Evaluation of the Effects of Closing Interstate 5 Lanes and Ramps

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16. Abstract

This report describes the changes which occurred in traffic volumes, vehicle occupancy rates, and transit ridership as a result of the reconstruction of southbound Interstate 5, north of the Seattle CBD. Available data indicate significant changes in the routes and time of day of travel taken in the morning commute period, but show insignificant changes in the levels of carpooling and transit ridership despite aggressive attempts by local and state agencies to encourage high occupancy vehicle utilization during the reconstruction period.

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EVALUATION OF THE EFFECTS OF CLOSING INTERSTATE 5 LANES AND RAMPS

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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Washington State Transportation Commission, Department of Transportation, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

TABLE OF CONTENTS

LIST OF EXHIBITS

FINDINGS AND RECOMMENDATIONS

After an extensive review of the data gathered for this project, the project findings are as follows:

- Volumes changed as expected, with I-5 (main lanes) usage decreasing, and traffic on the express lanes, Aurora, and Eastlake increasing.
- Traffic volumes southbound, west of Lake Washington, decreased throughout the project by roughly 11 percent in the AM peak and 7 percent for total weekday traffic.
- Vehicle occupancy rates did not change appreciably throughout the reconstruction project.
- A 300 vehicle per morning increase in usage of the express lanes HOV ramp at Columbia/Cherry did occur, although previous studies indicate that only about 60 to 75 percent of these vehicles are carpools.
- Morning bus ridership increased 5.2 percent during the project in the study corridor. This increase is not statistically larger than the 3.8 percent increase measured over a similar time frame in 1983 when no major construction work was being performed.
- A significant increase in early morning traffic volumes was observed on all roads impacted by changing travel patterns.
- Only modest changes in volumes were observed on the Mercer/Valley one-way couplet as a result of the closing of the Mercer Street off-ramp from the I-5 main lanes.

As a result of the above findings, the project team makes the following recommendations for future major reconstruction efforts in the Seattle area:

- Continued emphasis on improvements to the traffic carrying capacity of parallel arterials (through signal timing, reduction in the number of allowed bridge openings, etc.) is of the utmost importance as these roads absorb a significant portion of the rerouted traffic.
- The early start and extensive nature of the public information campaign should be maintained, as the campaign appears to have succeeded in allowing companies and workers to schedule changes in their work hours, and allowed them to take significant portions of their vacation during the reconstruction period.
- New techniques are needed to increase the temporary mode shift of single person automobile users into transit or multi-occupancy vehicles. Such techniques might include providing carpool staging areas, providing for a higher profile enforcement of existing HOV facilities, installing ramp metering downtown with HOV by-pass lanes, easing the carpool restriction temporarily to allow two person carpools, and more aggressive marketing (including offering financial incentives) to major employers downtown.
- Conversely, it may be more cost effective to concentrate on encouraging changes in work hours and the taking of vacation time during the reconstruction project, as the shift in the times vehicles traveled and the loss of discretionary trips seemed to be the primary cause for the fairly high degree of success in minimizing traffic delays during the project. It must be noted, however, that previous attempts in this area have been hindered by construction scheduling changes.

EXECUTIVE SUMMARY

This report documents the investigation of the traffic effects of the reconstruction of Interstate 5, southbound, north of Seattle, during the summer of 1985. During the project, all southbound freeway lanes were reconstructed, with only two lanes open at any one time. Furthermore, for portions of the reconstruction period, two off-ramps from the freeway to the Seattle CBD were also closed. This study describes the alternative travel patterns, particularly changes to southbound morning commute patterns, which resulted from the closures. Exhibit E-1 presents a map of the study area. Exhibit E-1 also shows the alternative corridors available to travelers moving into downtown from the northern and northeastern portions of the metropolitan region.

