1 Data Sources

The equity analysis includes data from several other analyses in the national evaluation. Travel times and vehicle miles traveled (VMT) based on traffic sensor data were obtained from the congestion analysis in Appendix A, as were the findings from the Volpe household travel survey and WSDOT SR 520 Tolling Final Evaluation Survey Report. Appendix B – Tolling Analysis and the WSDOT SR 520 Tolling Final Evaluation Survey Report provided data on tolling transactions based on *Good to Go!* toll tags and pay by plate methods. Appendix C – Transit Analysis provided data on results of an on-board transit survey. Appendix G – Environmental Analysis provided input for assessing air quality impacts. The data from those parts of the national evaluation were supplemented with socio-demographic data from the U.S. Census Bureau and King County Metro Transit rates from that agency's website.

H.2 Potential Equity Impact on SR 520 User Groups

The evaluation examined the potential variation of benefits and costs experienced by different users of SR 520 in the LWC before and after the implementation of tolling. Owing to the anticipated travel improvements for travelers in the SR 520 corridor and potential for consequential impacts to the I-90 or SR 522 corridors, it would be reasonable to expect that some users might benefit more than others. At the same time, for those paying a toll, costs could be higher for some users than others.

Data for assessing the equity impacts on user groups included mean travel time and travel time reliability drawn from the congestion analysis in Appendix A and average toll rates and payment options from Appendix B. Published fares from King County Metro Transit's website were used to estimate costs for transit riders.

Also presented are the perceptions of equity or fairness for different users of SR 520. Questions addressing equity were included in the on-board transit survey and the Volpe household travel survey, described in Appendix C and Appendix A, respectively. The surveys provide data for analysis of perceptions. These findings are presented in the latter part of this section.

User Benefits and Costs

As reported in Appendix A – Congestion Analysis, mean travel times on SR 520 were reduced in both the morning (about 2 minutes in both directions) and afternoon peak periods (2 minutes eastbound and about 8 minutes westbound). Mean travel times on I-90 increased by about 1 minute in both directions of travel in the morning peak-period, while in the afternoon peak period, mean travel times remained approximately the same in the eastbound direction and increased by about 3 minutes in the westbound direction. Travel-time reliability, as measured by the 95^{th} percentile travel time, improved on SR 520 in the post-deployment period, declining in the morning peak period by approximately 3 minutes in the eastbound direction and 6 minutes in the westbound direction, and by 6 minutes in the eastbound direction and 13 minutes in the westbound direction in the afternoon peak period. The 95^{th} percentile travel time on I-90 generally remained the same, but increased in the westbound direction in the afternoon peak period.

As reported in Appendix B – Tolling Analysis, toll rates vary by time-of-day and by toll payment option. On weekdays, tolls are highest during the morning and afternoon peak periods (7:00 a.m. to 9:00 a.m. and 3:00 p.m. to 6:00 p.m.) averaging $3.55 with a *Good to Go!* pass and lower during the other times of the day. The highest toll was $3.59 and the lowest was $1.60. The toll rates for weekends and holidays are lower overall, with the highest toll of $2.26 from 11:00 a.m. to 6:00 p.m. Tolls are about $1.50 higher than this for travelers using the Pay By Mail option. No tolls are charged between 11:00 p.m. and 5:00 a.m. during the week, and on weekends and holidays.

As published on the King County Metro Transit website, bus fare for users crossing Lake Washington on SR 520 is $3.00 for a trip during peak hours (6:00 a.m.-9:00 a.m. and 3:00 p.m.-6:00 p.m.) and $2.25 at other times. Discounted fare is available for seniors, riders with disabilities, Medicare card holders, and youth age 18 and under. In the eastbound direction, bus travel times were 0.9 to 1.7 minutes faster and there were 40-67 percent improvements in on-time performance, but no significant improvements occurred in the westbound direction.

Both drivers and transit users on the SR 520 bridge benefit from improved travel times and travel time reliability. Travelers on SR 520 pay similar costs for a toll or a bus fare, although drivers have additional vehicle operating costs. Travelers on I-90 experienced a minor dis-benefit in the post-deployment with slightly higher travel times. Drivers who switched from SR 520 before tolling to I-90 after tolling likely paid higher costs due to increased vehicle operating costs and travel time, depending on the relative proximity of their origin and destination to the SR 520 and I-90 corridors.

Table G-1. Comparison of Travel Time and Costs per Trip across Lake Washington by User Group in the Morning and Afternoon Peak Travel Periods

User Group	Mean Travel Time[1]		Net Change in Costs[2]
	Before	After	After
SR 520 Drivers			
a.m. peak	9.5	7.2	+$3.19
p.m. peak	13.5	8.7	+$3.34
I-90 Drivers			
a.m. peak	7.9	8.6	
p.m. peak	9.7	11.2	
SR 520 Transit Riders			
a.m. peak	5.7	5.2	
p.m. peak	6.9	5.9	

Source: Battelle

[1] Mean travel time of both directions in minutes obtained from Appendix A – Congestion Analysis that used peak hours of 6:00-10:00 a.m. and 3:30-7:00 p.m., and Appendix C – Transit Analysis that used peak hours of 6:00-9:00 a.m. and 3:00-7:00 p.m. Times are for travel between I-5 and I-405.

[2] Net change in cost is based on the average toll on the SR 520 bridge.

Trip, Mode, and Route Choice

The Volpe household travel survey investigated the reasons why respondents made changes to their travel patterns before (Wave 1 survey in 2010) and after (Wave 2 survey in 2012) tolls were implemented on SR 520. Of all respondents who identified SR 520 as their primary route across Lake Washington before tolling, only 55 percent continued to use it as their primary route after tolling. The 24 percent of respondents who had switched to I-90 were more likely to be male, have lower incomes, and to have less workplace flexibility, compared to those who continued to use SR 520 after tolling. Specifically, 32 percent of SR 520 users with incomes under $100,000 switched to I-90 after tolling began, compared with only a 21 percent among SR 520 users with incomes over $100,000. SR 520 users with incomes over $250,000 are more likely to still use SR 520 after tolling (73 percent) than users across all incomes (55 percent).

Volpe also administered 2-day household travel diaries, which showed similar results. Lower income households (under $50,000) made 62 percent fewer trips on SR 520 after tolling began, versus only 41 percent fewer trips on SR 520 for higher income households (over $150,000). The travel diaries also showed that higher income households generally pay higher tolls. Households with an income greater than $200,000 logged about $3 paid in tolls over the 2-day period compared to $1 for households with an income under $50,000 in the same period. Regardless, 14 percent of households with incomes under $100,000 paid over $4 in tolls over the 2-day period.

Household data from these findings were also aggregated from 11 income groups into three income groups; under $75,000 annual household income, $75,000 to $150,000 annual household income, and $150,000 and over. Table H-2 presents summary statistics for tolls paid by household income. Statistical analysis using a one-way analysis of variance (ANOVA) test revealed highly significant differences between these three income groups, with a p-value <0.0001. Comparisons between pairs of income groups (using a Tukey multiple comparison procedure) revealed significant differences between all three groups, as shown in Table H-3 with the high income group spending significantly more on tolls than the medium and low income groups and the medium income group spending significantly more on tolls than the low income group.

Table H-2. Summary Stats for Tolls Paid by Income

Household Income	Mean	Std. Dev.	Number of Households	Range
< $75,000/year (low)	$0.99	2.99	528	$0-$23.80
$75,000 < $150,000 (med)	$1.64	3.95	818	$0-$25.20
$150,000/year + (high)	$2.59	5.15	450	$0-$27.45
Total Households reporting data			**1,796**	**$0-$27.45**

Source: Battelle

Table H-3. Comparison of Tolls Paid by Income

Comparison of Two Income Groups	Difference Between Means	95% Confidence Interval	
		Upper	Lower
Medium vs. low	$0.65*	$0.19	$1.12
High vs. medium	$0.95*	$0.42	$1.39
High vs. low	$1.60*	$1.03	$2.10

* This difference is significant at the 0.10 level.

Source: Battelle

Volpe also investigated the possibility of lost mobility given the significant reduction in trips identified in the household travel diaries. Findings showed that vanpools were utilized most by higher income groups, and had increased usage from those who had previously driven. The analysis also showed the magnitude of new transit trips decreased as income increased (with the exception of the lowest income group, which had also been less likely to use transit than the second-lowest income group in the pre-deployment Wave 1 survey).

In analyzing the Volpe household travel diaries for changes in cross-lake trips by trip purpose and income group, the lowest income group had the largest decrease in total trips and an overwhelming 51 percent decrease in discretionary trips. This same group did not have a proportional increase in discretionary trips that did not cross Lake Washington, at least for employed individuals. Table H-4 shows the percent change in trips across Lake Washington by income group. These findings indicate that users in the lowest income group were less able to switch modes, thus making fewer discretionary trips than other users.

Table H-4. Percent Change in Trips across Lake Washington by Income Group

Income	Home	Work/School/ Child Care	Discretionary	Other	Total
<3 times the poverty level	-9%	-34%	-51%	-27%	-28%
3-5 times the poverty level	-16%	-18%	-27%	-17%	-18%
5-10 times the poverty level	-13%	-19%	-19%	-30%	-18%
10+ times the poverty level	-19%	-18%	-24%	-16%	-19%
Unreported	-18%	-23%	-24%	-10%	-21%
Total	-15%	-20%	-25%	-22%	-19%

Source: Volpe

Additionally, the WSDOT SR 520 Tolling Final Evaluation Survey Report showed an increase in various travel modes after tolling began. Specifically, respondents reported an increase in carpooling (15 percent), teleworking (11 percent), use of public transit (9 percent), and vanpooling (4 percent) after tolling began on SR 520. Respondents with incomes under $30,000 were more likely (28 percent) to report increased use of public transit versus those with an income over $30,000. Similarly, respondents with incomes under $55,000 were more likely to report increased carpooling (25 percent) and/or vanpooling (9 percent) on SR 520 than those with incomes over $55,000 (11 percent and 2 percent, respectively).

Toll Payment Methods

There are seven ways to pay tolls on the SR 520 bridge, six of which require individuals to open an account. The other option, Pay By Mail, does not require an account. Individuals can open *Good To Go!* and other accounts on-line, by telephone, by mail, and at three area customer service centers. *Good To Go!* sticker passes may also be purchased at participating retail stores in the region, which are listed on the SR 520 bridge website. There are five *Good To Go!* pass options available, ranging in price from $5.00-to-$12.00.

The *Good To Go!* pass is by far the most frequently used type of toll account, representing approximately 88 percent of the total 275,311 accounts opened during the 23-month period. Pay By Plate accounts were a distant second, representing approximately 9 percent of the total accounts; followed by short-term accounts, with almost 2 percent; commercial accounts, with 0.4 percent; unregistered accounts, with 0.1 percent; and government accounts, with 0.1 percent.

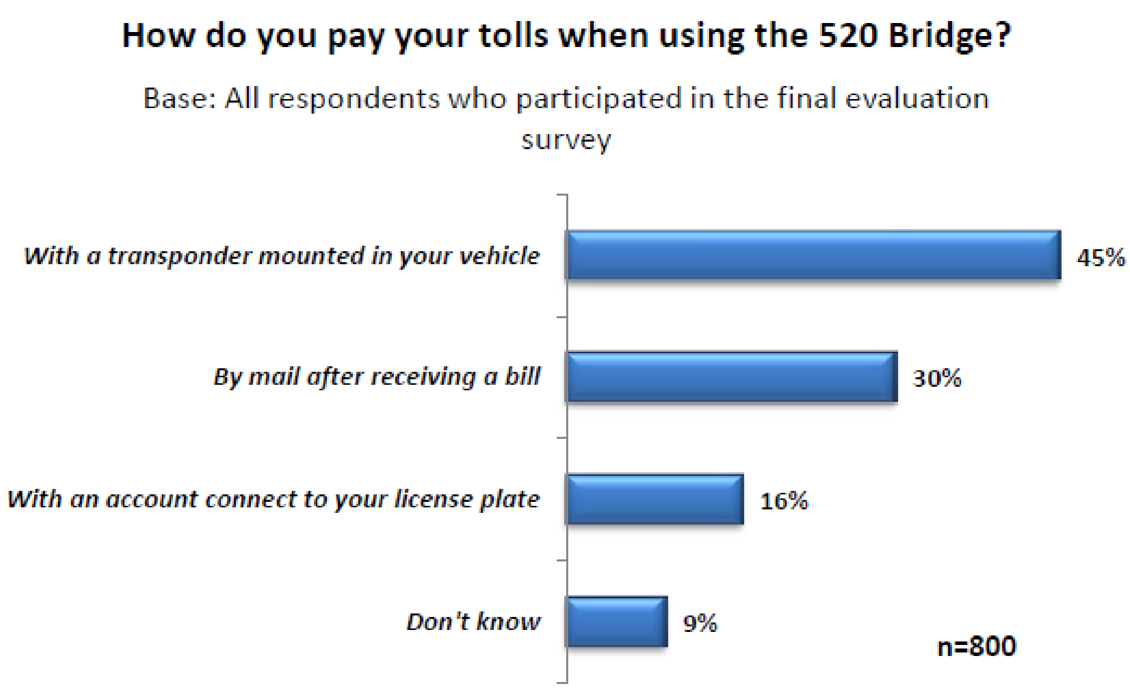
The *Good To Go!* account bills and toll charges can be paid using credit cards, debit cards, checks, and electronic checks. Cash payments are only accepted at customer service centers. If an individual fails to pay a toll within 15 days, a second bill is sent, which includes a $5 processing fee. Failure to pay a toll within 80 days results in an individual receiving a notice of civil penalty, which includes a $40 assessment for each unpaid toll transaction, plus all accumulated tolls and fees. Failure of a vehicle owner to pay or dispute a civil penalty within

20 days may result in the Department of Licensing placing a hold on the vehicle registration and the unpaid tolls, fees, and penalties may be sent to collections.

The WSDOT SR 520 Tolling Final Evaluation Survey Report asked respondents how they paid tolls incurred while crossing the SR 520 bridge. The findings from this question are presented in Figure H-1. While a majority paid using a *Good To Go!* transponder (45 percent) or a registered account connected to their license plate number (16 percent), 30 percent paid the toll by mail only after receiving a bill. Of these 30 percent of respondents who pay by mail, they are more likely to have an income under $75,000 (50 percent vs. 27 percent). Respondents age 35 or older are more likely to pay using a transponder (52 percent vs. 32 percent).

The Volpe household traveler survey showed a direct correlation of *Good To Go!* transponder ownership and use of Pay By Plate to respondents with higher incomes. While lower income respondents were less likely to purchase a *Good To Go!* transponder, most responded that this was due to infrequent use of SR 520 and not the expense or difficulty of opening and maintaining a *Good To Go!* account. The Pay By Plate payment method was utilized more by infrequent higher income users than by a substitute for *Good To Go!* transponders by lower income users.

More on toll payment methods can be found in Appendix B – Tolling Analysis.



Source: WSDOT SR 520 Tolling Final Evaluation Survey Report.

Figure H-1. WSDOT Survey Response for How SR 520 Users Pay for Tolls

The variety of options available to users of the SR 520 bridge indicates good faith effort toward convenience and for inclusiveness of all users. No account is necessary to use the bridge, although an account can be created in a variety of places in-person, by mail, online, or by phone. Additionally, numerous payment options are available. These options allow drivers without regular access to a computer or credit cards to use the SR 520 bridge.

Perceptions of Fairness

As noted previously, two surveys conducted during the course of the evaluation provide data for examining the perception of fairness of tolling on SR 520. The on-board transit survey of King County Metro Transit and Sound Transit riders on SR 520 were asked the extent to which they agreed that SR 520 tolls are unfair to people on limited incomes.