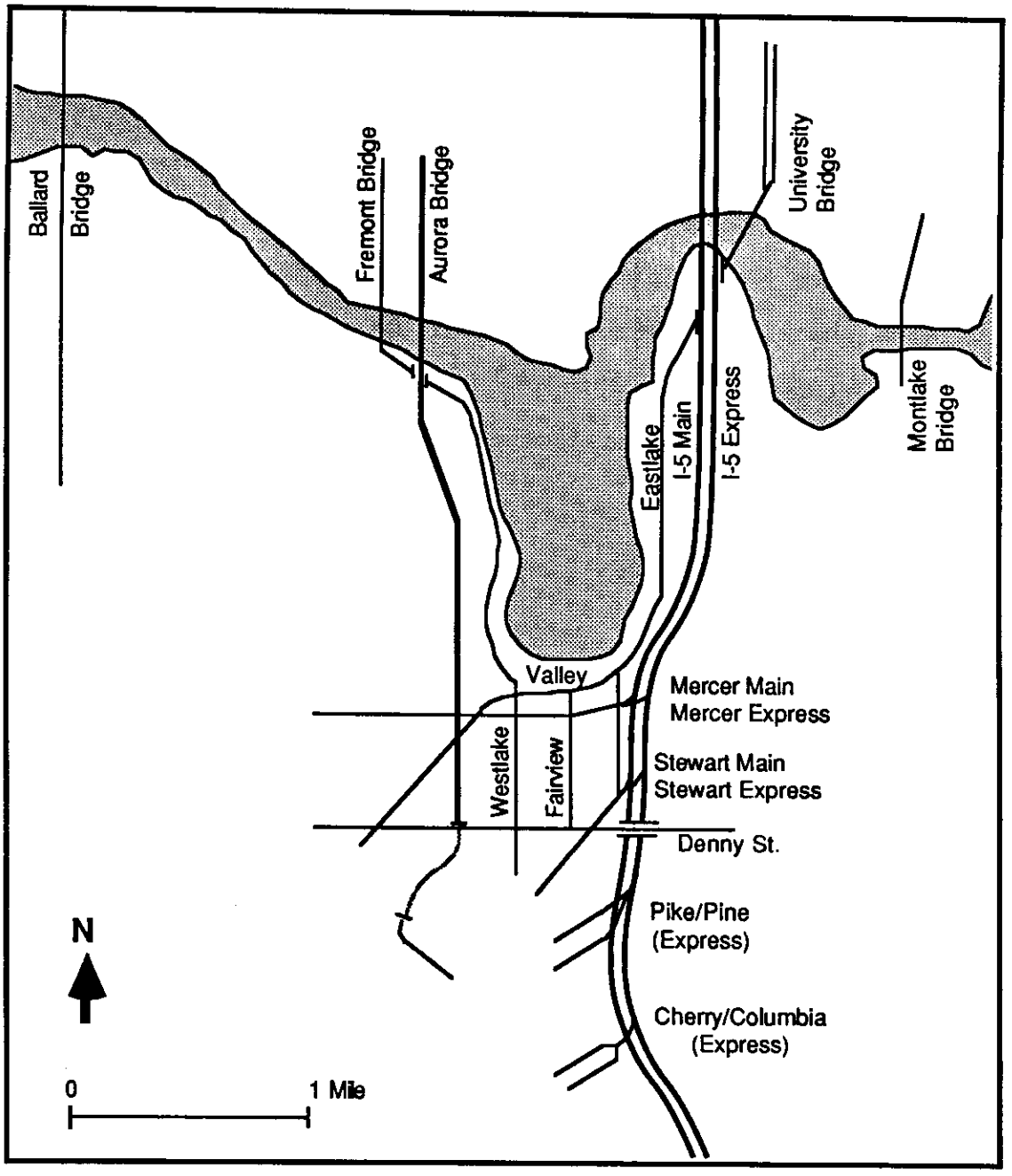
BACKGROUND

As can be seen in Exhibit E-1, I-5 is the primary north/south corridor on the western side of Lake Washington. Aurora Boulevard (SR 99) is the second major corridor. Both of these routes operate at or near capacity during the peak travel times of the day. In addition to the main lanes on I-5, four reversible express lanes, located in the center of the interstate, and several city arterials were available for traffic in the peak direction.