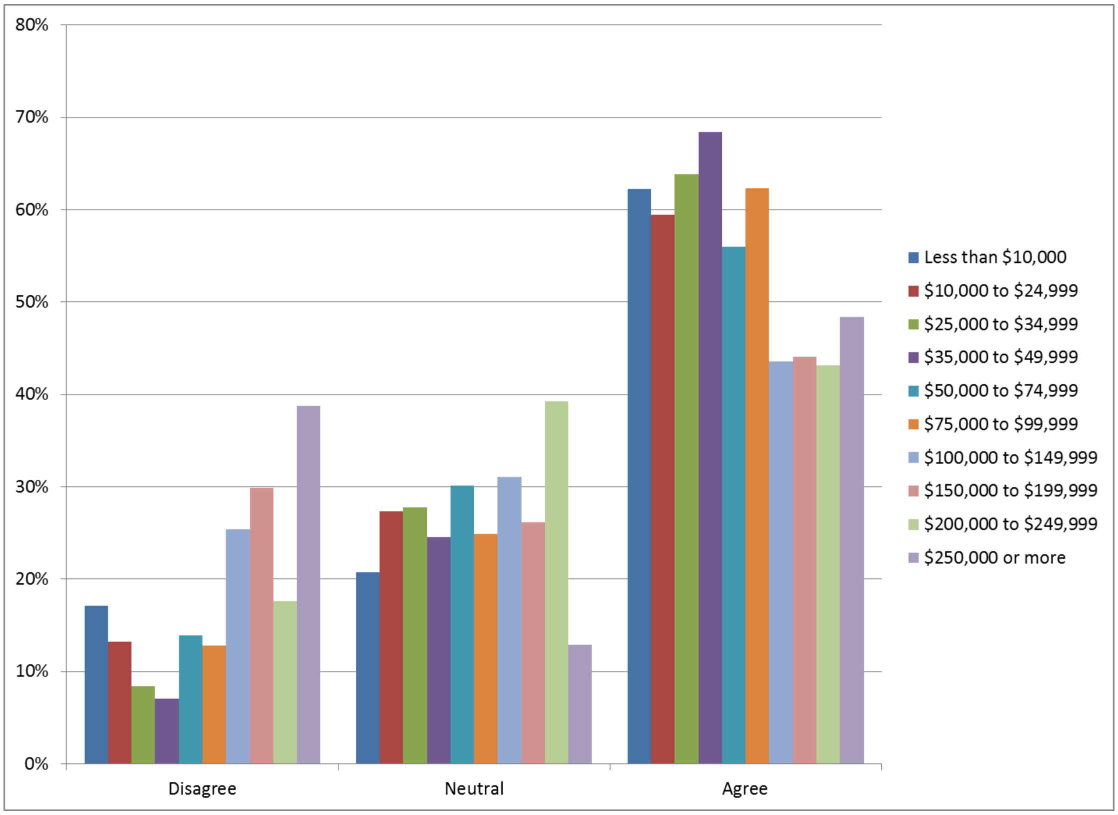
As shown in Table H-5, a majority of 55 percent somewhat agreed, agreed, or strongly agreed that tolls on SR 520 are unfair to people on limited incomes, a perception that was held by a majority riders of all income levels.

Table H-5. Tolls on SR 520 are Unfair to People on Limited Incomes

Response	Frequency	Percent	Aggregate
Strongly Disagree	77	4%	
Disagree	106	6%	17%
Somewhat Disagree	135	7%	
Neutral	540	28%	28%
Somewhat Agree	391	20%	
Agree	325	17%	55%
Strongly Agree	335	18%	

Source: CUTR based on data from King County Metro Transit

The responses from Table H-5 were cross-tabulated against reported incomes to see if there was any disparity in the responses. With regards to the attitudinal statement that tolls on SR 520 are unfair to people on limited incomes, Figure H-2 shows that respondents with lower incomes were more likely to agree with the statement that the tolls are unfair while respondents with higher incomes were less likely to agree.



Source: CUTR based on data from King County Metro Transit

Figure H-2. Percent who Agree that Tolls on SR 520 are Unfair to People on Limited Incomes (Cross-tabulation by Income)

The Volpe household travel survey also asked respondents their opinion toward tolling before (2010 survey) and after (2012 survey) tolls were implemented. On a scale where 1 is strongly disagree, 4 is neutral, and 7 is strongly agree, there was a change in the mean response of 5.0 before to 4.8 after of respondents who felt tolls are unfair to those with limited income.

H.3 Potential Equity Impacts by Geographic Areas

Analysis of geographic equity seeks to understand whether the impacts of the UPA, positive or negative, vary according to locations and, consequently, to the people living in those locations. Of course, the UPA itself was designed to improve travel in a specific geographic area—the LWC—and thus the question can be reframed to assess variation in impacts within parts of the corridor and elsewhere. Potential impacts by geographic areas were assessed by examining the geographic attributes of users of the UPA-funded King County Metro Transit bus service and the tolled SR 520 bridge.

The transit analysis presented in Appendix C described the transit enhancements that were part of the UPA deployment. The UPA funded the purchase of 44 new buses to add or enhance services for 90 additional one-way peak period trips; improvements to transit stops and park-and-ride lots; and new travel time signs. The transit enhancements were meant to provide a reliable commute and an alternative to paying a toll for travelers on the SR 520 corridor.

The geographic distribution of users of the SR 520 bridge was examined based on the town associated with the ZIP code of each toll transaction. Users with *Good To Go!* accounts provided their ZIP code at the time of registration. Tolling transactions were logged from 7945 unique ZIP codes in all 50 states and 5 U.S. territories, as well as 30 countries, including 695 ZIP codes for locations within Washington. Out-of-state toll transactions, not including those with unknown locations, represented only 2.7 percent of all trips for SR 520 bridge users.

Table H-6 shows the 15.5 months of SR 520 tolling transactions in both directions according to the town associated with the ZIP codes. The trips include transactions of all payment types, including *Good To Go!* pass, *Good To Go!* Pay By Plate, and Pay By Mail. Approximately 11.8 percent of these transactions have an unknown location; this is a result of lag time for ongoing processing of tolling information and this number will ultimately be lower for this time period.

Table H-6. Number and Percent of SR 520 Tolling Transactions by Town of ZIP Code, December 2011 – April 2013

Town	ZIP Code	Payment Type			Grand Total	Percent of Total
		Good To Go! Pass	*Good To Go!* Pay By Plate	Pay By Mail		
Redmond	98052	1,070,650	159,292	22,498	1,252,440	6.4%
Kirkland	98033	1,029,768	137,364	16,114	1,183,246	6.1%
Bellevue	98004	876,756	117,304	11,094	1,005,154	5.1%
Seattle	98103	718,589	94,091	17,641	830,321	4.3%
Seattle	98115	696,914	89,029	17,093	803,036	4.1%
Seattle	98112	551,790	68,654	8,305	628,749	3.2%
Kirkland	98034	518,335	80,752	17,443	616,530	3.2%
Seattle	98105	462,196	68,341	10,076	540,613	2.8%
Bellevue	98005	445,777	57,009	8,286	511,072	2.6%
Seattle	98102	406,121	50,652	6,693	463,466	2.4%
Sammamish	98074	369,543	55,491	10,342	435,376	2.2%
Seattle	98122	350,691	50,871	8,437	409,999	2.1%
Seattle	98109	340,784	50,836	8,409	400,029	2.0%
Redmond	98053	320,699	50,492	8,201	379,392	1.9%
Woodinville	98072	299,675	45,905	10,950	356,530	1.8%
Seattle	98117	293,044	39,081	12,998	345,123	1.8%
Bellevue	98008	262,366	35,997	8,003	306,366	1.6%
Seattle	98107	258,275	36,620	9,422	304,317	1.6%
Seattle	98119	255,530	36,896	7,596	300,022	1.5%
Seattle	98104	242,442	47,973	3,811	294,226	1.5%
Seattle	98125	243,373	37,671	11,269	292,313	1.5%
Seattle	98133	227,844	35,496	13,078	276,418	1.4%
Bellevue	98007	208,981	30,737	6,782	246,500	1.3%
Medina	98039	206,620	25,230	1,394	233,244	1.2%
Woodinville	98077	190,488	28,714	5,578	224,780	1.2%
Seattle	98199	173,176	27,610	8,607	209,393	1.1%
Seattle	98121	177,184	25,297	3,061	205,542	1.1%
All other Washington towns each with <1.0% of total		2,683,587	555,026	525,989	3,764,602	19.3%
Washington Total		**13,881,198**	**2,138,431**	**799,170**	**16,818,799**	**86.2%**
Grand Total		**13,982,322**	**2,420,305**	**3,117,824**	**19,520,451**	**100.0%**

Source: Battelle with data from WSDOT

Note: All listed towns are located in King County; 11.8 percent of reported total toll transactions have an unknown location, including 0.7 percent from Washington with an unknown ZIP code.

This presentation of tolling transactions by location show that drivers from a diverse set of places use the SR 520 bridge. However, as shown in the congestion analysis in Appendix A, there was a change in VMT in the LWC: a total decrease of over 20 percent on SR 520 during peak periods and a total increase of 4.6 percent on I-90 during peak periods. As a result, mean travel times on SR 520 were reduced in both the morning (approximately 2 minutes in each direction) and afternoon peak periods (about 2 minutes in the eastbound direction and about 8 minutes in the westbound direction). Mean travel times on I-90 increased in the morning peak period (about 1 minute in each direction) and remained about the same in the afternoon peak period in the eastbound direction and increased in the westbound direction (about 3 minutes). Other travel measures are presented in more detail in Appendix A. These findings indicate that drivers on alternate routes for the SR 520 bridge, particularly I-90, were impacted in a way that increased geographic inequity.

Similar findings on geographic equity were shown in the Volpe household travel survey. Details about the survey are presented in the congestion analysis in Appendix A. Respondents recorded their satisfaction with three elements of every trip across Lake Washington on a 7-point scale. In the Wave 1 survey from the pre-deployment period, differences in responses between SR 520, I-90, and SR 522 were minor, though statistically significant. Responses on the Wave 2 survey in the post-deployment period differed more, with drivers on SR 520 averaging about one point more satisfaction on all three elements than drivers on I-90. Respondents who had driven on I-90 in the pre-deployment period remained less satisfied than SR 520 drivers in the pre-deployment period, regardless of whether they chose SR 520 or I-90 in the post-deployment period. These findings also suggest that tolling increased geographic inequity due to worsened congestion on I-90.

H.4 Potential Air Quality Impacts by Geographic Area and Socio-Economic Groups

The environmental analysis reported in Appendix G showed emissions reductions of over 30 percent for all pollutants on SR 520 in the year following the beginning of tolling operations. However, when considering the combined effects of other corridors in the Lake Washington Corridor: SR 520, I-90, I-5, and I-405, emissions were reduced between 2.5 and 5.8 percent. To determine the potential variation in air quality impacts, vehicle miles traveled from the congestion analysis (Appendix A) were examined by road segment. In this analysis, VMT serves as a proxy for air quality impacts since emissions are a function of miles traveled. Speed is also a key factor, but emissions analysis using both VMT and speed at the segment level was beyond the scope of the analysis.

Table H-7 shows the corridors and segments analyzed in the congestion analysis (Appendix A) and environmental analysis (Appendix G). VMT is a primary driver for emissions and energy consumption, thus changes in VMT provides additional perspective to changes in emissions and fuel consumption. VMT is given for the pre-deployment period (2010) and post-deployment period (2012) from 6:00 a.m. to 7:00 p.m., which includes the morning peak, mid-day, and evening peak periods. The percent change in VMT by road segment indicates a major reduction on SR 520, minor reduction on I-5, and increases on I-90 and I-405. These changes in VMT are reflected in proportional changes in emissions and fuel use.

Table H-7. VMT, Emission, and Fuel Consumption Changes for select LWCs

Corridor			VMT	VOC (lbs)	NOx (lbs)	$PM_{2.5}$ (lbs)	CO (tons)	CO_{2e} (tons)	Fuel Use (gal)
SR 520 (I-5 to I-405)	Deployment Period	Pre	510,557	202.4	1,788	59.2	6,293	277.8	28,951
		Post	362,919	125.6	1,252	37.4	4,364	188.0	19,623
	Net Change	Amount	-147,638	-76.8	-536	-21.9	-1,929	-90	-9,328
		Percent	-28.9%	-37.9%	-30.0%	-36.9%	-30.6%	-32.3%	-32.2%
I-90 (I-5 to I-405)	Deployment Period	Pre	772,846	264	2,667	78	9,271	399	41,633
		Post	855,365	296	2,957	88	10,263	444	46,320
	Net Change	Amount	82,519	33	290	9	993	45	4,686
		Percent	10.7%	12.4%	10.9%	12.0%	10.7%	11.3%	11.3%
I-5 (SR 520 to I-90)	Deployment Period	Pre	525,566	200	1,799	200	6,408	278	28,968
		Post	497,573	196	1,720	196	6,063	268	27,900
	Net Change	Amount	-27,993	-4	-79	-4	-345	-10	-1,068
		Percent	-5.3%	-2.0%	-4.4%	-2.0%	-5.4%	-3.7%	-3.7%
I-405 (SR 520 to I-90)	Deployment Period	Pre	493,471	179	1,713	52.88	3.0	260	27,135
		Post	524,942	193	1,837	56.17	3.2	279	29,118
	Net Change	Amount	31,472	13.4	124	3.29	0.2	19	1,983
		Percent	6.4%	7.5%	7.2%	6.2%	6.8%	7.3%	7.3%

Source: Battelle

Census data on socio-demographic characteristics of communities adjacent to the corridor were gathered to assess the impact of VMT changes, and hence air quality changes, on the population. Specifically, did minority or lower income populations experience different air quality effects than other populations of the corridor? The road segments mapped to ZIP codes are shown in Table H-8.

Table H-8. ZIP Codes for Road Segments in Lake the LWC

Corridor	ZIP Code*
SR 520 (I-5 to I-405)	**98004**
	98033
	98039
	98102
	98112
I-90 (I-5 to I-405)	**98004**
	98005
	98006
	98040
	98144
I-5 (SR 520 to I-90)	98101
	98102
	98104
	98109
	98122
	98134
I-405 (SR 520 to I-90)	**98004**
	98005

Source: Battelle

*ZIP Codes listed in bold are adjacent to more than one corridor

Table H-9 presents age, race and ethnicity, and income data for the ZIP code areas. Comparing the net emissions change for each ZIP code area based on the corridor (or corridors) that is adjacent to or bisects that area, any improvements or adverse air quality impacts appear to be distributed across a variety of socio-economic groups, such that no individual group is unfairly impacted.

Table H-9. Socio-economic Characteristics of Population by ZIP Codes Adjacent to the LWC

Socio-Economic Characteristics	ZIP Codes														
	King County	98004	98005	98006	98033	98039	98040	98101	98102	98104	98109	98112	98122	98134	98144
Total Population	1,931,249	27,946	17,714	36,364	34,338	2971	22,699	10,238	20,756	13,095	20,715	21,077	31,454	644	26,881
Male %	49.8	49.7	50.4	49.5	48.9	49.4	48.7	55.5	53.6	61.4	50.4	48.9	52.2	66.9	50.5
Female %	50.2	50.3	49.6	50.5	51.1	50.6	51.3	44.5	46.4	38.6	49.6	51.1	47.8	33.1	49.5
Age															
Under 20 years %	23.9	10.6	21.7	27.3	21.8	31.0	26.4	4.2	6.4	8.2	8.6	18.1	16.5	5.2	19.6
20 – 44 years %	38.2	19.9	38.2	26.7	37.6	17.7	22.0	49.4	65.8	48.0	60.2	41.5	56.7	49.4	42.0
45 – 64 years %	26.9	12.3	26.0	32.8	29.2	32.8	32.0	27.5	20.7	27.2	20.8	27.7	19.5	38.2	25.5
65 years and over %	10.9	7.0	14.0	11.6	11.4	16.1	19.4	18.8	6.5	16.5	10.4	12.8	7.4	7.2	12.8
Median age (years)	37.1	37.7	38.1	42.4	39.3	45.5	46	42.1	33.0	40.8	34.2	39.4	32.1	43.1	38.1
Race															
White %	68.7	71.2	64.7	62.4	82.0	83.4	77.9	72.1	82.5	47.8	81.2	83.7	63.4	55.4	43.8
Black or African American %	6.2	2.0	2.4	1.6	1.3	0.3	1.3	7.5	2.6	18.7	4.1	5.5	16.9	15.5	18.2
American Indian and Alaska Native %	0.8	0.3	0.3	0.3	0.4	0.2	0.2	1.6	0.6	2.3	0.7	0.3	0.9	5.3	0.9
Asian %	14.2	21.2	25.8	30.1	10.5	11.7	15.9	12.4	8.1	24.2	8.2	5.5	9.6	16.0	24.5
Native Hawaiian and Other Pacific Islander %	0.8	0.1	0.1	0.2	0.2	0.1	0.1	0.3	0.2	0.3	0.3	0.1	0.4	0.6	0.4
Hispanic or Latino															
Hispanic or Latino %	8.9	4.3	6.8	3.4	4.9	2.6	2.8	6.0	5.8	7.2	5.1	3.7	7.5	6.5	11.4
Not Hispanic or Latino %	91.1	95.7	93.2	96.6	95.1	97.4	97.2	94.0	94.2	92.8	94.9	96.3	92.5	93.5	88.6

Table H-9. Socio-economic Characteristics of Population by ZIP Codes Adjacent to the LWC (Continued)

Socio-Economic Characteristics	ZIP Codes														
	King County	98004	98005	98006	98033	98039	98040	98101	98102	98104	98109	98112	98122	98134	98144
Employment Status															
Population 16 years and older	1,546,184	22,299	14,299	28,770	27,916	2184	17,898	9316	20,136	11,453	18,813	18.440	27,892	815	21,903
In civilian labor force %	70.5	65.6	69.1	66.3	74.1	53.6	60.2	64.3	85.2	51.1	81.7	73.1	74.3	39.3	70.2
Employed %	65.5	61.5	65	62.2	69.9	51.9	57.6	60.0	80.2	45.5	77.3	69.1	69.7	35.0	65.4
Unemployed %	4.9	4.1	4.2	4.1	4.2	1.6	2.5	4.3	5.0	5.6	4.4	4.0	4.6	4.3	4.7
Household Income and Benefits*															
Total households	790,070	12,875	7610	13,245	14,985	1037	9253	6923	13,576	6634	11,882	10,327	52,568	262	11,620
Less than $25,000 %	16.1	13.0	11.2	9.0	8.8	6.6	7.7	38.4	16.8	52.3	14.1	12.9	28.7	11.8	25.8
$25,000 to $49,999 %	19.3	12.9	19.3	10.3	12.5	8.3	13.2	21.2	26.4	18.7	23.8	17.3	23.2	69.1	21.4
$50,000 to $99,999 %	31.0	31.4	28.5	25.8	25.2	13.6	21.7	18.5	32.6	16.6	31.3	24.8	25.0	19.1	28.4
$100,000 or more %	33.6	42.7	41.0	54.8	53.5	71.5	57.5	22.0	24.2	12.3	30.8	45.1	23.1	0.0	24.5
Median household income (dollars)	70,567	84,413	80,320	107,007	105,065	176,354	123,328	35,749	55,311	22,648	64,801	89,054	47,405	40,458	52,128
Adjacent Corridor(s)	All	SR 520, I-90, I-405	I-90, I-405	I-90	SR 520	SR 520	I-90	I-5	SR 520, I-5	I-5	I-5	SR 520	I-5	I-5	I-90
Net Emissions Change	↓	↓	↑	↑	↓	↓	↑	↓	↓	↓	↓	↓	↓	↓	↑

*In 2011 inflation-adjusted dollars

Source: Battelle based on 2007 – 2011 American Community Survey 5-Year Estimates

H.5 Impact of Planned Re-investment of SR 520 Toll Revenues

A key driver of adding tolls to the existing SR 520 bridge was to generate revenue for a replacement bridge. The existing SR 520 bridge is at capacity and has reached the end of its useful structural life. However, revenue was lacking to replace the current bridge. Tolling the existing SR 520 bridge was a way to generate revenue from users who would benefit from a new, improved SR 520 bridge. Stakeholders and decision-makers in the region successfully implemented tolling on the existing SR 520 bridge through the understanding that the collection of revenue on the existing bridge would serve as a down payment for the construction of a new SR 520 bridge.

All toll revenues from the SR 520 bridge (after paying for operations and maintenance of the toll system) are being used to pay for a replacement bridge. The new SR 520 bridge will benefit all transportation users of SR 520 with features that are likely to improve safety and mobility. This bridge will benefit drivers and transit users, as well as pedestrians and bicyclists who cannot use the existing bridge, but will be able to use the new bridge.

Table H-10 shows the tolling revenues generated from the SR 520 bridge over the course of the one-year post-deployment period by quarter. In total, the SR 520 tolls generated $54,879,495 in 2012 during the post-deployment period.

Table H-10. Tolling Revenues by Quarter for 2012

Quarter	Toll Revenue
January-March	$11,648,744
April-June	$14,173,251
July-September	$13,867,862
October-December	$15,180,548
Total	**$54,870,405**

Source: Texas A&M Transportation Institute, based on data from the Washington Division of Accounting and Services, July 2013.

H.6 Summary of Equity Analysis

Table H-11 presents a summary of the equity analysis across the four questions. The impacts of tolling showed mixed results. Drivers incurred higher costs by either paying tolls on SR 520 (although also experiencing travel time improvements), experiencing increased travel times on I-90, and/or making longer trips by switching to I-90 from SR 520. However, transit users tended to benefit from the implementation of tolling with improved transit travel times and on-time transit performance. No disparity in environmental impacts or benefits among any particular socioeconomic group was identified. The reinvestment of revenues from tolling on SR 520 shows a direct benefit since all toll revenues are being used to pay for a replacement bridge that will benefit not only current transportation users, but also pedestrians and bicyclists who cannot utilize the current bridge.

Table H-11. Summary of Equity Impacts Across Hypotheses

Hypotheses/Questions	Result	Evidence
What are the direct social effects (tolls paid, travel times, adaptation costs) for various transportation system user groups from tolling the SR 520 bridge, transit, and other UPA strategies?	Mixed	Tolling caused shifts in traffic from SR 520 to I-90. Travel times decreased on SR 520 and increased slightly on I-90. Lower income groups eliminated a greater proportion of trips across Lake Washington than other income groups. Transit users experienced higher quality trips.
What is the spatial distribution of aggregate out-of-pocket and inconvenience costs, and travel time and mobility benefits?	Mixed results	Drivers on both SR 520 and I-90 experienced higher costs by the implementation of tolls. Drivers on SR 520 began paying $1.60-$3.59 per trip, although they experienced improved travel conditions. Drivers on I-90 experienced slightly increased travel times. Transit users on SR 520 experienced improved and faster service.
Are there any differential environmental impacts on certain socio-economic groups?	None identified	An examination of environmental impacts in each corridor by ZIP code area shows a distribution of positive and negative effects across all socio-economic groups, with no individual socio-economic group unfairly benefiting or adversely impacted.
How does reinvestment of revenues from tolling SR 520 impact various transportation system users?	Direct benefit	All toll revenues from the SR 520 bridge (after paying for operations and maintenance of the toll system) are being used to pay for a replacement bridge that will benefit all transportation users of SR 520, including drivers and transit users, as well as pedestrians and bicyclists who will be able to use the new bridge.

Source: Battelle

Appendix I. Non-Technical Success Factors Analysis

This analysis examines the non-technical success factors associated with the Seattle/LWC UPA. These non-technical success factors include outreach activities, media coverage, political and community support, and the institutional arrangements used to manage and guide implementation of the Seattle/LWC UPA projects. Information on the non-technical success factors is of benefit to the U.S. DOT, state and local departments of transportation, MPOs, and local communities interested in planning, developing, deploying, implementing and operating and maintaining similar projects.

Table I-1 presents the questions, measures of effectiveness and data sources associated with the analysis of the non-technical success factors. The first question focuses on understanding how a wide range of variables influence the success of the Seattle/LWC UPA project deployments. The variables are grouped into five major categories: (1) people, (2) process, (3) structures, (4) media, and (5) competencies. The second question guiding this analysis focuses on examining public support for the Seattle/LWC UPA projects and whether the public views the UPA projects as effective and appropriate ways to reduce congestion.

Table I-1. Non-Technical Success Factors Analysis Questions

Questions
• What role did factors related to these five areas play in the success of the deployment? 1. People (sponsors, champions, policy entrepreneurs, neutral conveners) 2. Process (forums [including stakeholder outreach], meetings, alignment of policy ideas with favorable politics and agreement on nature of the problem) 3. Structures (networks, connections and partnerships, concentration of power and decision-making authority, conflict-management mechanisms, communications strategies, supportive rules and procedures) 4. Media (media coverage, public education) 5. Competencies (cutting across the preceding areas: persuasion, getting grants, conducting research, technical/technological competencies; ability to be policy entrepreneurs; knowing how to use markets)
• Does the public support the UPA strategies as effective and appropriate ways to reduce congestion?

Source: Battelle.

This appendix is divided into seven sections: the data sources used in the analysis are described in Section I.1. Information on the multi-agency organizational structure of the Seattle/LWC UPA is presented in Section I.2 followed by a discussion of the communications and outreach activities in Section I.3 and a content analysis of news media coverage of the Seattle/LWC UPA in Section I.4. The major themes from the interviews and workshops with the local partners are presented in Section I.5 and results from questions measuring public perception of the Seattle/LWC UPA are summarized in Section I.6. In conclusion, a summary of the Seattle/LWC UPA non-technical success factors is presented in Section I.7.

I.1 Data Sources

A variety of data sources was used in the non-technical success factors analysis. First, two rounds of interviews and workshops were conducted by the national evaluation team with representatives of the local UPA partners. Second, news media coverage of the Seattle/LWC UPA projects collected by the national evaluation team were reviewed and analyzed. Third, Seattle/LWC UPA partners shared with the national evaluation team formal partnership documents and outreach materials and activities for examination and analysis. Finally, data on public opinion about the UPA projects came from several surveys – the Volpe household travel survey, the WSDOT-sponsored SR 520 Evaluation Surveys, and the King County Metro Transit SR 520 On-Board Intercept Survey.

I.2 Seattle/LWC UPA Multi-Agency Organizational Structure

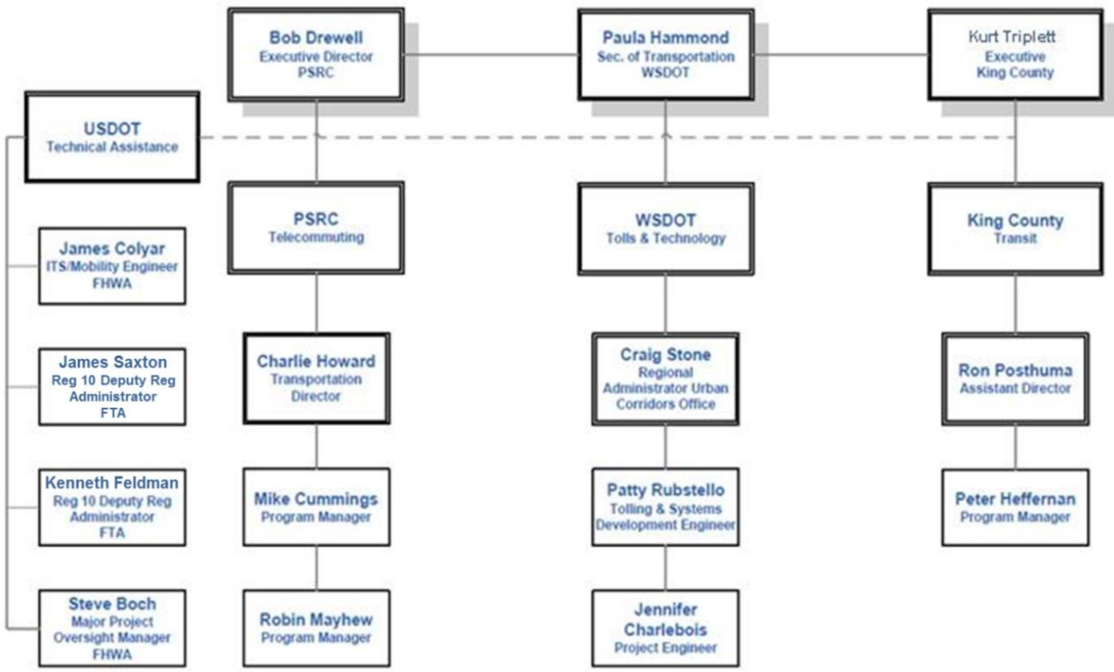
The Seattle/LWC local UPA partners consist of the Washington State Department of Transportation (WSDOT), Puget Sound Regional Council (PSRC), and King County, Washington. These partners are coordinating planning, implementation and/or operation of various UPA projects with a number of other local agencies such as the City of Seattle and Sound Transit.

WSDOT is responsible for the overall project schedule and financial management, coordinating project activities and reporting to federal agencies. WSDOT is leading the SR 520 bridge variable tolling, real-time travel time signage, and SR 520/I-90 active traffic management (ATM) projects.

The PSRC is the metropolitan planning organization for the Seattle urban area including King, Pierce, Snohomish and Kitsap Counties. PSRC is leading the telecommuting/travel demand management (TDM) projects which are part of the UPA but are being implemented without federal UPA funds.

King County operates the Metro Transit service, which comprises the majority of the transit service in the SR 520 corridor. King County is leading the Seattle/LWC UPA bus transit projects, consisting of enhanced bus service along SR 520, real-time information signs at transit stations, and expansion of two existing park-and-ride facilities.

Figure I-1 presents the Seattle/LWC UPA team. The three Seattle/LWC UPA local partner agencies (WSDOT, PSRC and King County) coordinate their UPA activities with U.S. DOT headquarters in Washington, D.C., the Federal Highway Administration (FHWA) Washington State Division, and with the Federal Transit Administration (FTA) Region 10 office in Seattle.



Source: "UPA Program Management Plan," WSDOT, April 2008. Modified by Battelle.

Figure I-1. Seattle/LWC UPA Team

I.3 Public Information and Outreach Activities

The following section describes the outreach approach and activities employed by the local partners as evidenced through the outreach materials and activities shared by the local partners with the national evaluation team and through the interviews and workshops with local partners conducted by the national evaluation team. The section concludes with reflections from the local partners on both the challenges and lessons learned associated with implementing a communications and outreach plan for the Seattle/LWC UPA.

Local Partner Roles and Responsibilities. The Seattle/LWC UPA outreach and communications plan built upon efforts already in place by each of the three main Seattle/LWC UPA partner agencies (WSDOT, King County, PSRC) to communicate the multiple strategies used in the region to manage congestion that includes tolling, technology, transit, and TDM (i.e., 4Ts). Specific agency roles included:

- WSDOT managed overall outreach and communications for the technology and tolling components on the SR 520 bridge and congestion management in the corridor and the region.
- King County marketed for transit in the corridor and assisted PSRC in the outreach to TDM organizations.
- PSRC coordinated with TDM program managers to help their customers learn about the changes coming to the corridor around tolling and transit enhancements.

Communications and Outreach throughout the Project Lifecycle. It has been known for well over a decade that the SR 520 bridge needs to be replaced, therefore, communications and outreach regarding the SR 520 bridge had been occurring long before the UPA project and funding. Communications and outreach related to the UPA funding was about the early tolling of the existing facility to help pay for the new bridge. One of the biggest outreach efforts occurred early on in 2008 when the chair of the Transportation Commission, the Secretary of Transportation, and the director of the Puget Sound Regional Council engaged with key stakeholders of the SR 520 corridor through public meetings and focus groups to garner support and receive feedback on the proposed implementation of early tolling. This outreach laid the groundwork for public understanding and acceptance of early tolling and paved the way for the marketing and advertising phase to distribute and install transponders and inform people about transportation alternatives.

Interviewees all expressed satisfaction with the outreach and communications efforts and felt they had been successful. As one interviewee stated,

> "Having the outreach prior to implementation of the tolling was critical to getting public acceptance that tolling was needed for replacement. There was a lot of information out prior to even the UPA program coming to existence that the 520 bridge needed to be replaced. So the state had done a good job at laying out the need for the project and it came down to we need tolls to help pay for that. I think that was really critical to getting public perception that this was needed…bringing that coordination together was critical to the success of the project."

Local partners also undertook strategic partnerships with local celebrities like Bill Nye the Science Guy[1] and organizations like the Seattle Seahawks to assist in their advertising and messaging efforts.

Key Messages. The primary focus of all communications and outreach was on the congestion management strategies being employed and not to create a separate UPA brand. The goal being to focus on the outcome of effectively managed congestion, enhanced safety, and providing more options in the corridor like carpools, vanpools, bicycles, and telework.

Key Audiences.

- Corridor commuters (all modes)
- Corridor employers
- Affected low-income and minority populations
- Corridor discretionary drivers
- General public
- Policy makers

[1] Bill Nye was the star of the educational television program, *Bill Nye the Science Guy*, which aired in the mid-1990s. The show was created and produced out of Seattle.

Outreach Activities. The Seattle/LWC UPA partners deployed their messaging using different methods that targeted specific audiences through a variety of venues. The overall strategy was to incorporate information about at least two of the 4Ts in all communications, and a specific outreach and communications plan was created for each of the 4Ts. The various methods used by the Seattle/LWC UPA partners are listed below, including some examples:

> "It was a whole bunch of technical analysis that was put into a very consumable format for the public." – local stakeholder interviewee

In-person Activities

- Public forums and focus groups conducted by the chair of the Transportation Commission, the Secretary of Transportation, and the director of the PSRC – this outreach was requested by the Governor to inform the legislature in their decision to allow early tolling on the SR 520 bridge.
- Community outreach through grass roots organizations, a speaker's bureau, employer networks, fairs and festivals, and local governments and agencies
- Customer service centers: walk-up centers in Seattle's University District, Gig Harbor, downtown Bellevue and one online center, as well as mobile customer service centers
- Outreach and information materials designed to equip grass roots TDM program managers, such as sample messages and customizable outreach materials.
- Outreach targeted to low-income and minority populations, including information translated into six languages (Chinese, Korean, Japanese, Russian, Spanish and Vietnamese.)

Print and Online Communications

- Websites (WSDOT, *Good To Go!*)
- Social media (Facebook, Twitter, WSDOT blog)
- Press releases
- Materials including brochures, information sheets, presentation slides, welcome kits, postcards, letters, displays, giveaway promotional items, point of purchase displays
- Paid advertising on radio, newspaper, billboards, transit boards, Web sites and television.
- Communications specific to transit users:
    - Bus stop rider alerts, coach posters, facility signs and customer brochures.
    - Distribution of timetables on buses, in timetable racks at King County Metro Transit's two customer service offices, public buildings, and locations including retail partners and large employers.
    - Signs and kiosks with schedules at major bus stops. Updated regional maps of King County Metro Transit's route network posted at major stops and online.
    - Special rider alert brochure that includes summaries of changes in schedules and routing.

Figure I-2 illustrates the customer service home page of the *Good To Go!* pass. It is designed with the *Good To Go!* customer in mind, providing users access to manage their existing accounts and the ability to open a new account.

Source: Washington State Department of Transportation.

Figure I-2. Home Page of *Good To Go!* Website

Figure I-3 is an example of an advertisement for the *Good To Go!* pass appearing as a wraparound on a bus. Pictured holding the *Good To Go!* pass is local celebrity, Bill Nye The Science Guy.