The Washington State Department of Transportation, the City of Seattle and the Municipality of Metropolitan Seattle (METRO) took several coordinated steps to reduce the impact of the loss of the two ramps and two lanes of traffic. Among the measures taken by these agencies were increases in the amount of bus service provided, additional hours of service on the reversible express lanes in the affected direction, the dissemination of significant amounts of information to promote ridesharing and public transportation, and retiming of several city arterial traffic signal networks.

Exhibit E-1

Map of Study Area



DATA COLLECTION

The three government agencies and the Washington State Transportation Center (TRAC) collected data before the project began and then at least once more during the project. TRAC collected vehicle occupancy information at four freeway off-ramps and three city arterials. These data were collected from 7 AM to 9 AM on weekdays, before, during and after the reconstruction project. These vehicle occupancy data were used to determine whether the carpooling rates changed on roads affected by the reconstruction project.

The Washington State Department of Transportation collected traffic counts at freeway main lane and express lane on- and off-ramps. These traffic data were obtained for 15 minute periods and summarized for each 24 hour day. These data were used for determining the shift of traffic volumes across time periods, for estimating the increases in traffic volumes on freeway ramps, and for comparison with the manual vehicle counts collected by TRAC as part of the vehicle occupancy data collection.

City of Seattle volume counts on bridges spanning the Lake Washington Ship Canal were used to estimate the changes in volumes on city arterials.

METRO transit passenger volumes were available for before the reconstruction and for one or two points during the reconstruction project. METRO also provided TRAC with ridership counts taken at similar times of the year during 1983. These data were used to determine whether observed ridership changes were caused by seasonal fluctuations in bus ridership, or by the reconstruction effort and the various mitigation efforts. The year 1983 was chosen because it was the most recent year in which major construction had not taken place in the Seattle freeway network.

TRAFFIC VOLUME CHANGES

Three different types of traffic volume changes occurred during the study period. These changes included shifts in the travel paths used to reach the CBD; shifts in the

time periods used for commuting into the CBD; and shifts in the number of people using their own automobiles to reach the CBD. The first two of these subjects are discussed in the subsections immediately below detailing the changes in travel paths, the effects those changes had on freeway ramp volumes, the effects these changes had on the Mercer Corridor, and the changes in traffic pattern characteristics. The subject of changing travel modes is discussed under Vehicle Occupancy later in this summary.