Source: Washington State Department of Transportation.

Figure I-3. Example of Tolling Advertisement on Bus

Figure I-4 is an example of an advertisement for the *Good To Go!* pass prior to the opening of tolling. It informs potential customers that their tolls will help pay for the new bridge. This advertisement shows the original tolling opening date of spring 2011.

Source: Washington State Department of Transportation.

Figure I-4. Example of Tolling Advertisement

Challenges.

> "And everything was kind of building and building and building and then we were not ready to go live. So then there was a large delay and I think we lost some public credibility with that. So, definitely, make sure you're ready to go as you start building up the public's expectation. I think we did a good job of kind of educating the public as to what was going to happen, but they expected it to happen and it didn't."

– local partner interviewee

The outreach and communications activities of the Seattle/LWC UPA were not without its challenges. As the above quote indicates, due to the delays to the start date of tolling on SR 520, the public ended up experiencing a “hurry up and wait” as they rushed to get their transponders (crashing the *Good To Go!* customer service system) only to then wait almost a year for tolling to begin. Interviewees reported that it was not ideal to the success of their outreach to have the delays, however, it was necessary for the local partners to feel confident that the tolling would work once operational. They did not want to deal with the media storm if the toll facility opened and failed.

Conclusion. The Seattle/LWC UPA partner agencies, particularly WSDOT, created a deliberate, proactive approach to communicating the purpose and impacts of the Seattle/LWC UPA to key stakeholders over the course of the planning, development, and deployment of the Seattle/LWC UPA projects. Their activities focused on education, transparency, and public input to create an informed public that understood both the reason behind early tolling as well as the myriad options travelers had in crossing the tolled bridge facility. Early outreach efforts by key leaders from WSDOT, Transportation Commission, and PSRC paved the way for public trust and understanding of early tolling as well as garnered legislative support for the project.

I.4 News Media Content Analysis

The following section describes the content analysis for the period that spans planning through post-deployment of the Seattle/LWC UPA projects in order to understand the nature and occurrences of media coverage and its potential role in both providing information as well as shaping public opinion.

Methods. Media coverage was tracked from the first occurrence in 2010 through December 30, 2012, which was one year after tolling on the SR 520 bridge went live. News media coverage was gathered by WSDOT and the national evaluation team using LexisNexis, Proquest Newspapers, and Google News. From these sources, 2,379 individual pieces of news media coverage were found for the time period. The national evaluation team conducted a descriptive analysis for all news media coverage using four categories:

- Mainstream: Includes coverage from the major neighborhood, local, regional, national, and international news media outlets. (Note: Given the large amount of neighborhood media coverage, in some instances the analysis data from neighborhood media publications are presented separate from the rest of the mainstream media.)
- Blogs: Includes coverage created and/or disseminated by private entities, including local organizations and individuals.
- Op-Ed: Includes coverage in mainstream newspaper outlets from the Opinion and Editorial sections. Authors may include editorial staff from the newspaper or guest writers who are members of the readership community.
- Industry Publications: Includes coverage from national, non-peer reviewed publications from the transportation field.

Due to resource constraints, in-depth content analysis was limited to a 5 percent stratified simple random sample of English language print articles. Broadcasts were not included in the in-depth analysis due to variation in the quality of transcripts available. This resulted in a sampling frame of 1,676 instances of news media coverage.

The news media sample was stratified twice, first by media type and then by year. Within each subsample of media type, a proportionate amount of media was chosen from each year of the study to be represented in the sample. A random number generator was used to collect the stratified sample. Table I-2 shows distribution by media type and year. In the case of industry publications where the sample proportion was less than one media item, the number was rounded up, to account for at least one representation of that media type in every year available. In the case of Op-Ed articles, since there were only 17 total occurrences during the evaluation period, and Op-Ed pieces are intended to influence readers, the national evaluation team included all Op-Ed pieces in its content analysis.

Table I-2. 5 Percent Stratified Sample of Seattle/LWC UPA News Media by Media Type & Year

		Total # by Year			Total % by Year				5% Sample # by Year		
Media Category	Total #	2010	2011	2012	2010	2011	2012	5% Sample #	2010	2011	2012
Blog	237	52	149	36	22%	63%	15%	12	3	7	2
Industry	97	23	57	17	24%	59%	18%	5	1	3	1
Mainstream	859	72	536	251	8%	62%	29%	43	4	27	13
Neighborhood	483	45	311	127	9%	64%	26%	24	2	16	6
Total	**1676**	**192**	**1053**	**431**				**84**	**10**	**53**	**22**

Source: University of Minnesota.

The content analysis of the sampled news media coverage involved first analyzing the news content by organizing the articles into positive, negative, balanced, and neutral categories. By categorizing the articles, an assessment was made to determine whether the media was shaping opinion in a certain attitudinal direction (the assumption being that news media both informs and influences its readership). A definition of each category is as follows:

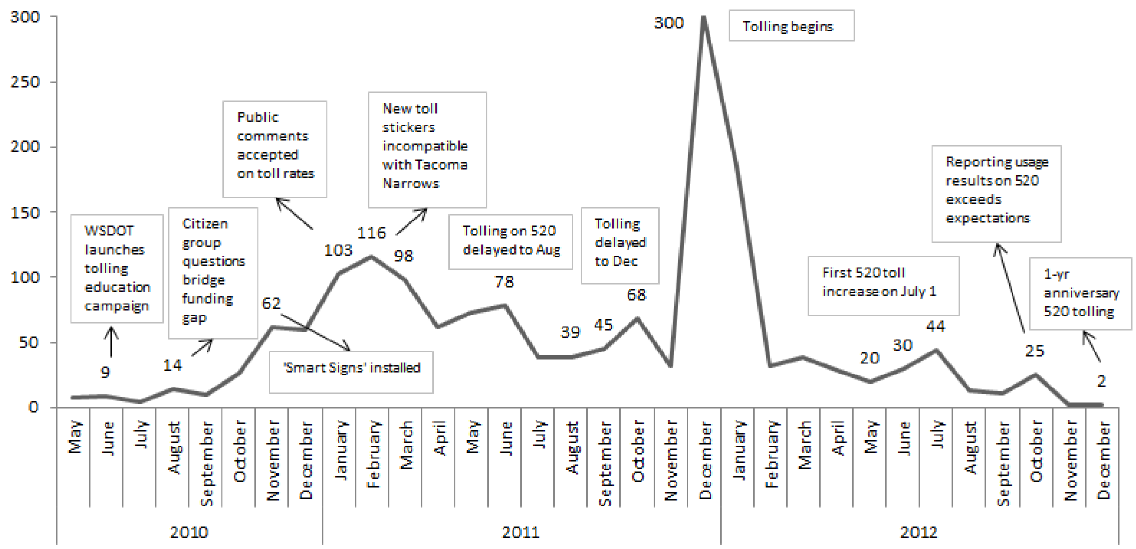
- Positive: The coverage presents an overwhelmingly positive case for the Seattle/LWC UPA project(s), typically giving detailed information about the benefits of the project. Sources and quotations come from only a positive perspective.
- Negative: The coverage presents an overwhelmingly negative case for the Seattle/LWC UPA project(s), typically giving detailed information about the risks or undesired outcomes of the project. Sources and quotations come from a negative perspective, or are put into a negative context.
- Balanced: The coverage presents a balanced story of both the potential benefits and risks or undesired outcomes of the Seattle/LWC UPA project(s). Sources and quotations may come from positive and negative perspectives and the author does not give a final verdict on whether the project is a net positive or negative.
- Neutral: Article presents information simply to inform the reading audience of some phenomenon or event without a particular viewpoint.

Next, the major themes and categories of ideas that arose from the topics in the news media coverage were identified by reading each sampled media item and coding for common themes using NVivo software.[2]

Findings.

Most media coverage came from local print or television sources, including major publications like The Seattle Times (176 pieces) or neighborhood publications like the Bellevue Reporter (72 pieces), as well as local television stations like KOMO news (96) and King TV (95). Over 200 blog posts were tracked during the evaluation period, coming from both blogs managed and written by individuals or by larger news organizations.

Figure I-5 shows the distribution of media coverage over time by tracking the number of media coverage by month. The greatest peak in coverage after tolling came in July 2012 when the toll rates were increased for the first time on the SR 520 bridge. Other peaks in coverage came in the months leading up to the launch of tolling on the SR 520 as coverage reported on and reacted to the delays in the start of tolling.

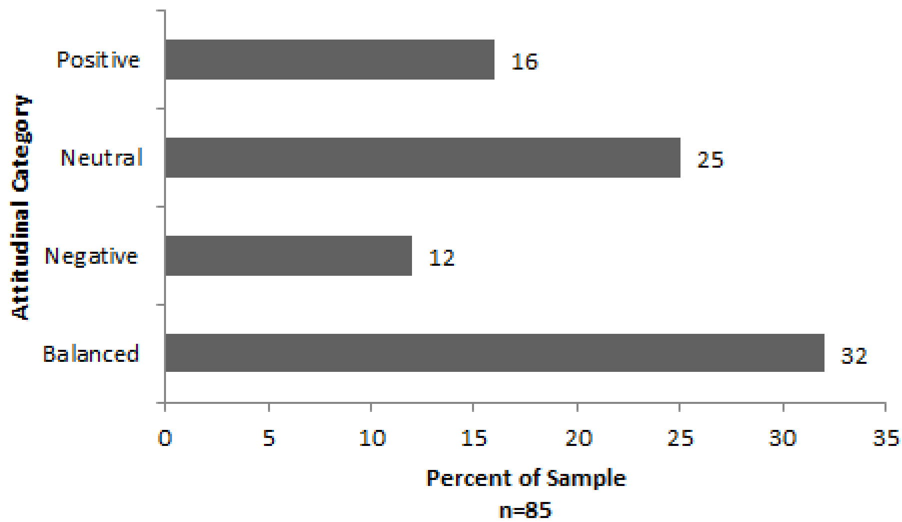


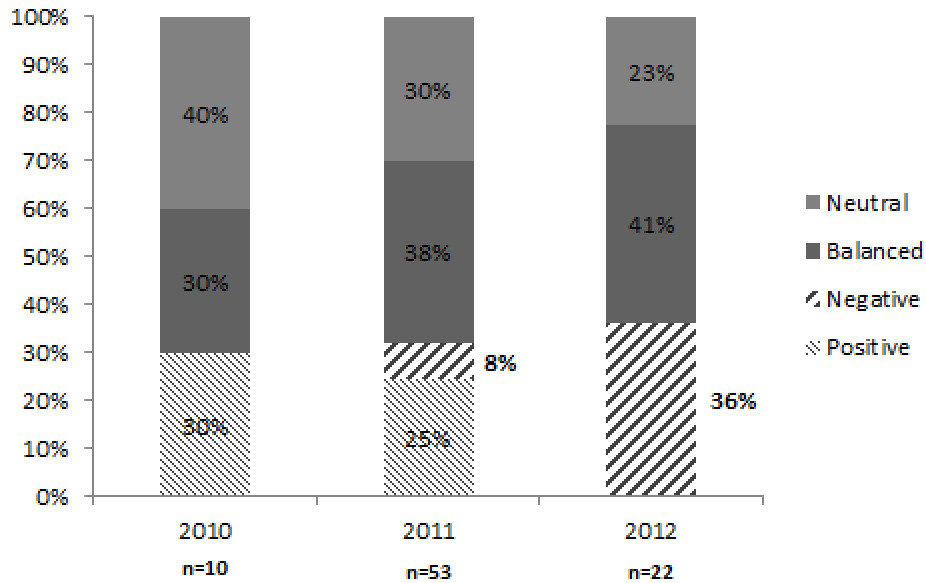
Source: University of Minnesota.

Figure I-5. Total Number Media Coverage by Month (2010-Dec 2012) and Events

[2] NVivo 10, a computer assisted qualitative data analysis software (CAQDAS), was used to conduct a descriptive coding analysis of all news media coverage and an in-depth content analysis of key themes of the news media coverage sample.

Figure I-6 displays the distribution of the 5 percent sample of media coverage by attitudinal direction. Of the 85 pieces of media examined, 12 percent was negative, 16 percent was positive, with 32 percent balanced, and 25 percent neutral.





Source: University of Minnesota.

Figure I-6. Percent Sample Media Coverage by Attitudinal Category

Prior to launching the Seattle/LWC UPA projects, the majority of the sampled news media was neutral or balanced, and there were more positive stories written on the Seattle/LWC UPA projects than negative stories prior to the tolling deployment. The positive articles were not necessarily ringing endorsements for tolling, but rather framed tolling as an unavoidable means for paying for transportation infrastructure. Positive articles often highlighted other features, like the bike/pedestrian lane on the new bridge. However, leading up to the launch of tolling in December 2011, much of the negative coverage framed the SR 520 tolling project as “delayed” or reporting that WSDOT is losing customer confidence due to the incompatibility between the transponder technology on the SR 520 and the Tacoma Narrows Bridge. The balanced coverage voiced the same issues as the negative coverage, but offered responses and explanations that offered evidence that WSDOT was handling the issues and that there were rational reasons for the issues. In 2012, most media coverage was centered around reporting facts, e.g., tolling has started, tolling rate will increase, floating pontoons being put into place. The negative reporting primarily had to do with glitches in the toll billing system where users were not receiving accurate toll bills. There was also coverage juxtaposing the alleged negative impacts of tolling experienced by commuters versus the positive impacts of tolling being reported by WSDOT.

In addition to the 85 news media pieces found in the sample, all opinion, editorial, and commentary (Op-Ed) coverage was reviewed and analyzed. There were thirty-eight total Op-Ed pieces reviewed for the period 2010-2012, the majority (30) occurring in 2011. Most Op-Eds had a positive slant toward the Seattle/LWC UPA projects, due to their focus on the Eyman ballot initiative[3] and advised its readers to vote no, while describing the value of congestion management and the role tolling plays in funding and managing an urban transportation system. This argument was coupled with the fear of Eastern Washington residents having to “pick up the bill” for Western Washington transportation infrastructure needs. Other positive leaning Op-Eds included arguments for why tolling is necessary and good, including the chance that it may influence driver behavior to choose transit and/or telecommuting options rather than driving at peak hours. The Op-Eds with a negative slant toward the Seattle/LWC UPA projects focused on the *Good To Go!* incompatibility with Tacoma Narrows Bridge and the resulting lack of confidence users have in WSDOT. Additionally, there were Op-Eds that argued against the principles of tolling, citing the inequities of tolls as regressive and unfair to the lower socio-economic class. Lastly, there were Op-Eds authored by those expressing their dissatisfaction with the funding gap for completing the bridge replacement and for the debate over the planning of the portion of the bridge coming into the City of Seattle. While these articles were not directly against tolling on the bridge, they expressed dissatisfaction with how WSDOT was handling the planning, execution, and funding of the bridge replacement project.

Overall, the sampled coverage focused almost exclusively on the tolling of SR 520 or on the construction of the new bridge over other aspects of the Seattle/LWC UPA projects, such as the funding for transit. The national evaluation team found very little mention of the transit projects funded as part of the Seattle/LWC UPA projects in the sampled media despite the frequent mention in the media that motorists would likely opt for taking transit over the bridge once tolling began.

The following describes in greater detail the key topics and themes that emerged from the sample.

[3] This refers to the Tim Eyman Initiative 1125 that was on the November 2011 ballot. The initiative would have changed state tolling laws, including requiring the state legislature to approve tolls instead of the Transportation Commission that is appointed by the governor. The initiative did not pass.

- <u>The Role of the Tacoma Narrows Bridge in Public Perception of Tolling on SR 520:</u> The electronic tolling technology for the SR 520 was chosen as the statewide tolling system, but due to the vendor contract on the Tacoma Narrows Bridge, there was an interim period where the new transponders would not work on the Tacoma Narrows Bridge and that toll charges on the Tacoma Narrows Bridge would be processed by reading license plates. News coverage over the technology focused, in general, on the incompatibility between the two systems and, specifically, on the incident where the company managing the Tacoma Narrows Bridge tolls mailed a large number of infractions to its users, some of which were in error. Despite rational explanations provided by WSDOT spokespersons to the reasons behind choosing a different technology, coverage on this issue remained negative, surmising that tolling customers were losing confidence in WSDOT's ability to deliver a well-functioning tolling system. This coverage seems to indicate that at least for the news media, tolling in the region is seen through a systems lens. In other words, one tolling facility has the power to impact others in the system, both on a technical level as well as on a reputation level.

  "Randy Boss, a fixture at meetings between the CAC [Citizen Advisory Committee] and WSDOT last fall, feels there are so many unanswered questions that he is asking for a redo of the entire tolling system discussions process and has filed a petition with the state Transportation Commission, which has a discussion of possible litigation related to the petition on its March 22 agenda. Boss said he is concerned that tolls will go up as a result of the lost revenues due to the new system."[4]

  "Rep. Larry Seaquist of Gig Harbor said "the repeated failure of WSDOT [Washington State Department of Transportation] to resolve conclusively a long series of tolling crises" warrants an audit from the state auditor's office."[5]

- <u>The Eyman Initiative as Catalyst for Tolling Support:</u> Washington State is a ballot initiative state and Tim Eyman is a professional ballot initiator. During the evaluation period, Eyman introduced ballot initiative 1125, which would significantly impact the state's tolling practices, limiting the rates and the use of revenues. His initiative drew out many opponents who, by virtue of their opposition, came out in support of tolling and of the SR 520 project. Media coverage, especially Op-Eds, described the important role tolls play in financing an aging transportation infrastructure. The initiative was ultimately defeated in the November 2011 election.

  "We think roads and bridges are expensive enough already. We also think part of their cost should be borne by those who use the roads and bridges. That's why we accept tolls as an uncomfortable but necessary strategy for funding transportation projects. And those road and bridge projects are not going away, especially in a growing state. Without the limited use of tolls, that revenue will have to come from somewhere else, i.e. all taxpayers. Tolls (and the gas tax, for that matter) keep Washingtonians from having to use

[4] Stewart, J. (March 19, 2011). New technology leaves Narrows Bridge tolling in the dust. *The News Tribune*.

[5] N.A. (June 1, 2011). Drivers on Tacoma Narrows Bridge slammed with tickets. *Q13 Fox News*.

systemwide tax structures for transportation funding…Without tolls, the biggest projects either would not get built, or would guzzle all the other road money that today is properly spread to projects around the state."[6]

- Building a Facility Without 100 percent Funding In Place Makes For Bad Press: Whether it is in reference to the need to toll other facilities to fully fund the SR 520 bridge replacement or comments by residents of Seattle complaining that their side of the bridge replacement will not be completed at the same time as the floating bridge – one-quarter of the sampled media coverage focuses on the roughly $2 billion funding gap for the SR 520 bridge replacement project that remains despite generated toll revenue.

  It's becoming apparent that a new Highway 520 floating bridge won't solve traffic jams without a tax increase, expansion of tolls to nearby Interstate 90, or both. More than three years ago, the state Department of Transportation (DOT) acknowledged a $2 billion shortfall for the $4.65 billion crossing from Bellevue to Seattle. It's a problem that has yet to be fixed.[7]

  "They're planning on building a partial bridge from the Eastside to over the water near Seattle and then stopping and running out of money," said Fran Conley, leader of the Coalition for a Sustainable 520. "Do the people of Washington really want to pay billions of dollars for a bridge to nowhere?"[8]

- Success does not make the news, complaints do: Nowhere in the sample media coverage was there documentation or recognition of the project's complexity and its innovative approach to combining the 4Ts (i.e., Tolling, Technology, Transit, TDM) to create a multi-modal corridor across Lake Washington. Rather, the news coverage dwelled on any drama related to the project, including lawsuits, delays, the ballot initiative, transponder incompatibility, etc. This phenomenon is evident in Figure I-5 where spikes in reporting related to tolling incompatibility and project delays earn double, sometimes triple, the amount of coverage than the reporting on the successful results of tolling (see, for example, the count differences between February (116), June (78), and October (68) 2011 versus October (25) and December (2) 2012).

I.5 Interviews and Workshops with Local Partners

The following section provides an analysis of the interviews and workshops conducted with representatives from the Seattle/LWC UPA local partners. The purpose of the interviews and workshops was to gain additional insights into the institutional arrangements, partnerships, outreach methods, and other activities contributing to planning, deploying, and operating the Seattle/LWC UPA projects.

---

[6] *The Columbian*," 'No' on I-1125," October 13, 2011.

[7] Lindblom, M. (August 4, 2010). 520 bridge shortfall: more tolls, taxes ahead. *The Seattle Times*.

[8] Porter. E. (June 9, 2011). 520 project one step closer, but needs more money. *KIRO 7 Eyewitness News*.

Two rounds of in-depth interviews were conducted by the national evaluation team with agency personnel involved in the Seattle/LWC UPA projects. The first round of interviews occurred in spring 2011 prior to tolling deployment and the second round in fall 2012, 10-11 months after tolling deployment.

Interviewees were identified by the national evaluation team with input from the Seattle/LWC UPA local partners. Once interviewing began, the national evaluation team asked interviewees for their recommendations of other stakeholders to interview. Table I-3 identifies the number of individuals from different agencies and organizations participating in the interviews and workshops.

Interviews were conducted one-on-one over the phone using questions developed by the national evaluation team with input from local partners and federal agency representatives. The questions were included in the *Seattle/Lake Washington Corridor UPA Survey, Interviews, and Workshops Test Plan*.[9] Interviews lasted between 30 and 90 minutes. In most interviews, two members of the national evaluation team were present. One individual led the interview, asking the questions and jotting down notes. The second individual took notes using a laptop computer. All interviews were audio recorded to produce a verbatim transcript. Interview transcripts were stored, organized, and analyzed using NVivo, a qualitative data analysis software. The software provides document coding and tracking capabilities based on key words and other characteristics.

Table I-3. Stakeholders Interviewed and Workshop Participants

Organization	Number of Participants			
	First Round Stakeholder Interviews	Second Round Stakeholder Interviews	First Round Stakeholder Workshop	Second Round Stakeholder Workshop
King County Metro Transit	2	2	2	2
Puget Sound Regional Council	2	2	2	2
University of Washington	1	1	1	1
Washington State Governor's Office	0	1	0	0
Washington State Legislature	2	2	0	1
Washington Transportation Commission	1	1	0	1
WSDOT	4	3	8	3
Total	**12**	**12**	**13**	**10**

Source: University of Minnesota.

[9] Burt, M. et al. Seattle/Lake Washington Corridor Urban Partnership Agreement National Evaluation: Surveys, Interviews, and Workshops Test Plan. Publication Number FHWA-JPO-TBD, January 11, 2011.

After each round of interviews, the national evaluation team convened a workshop where all of the individuals interviewed were invited, as well as other agency representatives. In addition, U.S.DOT personnel managing the Seattle/LWC UPA national evaluation and other national evaluation team members were in attendance. Both workshops were held in Seattle, the first in April 2011 and the second in November 2012.

The purpose of the workshop was to follow-up on the individual interviews by discussing the common themes that emerged and to draw lessons learned. To facilitate discussion during the workshop, the common themes from the interviews were summarized and presented. Workshop participants were encouraged to provide additional comments, including highlighting new points or by clarifying or reinforcing the identified themes and topics presented by the national evaluation team.

The following are key topics and themes that emerged from the two rounds of interviews and workshops:

- **High-functioning partnership:** There was unanimous reporting of good working relationships among the local partner agencies during both phases of interviewing. When interviewees were asked what leads to a good partnership and also what they do when there is conflict, respondents articulated the following factors as contributing to their success:
  - ***Clearly defined partnership/working relationships at all levels within and across agencies.*** Each respondent spoke clearly about their agency and their personal role in the project. Respondents never indicated any confusion of roles or responsibilities at any point in the planning and implementation of the project.
  - ***Frequent communication among partners.*** Respondents referred to the frequent and open communication among the partner agencies as a key to their successful collaboration and a lesson in how to implement a complex project.
  - ***Shared project goal.*** As indicated above, it was clear to all partners the need to fund the replacement of the SR 520 bridge and that the UPA project brought early tolling to the table as well as the opportunity to implement a multi-modal solution (i.e., inclusion of transit) to demand management in the corridor.
- **The right conditions were in place to pursue UPA funding:** The general environment and local contextual conditions already in place in the region allowed for the successful pursuit of UPA funding. This included the following conditions:
  - ***Early agreement on SR 520 corridor.*** This region had long considered the need to replace the SR 520 bridge. Many respondents commented that the bridge was one storm or earthquake away from catastrophe.
  - ***Buy-in from very top.*** Top leaders at each of the partner agencies and key legislators all saw the need for federal money and were willing to move the political hot button of tolling in the region in order to meet the UPA funding requirements.
  - ***Tolling as a policy discussion had already begun before the UPA came along.*** The tolling need in the region had already been identified. UPA fit into the regional planning design by simply bringing significant federal money to the table to fund a bridge project that was otherwise underfunded.

  - ***Solid regional strategy already in place when UPA came along.*** A mobility strategy for the region called *Moving Washington* had been championed by State Transportation Secretary Hammond and was already in place when the UPA funding came along. The *Moving Washington* mobility strategy included strategic capacity building, efficient operations, and demand management. The local partners believed the UPA fit the *Moving Washington* strategies.
  - ***Successful previous working relationships.*** When the UPA solicitation came out, each of the partner agencies immediately thought of each other and got in touch to discuss pursuing the funding. There was no indication from any of the partner agencies that they would attempt to pursue this funding opportunity without the support and collaboration of the other agencies.
- **Tolling for a tangible benefit:** The UPA funding program fit an existing need in the region – the bridge needed to be replaced. Therefore, tolling the bridge was an "easier sell" to the public because people knew they were getting a new bridge. This project was an innovative application of the 4Ts, bringing a complete electronic tolling facility and early tolling to fund replacement with variable pricing. It was an "easier sell" also due to a well-organized and well-executed communications and outreach plan. Ultimately, it is an easier sell when you have something tangible like a bridge rather than selling a concept that tolling in some future, unknown project will be good for a community. Additionally, tolling the SR 520 to pay for its replacement meant that the users of the bridge were paying for their new bridge. Therefore, residents in other parts of Washington were not responsible for bearing the cost of infrastructure with which they did not come in direct contact.
- **Communications and outreach plan designed to address benefits of early tolling:** The Seattle/LWC UPA projects were implemented where there is a well-informed, mostly supportive public (the previous votes for increasing the gas tax and the votes against ballot initiatives show that the majority of voters are in support of funding transportation infrastructure). This area is also used to tolling, therefore, the communications and outreach plan focused on the idea of early tolling.
- **The politics of ferry funding:** Funding for ferries was included as part of the final term sheet between U.S. DOT and the local partners. This funding inclusion was mentioned several times in both rounds of interviews. The local partners understood that without their agreement, the ferry funding, which was unrelated to the UPA projects, would not be released by U.S. DOT to the region.

The following are lessons learned shared by interviewees and workshop attendees about their experiences planning, implementing and deploying the Seattle/LWC UPA projects.

- **It is difficult to set realistic timelines for a complex, innovative project.** On the one hand, people need deadlines to create the pressure to get the work done, but on the other hand, the project timeline needs to allow for the project to be "done right." For the Seattle/LWC UPA partners, the spring 2011 tolling launch was originally thought doable, but once they were into the process of developing and implementing the back office and agency tolling division, the partners realized they needed to delay the tolling start date.
- Part of the delays addressed in the above lesson learned is **the importance of testing out new technologies before going live.** No one wanted to deploy the tolling before ensuring that the technology would work.

- **You cannot do too much outreach and marketing.** You must do your homework in order to know what to communicate, but once you know what to say then say it early and often.
- It is not enough to bring in experts to do something; **you must build internal capacity** in order to successfully deploy an electronic tolling project.
- The lesson of the UPA is that **the solution to congestion is not just one of the 4Ts, but a combination of tolling, transit, technology, and telecommuting/TDM** that make a corridor work. The more you can get the entities from these four areas working together toward the same goal, the better.
- **You cannot avoid the equity argument against tolling.** You have to have the debate. You also have to be ready to offer viable alternatives like high-quality transit service.
- Use of an **expert review panel** on tolling to provide advice and expertise to the state legislature helped legislators feel more comfortable with the decisions they were making on the SR 520 project.
- Often, there are more organizations and jurisdictions affected by a tolling project than are included in a core team of implementers. Therefore, it is critical to **provide opportunities for other entities to provide input and feel heard** in the planning and implementation stages in order to avoid the perception that the project is a top-down, dictated mandate.

I.6 Public Reaction to the UPA Projects

Several surveys reveal the public's reaction to the UPA projects – the Volpe household travel survey, the WSDOT-sponsored SR 520 Evaluation Surveys, and the King County Metro Transit SR 520 On-Board Intercept Survey. Overall, the findings show general satisfaction and positive responses.

Volpe surveyed a panel of the same households in November 2010 prior to tolling (Wave 1) and again in April and May 2012 after tolling (Wave 2). Details about the survey are presented in Appendix A – Congestion Analysis. Participants were asked about their satisfaction with LWC trips. The analysis identified a statistically significant increase in driver satisfaction with travel time, travel speed, and predictability with SR 520 trips, and a statistically significant decrease with these same measures for I-90 trips, as shown in Table I-4. The slight increase in transit rider satisfaction with travel time, and decrease in satisfaction with seating availability is consistent with an expanded transit service with increased ridership, which created more competition for seating.

Table I-4. Satisfaction with Peak-Period Trips Around or Across Lake Washington Before and After SR 520 Tolling

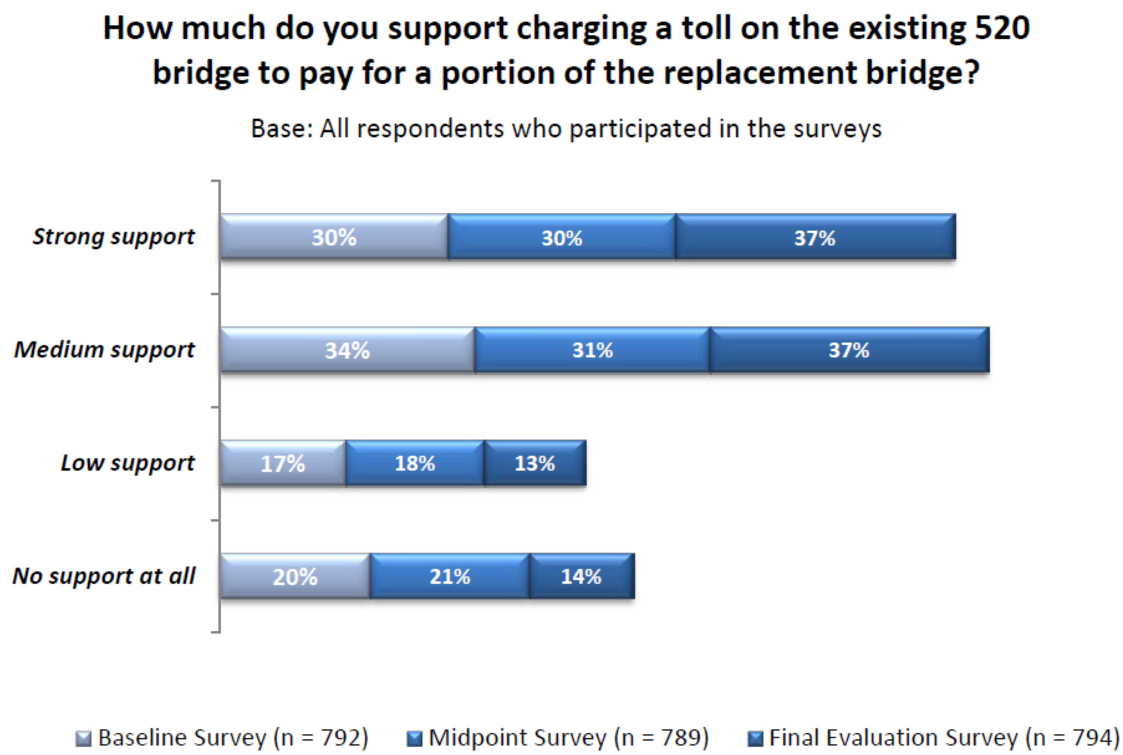
Trips and Corridor	Satisfaction with	Pre-Tolling	Post-Tolling	Change*
SR 520 N=1840 trips pre-tolling N=1032 trips post-tolling	**Travel Time**	**3.41**	**5.17**	+1.76
	Travel Speed	**3.35**	**5.16**	+1.81
	Predictability	**3.47**	**5.13**	+1.66
I-90 N=1306 trips pre-tolling **N=1199 trips post-tolling**	**Travel Time**	**3.98**	**3.87**	-0.11
	Travel Speed	**3.93**	**3.81**	-0.12
	Predictability	**4.03**	**3.68**	-0.35
SR 522 N=104 trips pre-tolling **N=169 trips post-tolling**	**Travel Time**	**3.34**	**3.66**	+0.32
	Travel Speed	**3.39**	**3.64**	+0.25
	Predictability	**3.91**	**3.97**	**+0.06**
Transit Trips N=758 trips pre-tolling **N=714 trips post-tolling**	**Travel Time**	**4.90**	**5.17**	+0.27
	Wait Time	**5.10**	**5.15**	**+0.05**
	Reliability	**5.23**	**5.23**	**0.00**
	Seating Availability	**5.19**	**4.73**	-0.46

Source: Volpe.

*Values in bold are statistically significant at the 95 percent level
Note: Scale: 1=Highly Dissatisfied, 4=Neutral, 7=Highly Satisfied

In terms of attitudes about tolling, the public had some mixed opinions on tolling, tending to be more negative about the project, but generally more satisfied with the overall transportation network. On a scale where 1 is strongly disagree and 7 is strongly agree, when asked about agreement with the statement "I will use a toll route if the tolls are reasonable and I will save time," agreement rose from 4.31 before tolling to 4.93 after tolling. When asked about the statement "Highway tolls as are unfair to people with limited incomes," agreement dropped slightly from 4.88 before tolling to 4.79 after tolling. Positive attitudes were expressed after tolling with respondents being more likely to agree that "I am satisfied with my commute" (with scores of 4.18 in Wave 1, and 4.31 in Wave 2), even though after tolling, 39 percent agreed that "overall, I am spending more time stuck in traffic since tolling started on SR 520" compared to 42 percent disagreeing.

The WSDOT survey showed increased support for tolling on the existing SR 520 bridge to pay for a replacement bridge, as shown in Figure I-7.



Source: WSDOT.

Figure I-7. Support for Tolling SR 520 to Pay for a Replacement Bridge

The King County Metro Transit rider survey consisted of two on-board surveys of riders, the first in March 2011, prior to tolling and the second in May 2012, five months after tolling began. Details of the survey are presented in Appendix C – Transit Analysis. In the post-deployment period, riders were asked whether they agreed or disagreed with a series of statements related to the SR 520 tolls. A majority of the riders (57 percent) agreed to various degrees with the statement that the SR 520 tolls have improved their personal travel. A smaller percentage (42 percent) agreed with the statement that the SR 520 tolls have been good for the region. A majority (55 percent) agreed with the statement that the SR 520 tolls are unfair to people on limited incomes.

In each survey, riders were asked to rate ten aspects of the service as well as their overall level of satisfaction with Metro Transit or Sound Transit. On-time performance and travel time perceptions are two service aspects one would expect to be positively impacted by the imposition of variable tolls on SR 520. In the case of on-time performance, the mean score dropped from 4.24 to 4.14, which still equates to a rating of “good” but is statistically significant at the 95 percent confidence level. The mean score for perception of travel time increased from 4.22 to 4.23, but the increase was not statistically significant. The mean scores for perceptions of wait time at the station/stop, availability of seats, and parking availability at the park-and-ride lots also decreased at statistically significant levels. Ironically, the drop in ratings for availability of seats and parking availability may be due to increased ridership. More riders translate into fewer seats and fewer available spaces at the park-and-ride lots. On a positive note, the mean score for overall satisfaction with King County Metro Transit by SR 520 riders improved from 3.94 to 4.03 (good) and was statistically significant at the 95 percent confidence level.

Riders were asked whether they were influenced to take transit because of the extra UPA funded transit service. Among new riders, 19 percent said they were influenced, 48 percent said they were not influenced, and 33 percent were not aware of the service changes. In the post-toll survey, riders were asked whether they began taking the bus before or after the SR 520 tolls began and whether they were influenced to take transit because of the tolls. As would be expected in a corridor where there was already a lot of transit service, most riders (81 percent) had already been riding the bus prior to tolling. Consequently, most of the riders were not influenced by the tolls to take transit. However among riders that only began taking transit after the start of tolls, 55 percent said they were influenced to take transit because of the tolls.

The survey also asked riders about the UPA-funded real time bus information technology installed at two bus stops (2 additional bus stops will be equipped in 2014). Riders were asked whether they used a bus stop that was equipped with real time bus arrival information, how easy the information was to understand, and how useful the information was. A majority responded that the information was both very useful (60 percent) and very easy to understand (73 percent).

I.7 Summary of Non-Technical Success Factors

As highlighted in Table I-5, people, process, structures, the media, and competencies all played supporting roles in the implementation, deployment, and operation of the Seattle/LWC UPA projects. The multi-organizational structure, with its specific roles and responsibilities, supported the implementation, deployment, and operations of the UPA projects. A team of competent staff were able to lead the region through the implementation of a technologically complex project, albeit with some delays. The UPA was only a portion of a larger bridge replacement project, which had been in the works years before the UPA funding was introduced. Likewise, tolling was not new to the region; however, early tolling on an existing facility to partly fund the new facility was a new strategy for the region. An extensive outreach and communications plan aided the local partners' ability to inform the public and cultivate users. The successful deployment of electronic tolling on the SR 520 has opened the door to discussions on tolling the other bridge across Lake Washington, the I-90 bridge, as well as in other critical corridors in the region. Additionally, the public tends to be more supportive of tolling and the UPA projects in the post-deployment period, although support is not overwhelming.

Table I-5. Non-Technical Success Factors

Questions	Results	Evidence
What role did the following areas play in the success of the Seattle/LWC UPA projects?		
People Processes Structures Media Competencies	Effective Effective Some project delays, but ultimately effective in delivering electronic tolling Some coverage problematic, but media also provided outlet to education public about tolling portion of UPA projects Effective	1./5. Agency staff held technical expertise and project management skills needed to successfully implement the projects. Staff held their colleagues in high regard. 1./5. Early tolling on the SR 520 was accepted publicly and politically through the deliberate outreach and communications of top agency leadership. 2. Delays to tolling were unfortunate, but necessary for the successful deployment of electronic tolling. 3. Clearly defined roles and responsibilities within the multi-agency organizational structure. 4. Media kept the projects in the public eye, although their contribution to public opinion sometimes leaned toward negative by focusing on delays and technical difficulties in implementing the electronic tolling.
Does the public support the UPA strategies as effective and appropriate ways to reduce congestion?	Partially Supported	Respondents tend to be more supportive of tolling and the UPA projects in the post-deployment period, although support is not overwhelming.

Source: University of Minnesota.

Appendix J. Benefit Cost Analysis

The purpose of the benefit cost analysis (BCA) is to quantify and monetize the societal benefits and costs of implementing the Seattle/Lake Washington Corridor (LWC) Urban Partnership Agreement (UPA) projects. The net benefit from the UPA projects, which is the difference between the total benefits and the total costs, indicates the net societal benefit of this public investment. As presented in Table J-1, the BCA focuses on quantifying the overall benefits, costs, and net benefits from the Seattle/LWC UPA. The term cost benefit analysis (CBA) was used in the Seattle/LWC UPA test plan. The use of BCA has become the commonly accepted term in the transportation community and is used in this appendix.

Table J-1. Question for the BCA

Question
• What are the overall benefits, costs, and net benefits from the Seattle/LWC UPA projects?

Source: Texas A&M Transportation Institute.

The timeframe used for the BCA encompasses the planning, implementation, and ten years of post-deployment operation. This approach includes all costs of the Seattle/LWC UPA projects from their planning stages to 10-years post-implementation and all benefits of the projects for a 10-year period after implementation. Within this evaluation time frame, the BCA estimates and compares the total benefits and costs between two scenarios – with and without the implementation of the Seattle/LWC UPA projects. Tolling on the SR 520 bridge started December 29, 2011. Therefore, 2012 was considered year one of post deployment.

The remainder of this appendix includes four sections. The Seattle/LWC UPA projects included in the BCA along with the data sources used in the BCA are presented in Section J.1. Cost information on the Seattle/LWC UPA projects included in the BCA is presented in Section J.2. The estimation of the benefits from the projects is described in Section J.3. The appendix concludes with a summary of the analysis in Section 0.

J.1 Seattle/LWC UPA Projects and Data Sources

The Seattle/LWC UPA projects had several components, the primary ones being variable tolling on the SR 520 bridge, improved transit services, park and ride lots, and active traffic management (ATM) with dynamic message signs on I-90 and SR 520. Also included in the UPA, but not this BCA, were the regional ferry boat improvements (these were not expected to impact the 520 corridor) and the South Kirkland Park and Ride lot (it is not open yet). Thus the Seattle/LWC UPA projects included in the BCA were:

- All costs required to design, build, operate, and maintain the new tolling system on the SR 520 bridge. This includes the electronic toll collection (ETC) system, setting up and maintaining ETC accounts, replacing computers, in lane enforcement equipment, labor, etc.

- All costs required to design and build the new Redmond park-and-ride garage in addition to the marginal cost of repair, maintenance, labor, etc. of the new garage versus the previous surface lot.
- All costs required to design, install, operate and maintain the new travel time signs and ATM equipment.
- Costs to purchase operate and maintain the new transit buses, the new transit information system, and the real-time transit information signs.
- Costs associated with additional emphasis and investment in telecommuting and vanpooling.

Data on the capital, operation and maintenance costs of the projects listed above were obtained from the Washington State Department of Transportation (WSDOT). Information on 10-year projections of travel-time changes, vehicle operating costs changes, and changes in amount of emissions were obtained from the travel demand forecast model developed and run by the Puget Sound Regional Council (PSRC).

J.2 Seattle/LWC UPA Projects – Costs

Data on the capital costs, the implementation costs, the operating and maintenance costs, and the replacement and re-investment costs for the UPA projects were obtained from WSDOT. To convert any future year costs to year 2012 dollars[1], a real discount rate of 7 percent per year was used based on federal guidance.[2]

As outlined in the *Cost Benefit Analysis Test Plan*,[3] a 10-year post-deployment timeframe was used for the BCA since many aspects of the projects were technology- or pricing-related. Both technology and pricing systems have relatively short life spans. Thus, only expenditures prior to December of 2021 incurred as a result of implementing the UPA projects were considered. In addition, only the marginal costs associated with the UPA projects were included in the cost data. The BCA timeframe began with the first expenses incurred and ends at the end of 2021, after 10 years of operations. The Seattle/LWC UPA projects with useful lives longer than 10 years, such as new buses, were accounted for by reducing the cost of that item by its salvage value in year 10.

[1] Tolling on SR 520 began on December 29, 2011. The national evaluation uses this as the start date for the project and the start of benefits analysis will therefore be January 1, 2012 and use 2012 as the base year.

[2] Office of Management and Budget guidance (http://www.whitehouse.gov/omb/assets/a94/a094.pdf (page 9)) and current FHWA guidance (Federal Register, Vol. 75, No. 104, p. 30476)). Accessed July 11, 2012.

[3] Seattle/Lake Washington Corridor (LWC) Urban Partnership Agreement (UPA) projects: Cost Benefit Analysis Test Plan, FHWA-JPO-11-064, January 10, 2011.

The U.S. DOT allocated $154.5 million for the Seattle/LWC UPA projects. The funding was used to plan, design, and construct the various projects – along with operating the new system in the early years. Operating and maintaining the projects over the BCA timeframe of 10 years requires additional funding. To address costs incurred in years after 2012, those costs are adjusted to a common year using a discount rate of 7 percent. Therefore, determining the costs of the UPA projects is more difficult than simply assuming that the costs total $154.5 million. The following section, along with Table J-2, provides details regarding the cost estimate of the Seattle/LWC UPA projects in 2012 dollars for the purpose of the BCA.

Table J-2. Seattle/LWC UPA Project Costs

UPA Project Component	Planning, Design, and Construction/Purchase Costs (2012 dollars)	Operation and Maintenance Costs (years 2012 to 2021 in 2012 dollars)
Redmond Park and Ride Garage	$17,834,445	$490,244
SR 520 Tolling System	$33,347,358	$6,662,166
Travel Time Signs and ATM	$39,934,788	$222,411
Transit Improvements	$39,934,788	$5,833,244
Telecommuting/TDM	$113,000	0
TOTALS	**$127,927,172**	**$13,208,065**

* Assumes these costs remain the same when the new system and bridge are operational.

Source: Texas A&M Transportation Institute, Washington State Department of Transportation, and King County.

In December 2021 some of the above items will still have value, which is known as salvage value. The salvage value will be subtracted from the total cost above ($127,927,172) to determine the net cost over the 10 year BCA timeframe. For the physical infrastructure (Redmond park-and-ride garage) Minnesota's BCA guidance[4] provided the following formula to obtain the salvage value:

$$\text{Salvage Value} = \frac{(1+r)^n \times \left[\left(\frac{(1+r)^L - 1}{r(1+r)^L} \right) - \left(\frac{(1+r)^n - 1}{r(1+r)^n} \right) \right]}{\left(\frac{(1+r)^L - 1}{r(1+r)^L} \right)}$$

Where r = the discount rate (0.07)

n = number of years in the analysis period (10)

L = useful life of the asset

[4] Minnesota Department of Transportation, "Benefit-Cost Analysis for Transportation Projects," available at http://www.dot.state.mn.us/planning/program/benefitcost.html. Accessed July 12, 2012.

This same guidance suggests the useful life of surface (pavement) is 25 years, sub-base and base are 40 years, and major structures such as a park and ride garage have a useful life of 60 years. The salvage value of the park and ride garage is therefore:

$$\text{Salvage Value} = \frac{(1+0.07)^{10} \times \left[\left(\frac{(1+0.07)^{60}-1}{0.07\times(1+0.07)^{60}}\right) - \left(\frac{(1+0.07)^{10}-1}{0.07\times(1+0.07)^{10}}\right)\right]}{\left(\frac{(1+0.07)^{60}-1}{0.07\times(1+0.07)^{60}}\right)} = \frac{1.97\times(14.04-7.02)}{14.04} = 0.983 = 98.3\%$$

Salvage value is 98.3 percent of the value of the Redmond P&R garage or $17,531,553.

In addition, the new buses purchased for the project will have some value at the end of the evaluation period. The buses were assumed to have a useful life of 12 years. Using the equation above, salvage value at the end of year 10 for the buses will be 22.8 percent of their original purchase price. This amounts to $8,353,589.

Therefore, the resulting 10-year costs from the Seattle/LWC UPA projects were $127,927,172 + $13,208,065 – $17,531,553 – 8,353,584 = $115,250,100.

J.3 Seattle/LWC UPA Projects – Benefits

The benefits of the Seattle/LWC UPA projects are similar to benefits from many transportation infrastructure projects and the calculation methodology will follow standard practice as provided by the Transportation Research Board (TRB) committee on transportation economics[5] and the Federal Highway Administration (FHWA)[6]. This section highlights how the benefits were calculated for the UPA projects.

The preferred option to estimate the impacts, and therefore benefits, of the UPA projects was to use the PSRC's travel demand model[7]. First, the traffic on key corridors (SR 520, I-90 and SR 522) both without and with the UPA projects was modeled. These values were compared to actual traffic volumes without (from 2010) and with (from 2012) the UPA projects. Modeled results for SR 522 were very similar to recorded traffic volumes. On SR 520 and I-90 the PSRC model yielded traffic volumes that were higher than observed values. However, the modeled change in traffic volumes with and without the UPA projects was very similar to the actual change. Therefore, the changes in travel times, vehicle operating costs, and emissions provided by the model should be reasonable and will be used to estimate those benefits. The model was also able to estimate benefits from improved travel time reliability. These will be listed at the end of the travel time benefit section of this report but are not part of the benefit to cost calculation.

---

[5] http://bca.transportationeconomics.org/. Accessed February 11, 2013.

[6] Federal Highway Administration, TIGER BCA Resource Guide, http://www.dot.gov/sites/dot.dev/files/docs/USDOT%20BCA%20Guidance.pdf. Accessed July 11, 2012.

[7] Puget Sound Regional Council, http://www.psrc.org/data/forecasts/travel-demand-forecast/. Accessed March 10, 2013.

J.3.1 Benefits – Travel Time Savings

For most transportation projects the largest societal benefits are a result of the travel time savings gained through reduced congestion. The amount of travel time savings from the project was obtained from PSRC's model. The model was run four times:

1. Base year 2010 without the UPA projects,
2. Base year 2010 with the UPA projects,
3. Future year 2025 without the UPA projects,
4. Future year 2025 with the UPA projects.

The base and future years indicate the population, demographics, and road network for those years. For the initial (opening) year of the project in late 2011 the results from the 2010 models were used. For all future years (from 2012 to 2021) a linear change in benefits from the 2010 model results to the 2025 model results was assumed. The impact of the UPA projects is taken as the difference in the model results from the two models for that year.

Note that the models calculate the consumer surplus resulting from changes in travel times and vehicle operating costs. These differ somewhat from simply multiplying the total change in travel time by the average value of time. Using consumer surplus adds to the analysis the costs and benefits to travelers from switching modes and routes and abandoning trips. In this manner it provides a more accurate BCA. PSRC's model uses their own locally derived values of time for several modes and trip purposes to determine these travel behavior changes. These local values of time (see Table J-3) were in year 2000 dollars and accounted for different trip purposes, income groups and vehicle types. The values were adjusted to other year dollars based on changes in household income and FHWA guidance[8]. The figures in Table J-4 were obtained from interpolating the 2010 and 2025 PSRC model results and were left in 2008 dollars as the PSRC model used 2008 dollars.

Table J-3. Seattle/LWC Value of Travel Time

User Class	Seattle VOT in Year 2000 ($/hour)
SOV work low-income	9.57
SOV work low-middle-income	17.64
SOV work high-middle-income	25.71
SOV work high-income	33.33
Drive alone non-work	15.68
Carpool and Vanpool	4.72
Transit	8.03
Light truck	24.75
Medium truck	27.85
Heavy truck	30.94

Source: Federal Highway Administration.

[8] Federal Highway Administration, http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf. Table 4, Accessed July 11, 2012.

Table J-4. Seattle/LWC UPA Travel Time Benefits (2008$)

Year	Auto Modes ($)	Transit ($)	All Trucks ($)	Total Benefit ($)
2012	8,581,861	3,468,210	-3,505,859	8,544,212
2013	8,099,500	4,664,528	-1,870,497	10,893,531
2014	7,617,140	5,860,845	-235,134	13,242,850
2015	7,134,779	7,057,162	1,400,228	15,592,170
2016	6,652,419	8,253,480	3,035,591	17,941,489
2017	6,170,058	9,449,797	4,670,953	20,290,808
2018	5,687,698	10,646,114	6,306,316	22,640,128
2019	5,205,337	11,842,432	7,941,678	24,989,447
2020	4,722,977	13,038,749	9,577,041	27,338,766
2021	4,240,616	14,235,066	11,212,403	29,688,086
TOTALS	64,112,386	88,516,382	38,532,719	191,161,487

Source: Texas A&M Transportation Institute and PSRC.

Adjusting the results from 2008 dollars to 2012 dollars results in a travel time benefit of $250,573,714.

The UPA projects also provided additional travel time reliability on the roadways and this was measured and monetized using PSRC's model. Note that including these benefits are not yet standard practice in the United States and will not be included in the total benefits listed at the end of this report and will not be part of the benefit to cost ratio. The PSRC model estimated the benefits from more reliable travel times for years 2010 and 2025. Reliability benefits for years 2012 to 2021 were then linearly interoperated from those model results. The total benefits from added travel time reliability, in year 2012 dollars, equaled $103,571,483.

J.3.2 Benefits – Emissions

The shift in vehicles between the different highways, plus shifts of travelers between modes has the potential to change the amount of emissions from vehicles. These emissions are harmful to humans and the environment and as such, a reduction or increase in emissions results in a societal benefit or cost. The change in emissions due to the Seattle/LWC UPA projects was calculated in Appendix H – Environmental Analysis. However, these changes could only be estimated for 2012 since they were based on measured travel speeds. Therefore, to calculate the change in emissions over the 10-year timeframe of this BCA it was necessary to use the changes in emissions as estimated by PSRC's travel demand model.

As with travel time savings, the change in emissions were based on the 2010 and 2025 urban planning model runs by PSRC (see Table J-5). The impact of the UPA projects was taken as the difference in emissions from the model results without the UPA projects minus the model results with the UPA projects for that year. It was assumed that emissions would change linearly from 2010 to 2025.

Table J-5. Seattle/LWC UPA Change in Emissions

Year	CO (tons)	CO2 (tons)	NOx (tons)	PM2.5 (tons)	VOC (tons)
2012	-202.1	-11251.6	-6.9	-0.1	-14.4
2013	-204.7	-13018.9	-6.9	-0.1	-14.9
2014	-207.3	-14786.1	-6.8	-0.1	-15.5
2015	-210.0	-16553.4	-6.8	-0.1	-16.1
2016	-212.6	-18320.6	-6.8	-0.2	-16.6
2017	-215.3	-20087.8	-6.7	-0.2	-17.2
2018	-217.9	-21855.1	-6.7	-0.2	-17.7
2019	-220.5	-23622.3	-6.7	-0.2	-18.3
2020	-223.2	-25389.6	-6.6	-0.2	-18.8
2021	-225.8	-27156.8	-6.6	-0.2	-19.4
TOTALS	**-2139.4**	**-192042.2**	**-67.5**	**-1.6**	**-168.9**

Source: Texas A&M Transportation Institute and PSRC.

The current year value of the societal benefit from reduced pollution was derived from the U.S. Environmental Protection Agency (EPA) estimates of the value of health and welfare-related damages (incurred or avoided) and are recommended for use in current FHWA guidance[9]. The values are found in the report Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2011 Passenger Cars and Light Trucks[10] and are shown in Table J-6.

Table J-6. Values of Reduced Emissions (in 2007 $)

Pollutant	Cost in 2009	Cost in 2015	Cost in 2020
VOC	$1,700 per ton	$1,200 per ton	$1,300 per ton
CO_2	$21 per metric ton	$24 per metric ton	$26 per metric ton
NO_X	$4,000 per ton	$4,900 per ton	$5,300 per ton
$PM_{2.5}$	$168,000 per ton	$270,000 per ton	$290,000 per ton

Note: CO is not included as no value per ton was available.

Source: Texas A&M Transportation Institute and NHTSA[11]

Future year values are taken from the Highway Economic Requirements System (HERS) documentation[12] and are shown in Table J-6.

The values in Table J-6 were interpolated (assuming a linear change in values per year) to obtain the monetary benefit of the four pollutants in each year from 2012 to 2021. Multiplying these values by the amount of pollution reduced (Table J-5), then adjusting the 2007 dollars to 2012 dollars using a discount rate of 7 percent, results in a total benefit of $305,515 from VOC, $470,083 from NO_x, $426,001 from $PM_{2.5}$, and $6,075,774 from CO_2. Combining the benefits of these individual emissions results in a total environmental benefit of $7,448,861.

[9] Federal Register, Vol. 75, No. 104, p. 30479, Accessed May 3, 2013.

[10] Office of Regulatory Analysis and Evaluation, National Center for Statistics and Analysis, National Highway Transportation Safety Administration, March 2009. Accessed July 11, 2012 (http://www.nhtsa.gov/DOT/NHTSA/Rulemaking/Rules/Associated%20Files/CAFE_Final_Rule_MY2011_FRIA.pdf, Table VIII-5, page VIII-60). Accessed July 11, 2012.

[11] *Corporate Average Fuel Economy for MY 2011 Passenger Cars and Light Trucks.* National Highway Traffic Safety Administration. 2009. Available at: http://www.nhtsa.gov/DOT/NHTSA/Rulemaking/Rules/Associated%20Files/CAFE_Final_Rule_MY2011_FRIA.pdf. Accessed September 27, 2013.

[12] Highway Economic Requirements System, Federal Highway Administration http://www.fhwa.dot.gov/infrastructure/asstmgmt/hersdoc.cfm. Accessed July 11, 2012.

J.3.3 Benefits – Vehicle Operating Costs

The UPA projects have the potential to change vehicle operating costs through reduced congestion or increase vehicle operating costs through travelers making longer trips around the lake avoiding the toll on SR 520. These vehicle operating costs are comprised of items such as maintenance, wear and tear on a vehicle, and fuel use. PSRC's urban planning model provided detailed estimates of total consumer surplus changes in vehicle operating costs (see Table J-7). Note that these were primarily negative due to traffic diversion from SR 520 and around the lake – a longer trip entailing additional operating costs.

Table J-7. Seattle/LWC UPA Vehicle Operating Cost Benefits (2008 $)

Year	Auto Modes ($)	Transit ($)	All Trucks ($)	Total Benefit ($)
2012	-2,474,615	-30,240	-2,562,115	-5,066,970
2013	-2,261,021	-24,611	-2,584,074	-4,869,706
2014	-2,047,428	-18,982	-2,606,033	-4,672,443
2015	-1,833,834	-13,352	-2,627,993	-4,475,179
2016	-1,620,241	-7,723	-2,649,952	-4,277,915
2017	-1,406,647	-2,094	-2,671,911	-4,080,651
2018	-1,193,054	3,536	-2,693,870	-3,883,388
2019	-979,460	9,165	-2,715,829	-3,686,124
2020	-765,867	14,794	-2,737,788	-3,488,860
2021	-552,273	20,424	-2,759,747	-3,291,597
TOTALS	**-15,134,439**	**-49,082**	**-26,609,312**	**-41,792,833**

Source: Texas A&M Transportation Institute and PSRC.

As with travel time savings, the change in vehicle operating costs were based on the 2010 and 2025 urban planning model runs by PSRC. The impact of the UPA projects was taken as the consumer surplus difference in vehicle operating costs from the model results without the UPA projects minus the model results with the UPA projects for that year. It was assumed that vehicle operating costs would change linearly from 2010 to 2025. After converting the results in Table J-7 to 2012 dollars there was an increase in vehicle operating costs of $54,781,879.

J.4 Summary of BCA

To summarize, the benefits of the Seattle/LWC UPA projects include:

- Travel time savings: $250,573,714
- Vehicle Operating Costs -$54,781,879
- Reduced emissions: $7,448,861
- TOTAL: $203,240,696

The cost of the UPA projects, in 2012 dollars, was $115,250,100.

As presented in Table J-8, the benefit-to-cost ratio for the Seattle/LWC UPA projects was 1.76 and the net societal benefit was $87,990,596. This BCA examined the net societal costs and benefits of the Seattle/LWC UPA projects. The analysis had several limitations and required numerous assumptions. One limitation was having only one year of crash data. This was too little data to include crash results in the BCA. Future travel time savings benefits, vehicle operating cost benefits and emissions benefits were all derived using the PSRC model. The model itself makes numerous assumptions in order to predict the future. In addition, the model was not able to accurately represent the current traffic volumes on the major routes around Lake Washington, possibly adding error to the estimates of benefits. The future year costs and benefits represent the best estimates available, but they are only estimates, and the actual costs and benefits may vary.

One other important item is that the toll revenue from this UPA project will be used to build a new bridge across the lake – replacing the aging floating bridge there now. This will enhance the safety and resiliency of the bridge and will benefit future travelers in this corridor. However, since the tolls collected as part of this UPA project are transfers of wealth from travelers to the DOT the tolls do not appear in this benefit cost analysis.

Table J-8. Question for the BCA

Hypotheses/Questions	Result	Evidence
What are the overall benefits, costs, and net benefits from the Seattle/LWC UPA projects?	Negative societal benefits	Benefits: $203,240,696 Costs: $115,250,100 Net Benefits: $87,990,596 Benefit-to-cost ratio of 1.76

Source: Texas A&M Transportation Institute

Appendix K. Exogenous Factors

The effectiveness of the Seattle/LWC UPA strategies may have been influenced by factors external to the projects themselves. To account for these factors, the national evaluation team monitored exogenous factors throughout the pre- and post-deployment periods. Information on unemployment rates, gasoline prices, roadway construction, non-typical weather conditions, and major special events were examined. Information in this appendix provided a resource for use in the other analysis areas.

This appendix is divided into four sections. Unemployment rates in the Seattle metropolitan area and the state of Washington, which reached highs in 2010 and have generally decreased through the end of the post-deployment period, are described in Section K.1. Gasoline prices, which have fluctuated over the course of deploying the UPA projects, are discussed in Section K.2. Major roadway construction, weather, and special events are described in Section K.3. Major transit changes are described in Section K.4.

K.1 Unemployment Rates

Unemployment rates were monitored throughout the pre- and post-deployment periods as the change in the number of people traveling to and from work influences traffic levels and bus ridership. The recession began before most of the Seattle/LWC UPA projects became operational. Information on unemployment rates was used to help examine the potential effects of the economic downturn on the UPA projects in the different analyses.

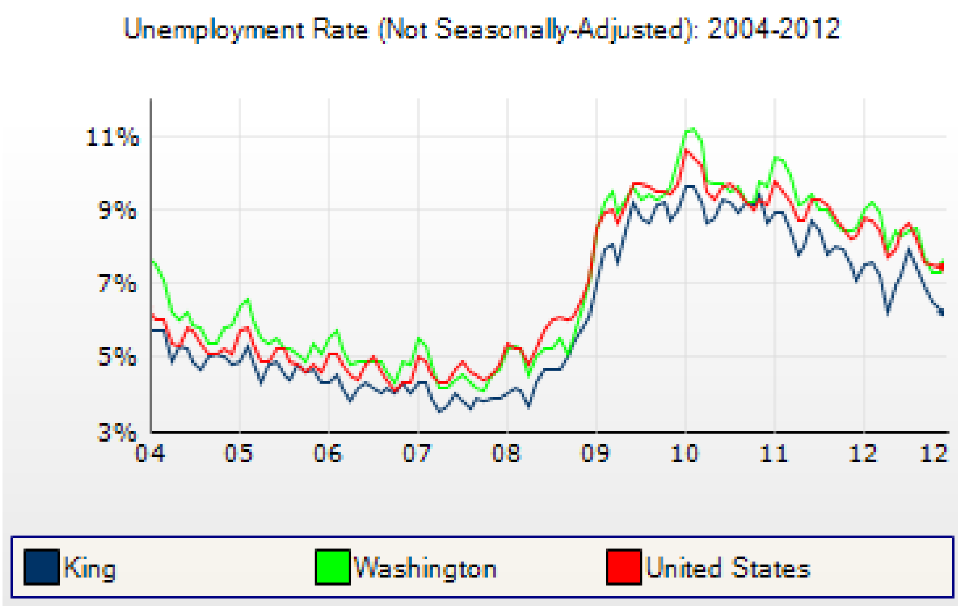
The Washington State Employment Security Department tracks historic unemployment data at the county level. The information is available through the Washington State Employment Security Department website[1]. For the Seattle/LWC UPA National Evaluation, the not-seasonally-adjusted unemployment statistics for King County and the state of Washington were monitored. Data from 2000 through 2012 was recorded.

Figure K-1 presents the not-seasonally-adjusted unemployment rates for King County, Washington state, and the United States from the Washington State Employment Security Department. Table K-1 presents the annual average King County and Washington state not-seasonally-adjusted unemployment rates for 2000 through 2012 from the Washington State Employment Security Department. Table K-2 contains the monthly Seattle area (King County and neighboring Snohomish Pierce Counties to the north and south, respectively) and Washington state not-seasonally-adjusted unemployment statistics for July 2008 through December 2012, which captures a one-year baseline period prior to the start of the first UPA-funded projects in July 2009.

As shown in Table K-1, the King County annual not-seasonally-adjusted unemployment rate ranged between 3.9 percent and 6.2 percent from 2000 to 2008, before increasing to 8.5 percent and 9.1 percent in 2009 and 2010, respectively. As shown in Table K-1 and Table K-2, the King County not-seasonally-adjusted unemployment rate steadily decreased through the pre- and post-deployment periods, falling from the high of 8.9 percent in January 2011 to a low of 6.1 percent in December 2012 for these periods. The King County not-seasonally-adjusted unemployment rate was 7.1 percent in December 2011 at the beginning of the post-deployment period when tolling commenced on the

[1] For more information, see: https://fortress.wa.gov/esd/employmentdata/reports-publications/regional-reports/numbers-and-trends

SR 520 Bridge. As shown in Figure K-1, the United States and Washington State not-seasonally-adjusted unemployment rates generally follow these trends.



Source: Washington State Employment Security Department. https://fortress.wa.gov/esd/employmentdata/reports-publications/regional-reports/numbers-and-trends.

Figure K-1. Monthly Unemployment Rates, Not-Seasonally-Adjusted

Table K-1. King County and Washington State Annual Average Unemployment Rate, Not-Seasonally-Adjusted

Month	Unemployment Rate	
	King County	Washington State
2000	4.1	5.0
2001	5.1	6.2
2002	6.1	7.4
2003	6.2	7.4
2004	5.1	6.2
2005	4.7	5.5
2006	4.1	4.9
2007	3.9	4.6
2008	4.7	5.4
2009	8.5	9.4
2010	9.1	9.9
2011	8.1	9.2
2012	7.0	8.2

Source: Washington State Employment Security Department. https://fortress.wa.gov/esd/employmentdata/reports-publications/regional-reports/numbers-and-trends.

Table K-2. Seattle area (King County, Snohomish County, and Pierce County) and Washington State Monthly Average Unemployment Rate, Not-Seasonally-Adjusted

Year	Month	Unemployment Rate			
		Seattle Area			
		King County	Snohomish County	Pierce County	Washington State
2008	July	4.7	5.3	5.7	5.2
	August	4.7	5.5	5.8	5.5
	September	5.0	5.7	5.4	5.1
	October	5.4	6.4	5.8	5.5
	November	5.7	6.7	6.3	6.2
	December	6.1	7.6	6.8	7.0
2009	January	7.0	8.8	8.4	8.4
	February	7.9	9.7	9.4	9.2
	March	8.1	9.7	9.9	9.5
	April	7.6	9.0	9.6	8.9
	May	8.4	9.8	9.9	9.3
	June	9.2	10.5	10.0	9.6
	July	8.8	10.1	9.9	9.3
	August	8.6	9.8	10.1	9.4
	September	9.1	10.4	9.6	9.3
	October	9.2	10.6	9.5	9.4
	November	8.7	10.3	9.6	9.6
	December	9.0	10.8	10.1	10.3
2010	January	9.6	11.3	11.3	11.1
	February	9.6	11.4	11.7	11.2
	March	9.2	10.9	11.4	10.8
	April	8.6	10.1	10.3	9.8
	May	8.8	10.2	10.3	9.7
	June	9.3	10.8	9.9	9.7
	July	9.2	10.5	9.7	9.5
	August	8.9	10.1	10.1	9.6
	September	9.2	10.4	9.4	9.2
	October	9.1	10.4	9.3	9.2
	November	9.4	10.7	9.7	9.8
	December	8.6	10.0	9.7	9.6

Table K-2. Seattle area (King County, Snohomish County, and Pierce County) and Washington State Monthly Average Unemployment Rate, Not-Seasonally-Adjusted (Continued)

Year	Month	Unemployment Rate			
		Seattle Area			
		King County	Snohomish County	Pierce County	Washington State
2011	January	8.9	10.6	10.6	10.4
	February	8.9	10.6	10.7	10.3
	March	8.4	10.0	10.5	9.9
	April	7.8	9.1	9.8	9.1
	May	8.0	9.2	9.9	9.2
	June	8.7	10.0	9.9	9.4
	July	8.4	9.8	9.5	9.0
	August	7.8	8.8	9.9	9.0
	September	8.0	8.9	9.3	8.6
	October	7.9	8.8	9.1	8.4
	November	7.5	8.7	8.8	8.4
	December	7.1	8.2	9.4	8.5
2012	January	7.5	8.8	9.7	9.0
	February	7.6	8.9	9.9	9.2
	March	7.2	8.3	9.7	8.9
	April	6.2	7.3	8.9	7.9
	May	6.9	7.8	9.1	8.4
	June	7.2	8.4	9.0	8.3
	July	7.9	8.4	9.0	8.4
	August	7.4	7.5	9.1	8.5
	September	6.9	7.1	8.1	7.7
	October	6.5	7.0	7.9	7.3
	November	6.3	6.8	8.0	7.3
	December	6.1	6.6	8.4	7.7

Source: Washington State Employment Security Department. https://fortress.wa.gov/esd/employmentdata/reports-publications/regional-reports/numbers-and-trends.

K.2 Gasoline Prices

Gasoline prices were monitored by the national evaluation team as changes in price may influence the demand for travel, which in turn influences vehicles miles of travel (VMT) and total trips. Increases in gasoline prices may also influence commuters who typically drive alone to take transit or to telecommute.

The U.S. Energy Information Administration monitors gasoline prices for selected regions, states and cities, including Seattle. Data on weekly and monthly retail gasoline prices for various grades since 2000 are available online on the Energy Information Administration website. Table K-3 presents the monthly average regular conventional retail gasoline prices in Seattle from the Energy Information Administration website from July 2008 through December 2012. Figure K-2 depicts the fluctuations of this data for this time period.

During the evaluation period gasoline prices reached a high of $4.36 per gallon in July 2008, as shown in Figure K-2. The major decline in gasoline prices in late 2008 reflects the decline in world crude oil prices, which dropped from a high of $147 per barrel in July to $70 per barrel in October and to $40 per barrel in December 2008. Figure K-2 shows that the price for a gallon of gasoline bottomed out at $1.77 in December 2008. In the pre-deployment period before the beginning of tolling on the SR 520 Bridge in December 2011, the price increased from $3.19 the week of December 27, 2010 to a peak of $4.06 in May 2011 to a trough of $3.48 the week of December 26, 2011. For the post-deployment period, gasoline prices were more volatile. The price of a gallon of regular conventional gasoline generally increased for the first five months to $4.33 the week of June 4, 2012, then dropped to $3.58 the week of July 16, 2012 before increasing to $4.11 the week of October 8, 2012, and finally decreasing again to a low of $3.37 the week of December 17, 2012.

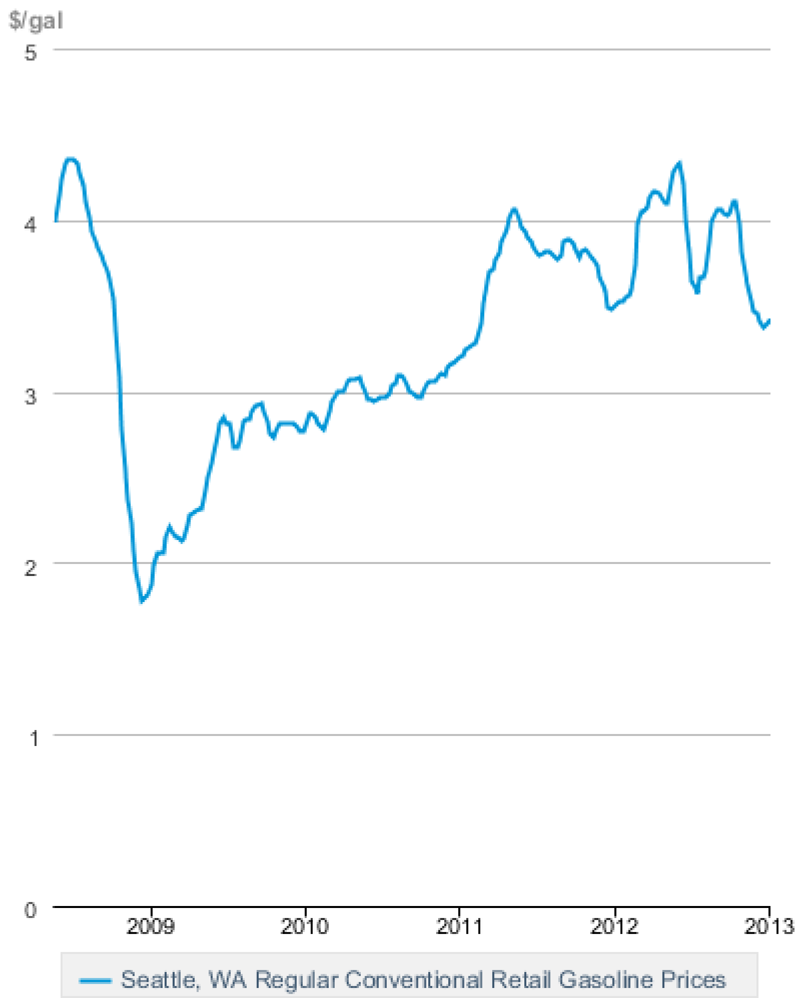
Table K-3. Monthly Average Seattle, WA Regular Conventional Retail Gasoline Prices

Year	Month	Gasoline Prices ($ per Gallon)
2008	July	4.289
	August	3.984
	September	3.748
	October	3.193
	November	2.305
	December	1.839
2009	January	1.992
	February	2.149
	March	2.159
	April	2.296
	May	2.457
	June	2.776
	July	2.73
	August	2.82
	September	2.915
	October	2.775
	November	2.815
	December	2.784
2010	January	2.85
	February	2.803
	March	2.96
	April	3.05
	May	3.03
	June	2.955
	July	2.991
	August	3.072
	September	2.984
	October	3.021
	November	3.084
	December	3.163

Table K-3. Monthly Average Seattle, WA Regular Conventional Retail Gasoline Prices (Continued)

Year	Month	Gasoline Prices ($ per Gallon)
2011	January	3.238
	February	3.375
	March	3.705
	April	3.891
	May	4.02
	June	3.887
	July	3.804
	August	3.797
	September	3.882
	October	3.815
	November	3.743
	December	3.544
2012	January	3.517
	February	3.717
	March	4.075
	April	4.147
	May	4.23
	June	4.09
	July	3.63
	August	3.901
	September	4.048
	October	4.011
	November	3.576
	December	3.407

Source: U.S. Energy Information Administration; http://www.eia.gov/dnav/pet/pet_pri_gnd_a_epmru_pte_dpgal_m.htm.



Source: U.S. Energy Information Administration;
http://www.eia.gov/dnav/pet/pet_pri_gnd_a_epmru_pte_dpgal_w.htm

Figure K-2. Seattle Historical Weekly Regular Retail Gasoline Prices – July 2008 to December 2012

K.3   Major Road Construction, Events, and Weather

Information from the WSDOT Toll Divisions Operations Team identified major construction activities, special events, and weather events in the region. Table K-4 summarizes the construction and weather conditions.

The Eastside Transit and HOV Project on SR 520 from Medina to SR 202 began in January 2011 and continued through the end of the post-deployment period. Being immediately to the east of the SR 520 bridge, this project disrupted traffic in the corridor and included full-weekend closures of all lanes of SR 520 on numerous occasions, as well as lane and ramp closures on SR 520 and adjacent streets as part of this project. This project influenced travel patterns in the corridor and transit operating speeds and travel times. Additionally, construction activities associated with the installation of the toll collection system on SR 520 in early 2011 could have impacted traffic on that corridor during the pre-deployment period. Major construction activities that impacted other corridors in the region, specifically I-90, I-405, and SR 99 are listed in Table K-4.

A number of events were recorded for the region during the pre- and post-deployment periods for consideration as exogenous factors. This included university basketball events and concerts at Key Arena; National Football League Seattle Seahawks events; Seattle Sounders Major League Soccer events; special exhibitions, and concerts at CenturyLink Field; exhibitions at the Washington State Convention and Trade Center; Seattle Mariners Major League Baseball events at SafeCo Field; and concerts, exhibitions, and festivals at the Seattle Center. Other events such as festivals and running and biking events in downtown Seattle and elsewhere in the area were also documented.

Only two major weather events were recorded during the analysis period. Snow was reported for the Seattle area for November 21-26, 2010 in the pre-deployment period and January 14-20, 2012 in the post-deployment period.

Table K-4. Major Road Construction and Weather Events During the Pre- and Post-Deployment Periods

Time Period	Affected Corridor	Major Event
Pre-deployment only; November 21-26, 2010	Regional event	Snow
Pre-deployment only; January 2011 – June 2011	SR 520	Toll Collection System Installation
Pre- and Post-deployment; began in January 2011	SR 520 (from Medina to SR 202)	Eastside Transit and HOV Project
Pre- and Post-deployment	SR 99	Aurora Corridor Project
Pre- and Post-deployment March 2010 – March 2012	I-90	Two-way Transit and HOV Operations Project
Pre- and Post-deployment; late 2009 – May 2012	I-405 (NE 8th St to SR 520)	Braided Ramps Project
Post-deployment only; January 14-20, 2012	Regional event	Snow
Post-deployment only; began in June 2012	I-405 (NE 6th Street to I-5)	Widening and Express Toll Lanes Project
Post-deployment only; began in June 2012	SR 99	SR 99 Tunnel Project

Source: WSDOT Toll Divisions

K.4 Major Transit Changes

King County Metro Transit also logged numerous exogenous factors that may have impacted transit service and ridership for the SR 520 corridor and around the region. These changes included fare changes, service changes, and changes to park & ride lots and other transit facilities. Although some highlights are given below, more information can be found in Appendix C: Transit Analysis.

In fall 2012, King County Metro Transit fare collection transitioned to a system-wide “pay on entry” system. This change meant that all riders pay as they enter the bus, making the system simpler to understand and use, although it likely increased travel time in the central business district in the p.m. peak period.

Additionally, changes were made to several park and ride lots. In particular, the number of spaces available at the South Kirkland Park and Ride lot, located on SR 520 between Lake Washington and I-405, decreased by 131 on August 20, 2012 and another 89 on October 22, 2012 during a construction project, leaving 376 parking spaces available through the end of the post-deployment period.

Appendix L. Compilation of Hypotheses/Questions for the Seattle/LWC UPA National Evaluation

Evaluation Analysis	Hypothesis/ Question Number	Hypothesis/Question
Congestion	SEACong-1	Deploying the UPA projects reduced travel times and increased speeds on SR 520 over Lake Washington (between I-5 and I-405)
	SEACong-2	Deploying the UPA projects did not increase travel times or decrease speeds of these nearby facilities: I-90 general purpose lanes (between I-5 and I-405) I-90 Express Lanes I-90 (between Issaquah/MP 19.41 and I-405) SR 522 (between I-405 and I-5) I-5 (between SR 522 and I-405) I-405 (between SR 167 and SR 522) SR 520 (between SR 202 and I-405)
	SEACong-3	Deploying the UPA projects improved travel time reliability on SR 520 over Lake Washington (between I-5 and I-405)
	SEACong-4	Deploying the UPA projects did not decrease travel time reliability of nearby facilities, namely: I-90 general purpose lanes (between I-5 and I-405) I-90 Express Lanes I-90 (between Issaquah/MP 19.41 and I-405) SR 522 (between I-405 and I-5) I-5 (between SR 522 and I-405) I-405 (between SR 167 and SR 522) SR 520 (between SR 202 and I-405)
	SEACong-5	Total Corridor Throughput of the roadways around and over Lake Washington remained the same or increased as a result of the Seattle/LWC projects
	SEACong-6	Vehicle and person throughput on SR 520 remained the same or increased as a result of the Seattle/LWC projects

Evaluation Analysis	Hypothesis/ Question Number	Hypothesis/Question
Congestion (Continued)	SEACong-7	The Seattle/LWC UPA projects did not reduce the throughput on nearby facilities, namely: I-90 general purpose lanes (between I-5 and I-405) I-90 Express Lanes I-90 (between Issaquah/MP 19.41 and I-405) SR 522 (between I-405 and I-5) I-5 (between SR 522 and I-405) I-405 (between SR 167 and SR 522) SR 520 (between SR 202 and I-405)
	SEACong-8	The UPA projects will improve averages speeds on SR 520 (to be consistently above a specific target speed to be agreed upon in advance by the local partners and U.S. DOT)
	SEACong-9	The UPA projects did not increase the temporal or spatial extent of congestion on nearby facilities, namely: I-90 general purpose lanes (between I-5 and I-405) I-90 Express Lanes I-90 (between Issaquah/MP 19.41 and I-405) SR 522 (between I-405 and I-5) I-5 (between SR 522 and I-405) I-405 (between SR 167 and SR 522) SR 520 (between SR 202 and I-405)
	SEACong-10	Travelers will perceive that congestion has been reduced in the SR 520 corridor
	SEACong-11	Travelers will not perceive that congestion increased on nearby facilities, namely: I-90 general purpose lanes (between I-5 and I-405) I-90 Express Lanes I-90 (between Issaquah/MP 19.41 and I-405) SR 522 (between I-405 and I-5) I-5 (between SR 522 and I-405) I-405 (between SR 167 and SR 522) SR 520 (between SR 202 and I-405)

Evaluation Analysis	Hypothesis/ Question Number	Hypothesis/Question
Tolling	SEATolling-1	How will travelers utilize the SR 520 tolling system?
	SEATolling-2	Variable pricing SR 520 will regulate vehicular access so as to improve the operation of SR 520
Transit	SEATransit-1	Seattle/LWC UPA projects will enhance transit performance in the SR 520 corridor through reduced travel times, increased reliability, and increased capacity
	SEATransit-2	Seattle/LWC UPA projects will facilitate an increase in ridership and a mode shift to transit on the SR 520 corridor
	SEATransit-3	Mode shift to transit will result in reduced road congestion on the SR 520 corridor
	SEATransit-4	What was the relative contribution of each Lake Washington UPA project element to increased ridership and mode shift to transit?
Telecommuting/TDM	SEATele/TDM-1	Promotion of commute alternatives and other options (mode, time) removes trips and VMT from SR 520
	SEATele/TDM-2	What was the relative contribution of the various Seattle UPA Telecommuting/TDM initiatives on reducing SR 520 vehicle trips/VMT?
	SEATele/TDM-3	Employees who use telecommuting as an alternative to commuting and their managers will perceive no reduction in the employees' productivity
Technology	SEATech-1	The travel time signs will promote a more even distribution of traffic between SR 520 and alternate routes (I-405 and SR 522)
	SEATech-2	Active Traffic Management will promote smoother traffic flow and better throughput on SR 520 and I-90 during non-incident conditions
	SEATech-3	Active Traffic Management will reduce the number of congestion-causing crashes on SR 520 and on I-90.
	SEATech-4	Active Traffic Management in the Lake Washington Corridor will reduce the duration of congestion-causing incidents on SR 520 and I-90
	SEATech-5	Active Traffic Management will reduce the impact severity of congestion-causing incidents
Safety	SEASafety-1	Tolling, ATM and traveler information (e.g., travel time sign) strategies that entail unfamiliar signage and which may alter existing traffic flows will not adversely affect highway safety

Evaluation Analysis	Hypothesis/ Question Number	Hypothesis/Question
Equity	SEAEquity-1	What are the direct social effects (tolls paid, travel times, adaptation costs) for various transportation system user groups from tolling the SR 520 Bridge, transit, and other UPA strategies?
	SEAEquity-2	What is the spatial distribution of aggregate out-of-pocket and inconvenience costs, and travel time and mobility benefits?
	SEAEquity-3	Are there any differential environmental impacts on certain socio-economic groups?
	SEAEquity-4	How does reinvestment of revenues from tolling SR 520 impact various transportation system users?
Environmental	SEAEnvironmental-1	What are the impacts of the UPA strategies in the SR 520 corridor on air quality?
	SEAEnvironmental-2	What are the impacts on perceptions of overall environmental quality?
	SEAEnvironmental-3	What are the impacts on energy consumption?
Non-Technical Success	SEANon-Tech-1	What role did factors related to these five areas play in the success of the deployment? 1. People (sponsors, champions, policy entrepreneurs, neutral conveners) 2. Process (forums [including stakeholder outreach], meetings, alignment of policy ideas with favorable politics and agreement on nature of the problem) 3. Structures (networks, connections and partnerships, concentration of power and decision-making authority, conflict-management mechanisms, communications strategies, supportive rules and procedures) 4. Media (media coverage, public education) 5. Competencies (cutting across the preceding areas: persuasion, getting grants, conducting research, technical/technological competencies; ability to be policy entrepreneurs; knowing how to use markets)
	SEANon-Tech-2	Does the public support the UPA strategies as effective and appropriate ways to reduce congestion?
Cost Benefit	SEACostBenefit-1	What is the net benefit (benefits minus costs) of the Seattle/ LWC UPA projects?

This page intentionally left blank

U.S. Department of Transportation
ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

Toll-Free "Help Line" 866-367-7487
www.its.dot.gov

FHWA-JPO-14-127

U.S. Department of Transportation