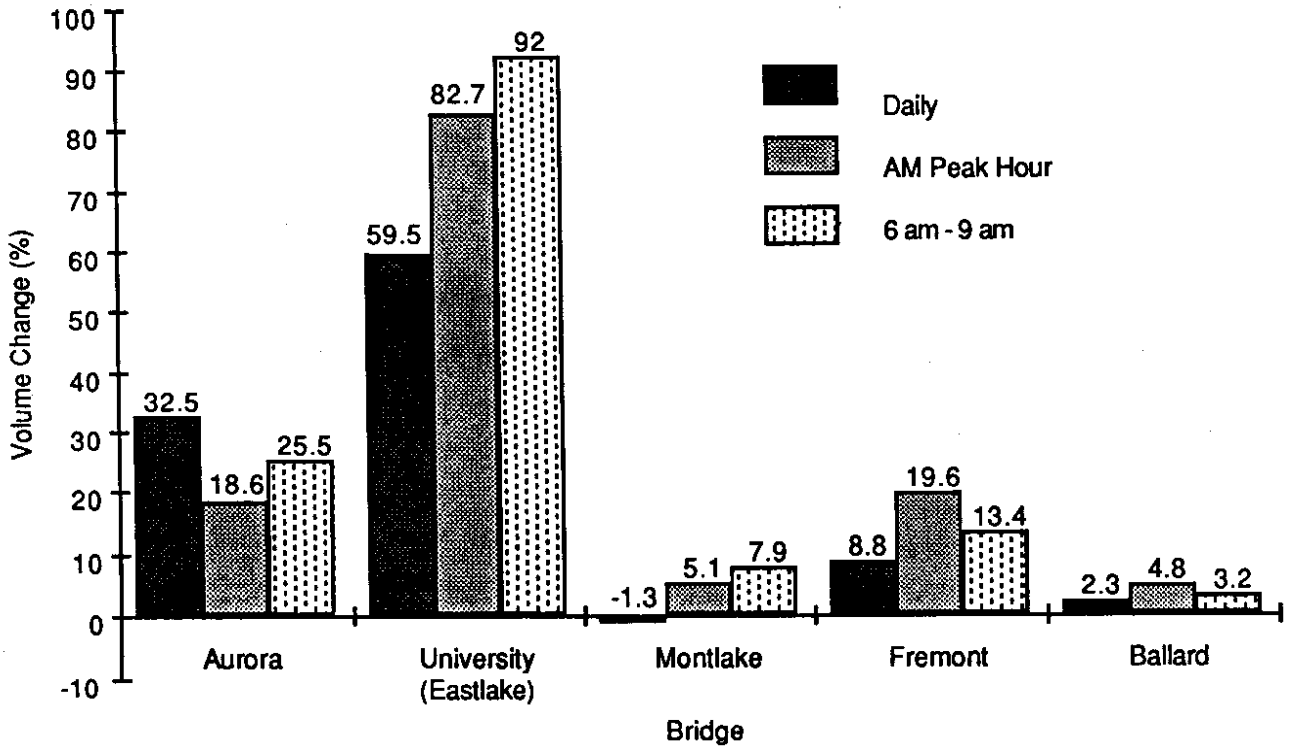
Travel Path Changes

With the reduction of two lanes of capacity on the interstate, I-5 (main and express lanes combined) carried roughly 4,700 fewer vehicles in the peak hour than normal, a 33.7 percent decrease. About half of these vehicles switched to alternative arterials during the peak hour. The majority of the arterial increases came on Aurora Avenue (747 additional vehicles in the peak hour) and Eastlake (844 additional vehicles per peak hour). While these increases were large, these roads showed even higher percentage increases in vehicles during the early morning time periods (i.e., 6:00 AM to 7:15 AM) than during the peak hour (see Exhibit E-2). For the morning period from 6 to 9 AM, Eastlake showed an increase in traffic of 92 percent (1,894 vehicles). Its peak hour volume increase was only 83 percent. Similarly, Aurora volumes increased over 25 percent for the three hour period and only 18.5 percent during the peak hour. On Aurora, the higher percentage increase during the three hour morning commute was the result of the roadway being near capacity during the peak hour even without the I-5 construction project. On Eastlake, the higher percentage increase was more likely due to the low volumes normally present on that road at that time of day.

The Ballard and Montlake bridges showed the lowest increase in volumes, both in percentage and absolute terms. The low increases on Montlake may have been due to several factors, including the heavy congestion which sometimes occurs on Montlake during peak periods, the rerouting of traffic due to the closure of the ramp to

Exhibit E-2

Daily and AM Percentage Volume Changes



westbound SR-520, or it may indicate that Eastlake was a faster travel path than using Montlake and passing through Capitol Hill. Montlake traffic levels did rise considerably more during the three hour AM period than during the single peak hour (377 versus 107).

Lake Washington Boulevard from SR-520 to Madison Avenue did not show a substantial increase in traffic despite the fact that it serves as an alternative route into the CBD for vehicles crossing the Evergreen Point Floating Bridge. This is somewhat surprising in that the congestion at the connection between I-5 and SR-520 was fairly heavy throughout the reconstruction effort, although less severe than originally anticipated.

Daily changes in traffic volumes were as significant as AM peak changes. I-5 southbound experienced a 37,200 vehicle decrease in total daily weekday traffic. This represents a decrease of 31 percent. Of these vehicles 21,700, or 58 percent, switched to SR-99 or city arterials to cross the Lake Washington Ship Canal. The remaining 42 percent either used I-405, switched modes (i.e., became carpools or used the bus) or did not make the trip.

Ramp Usage

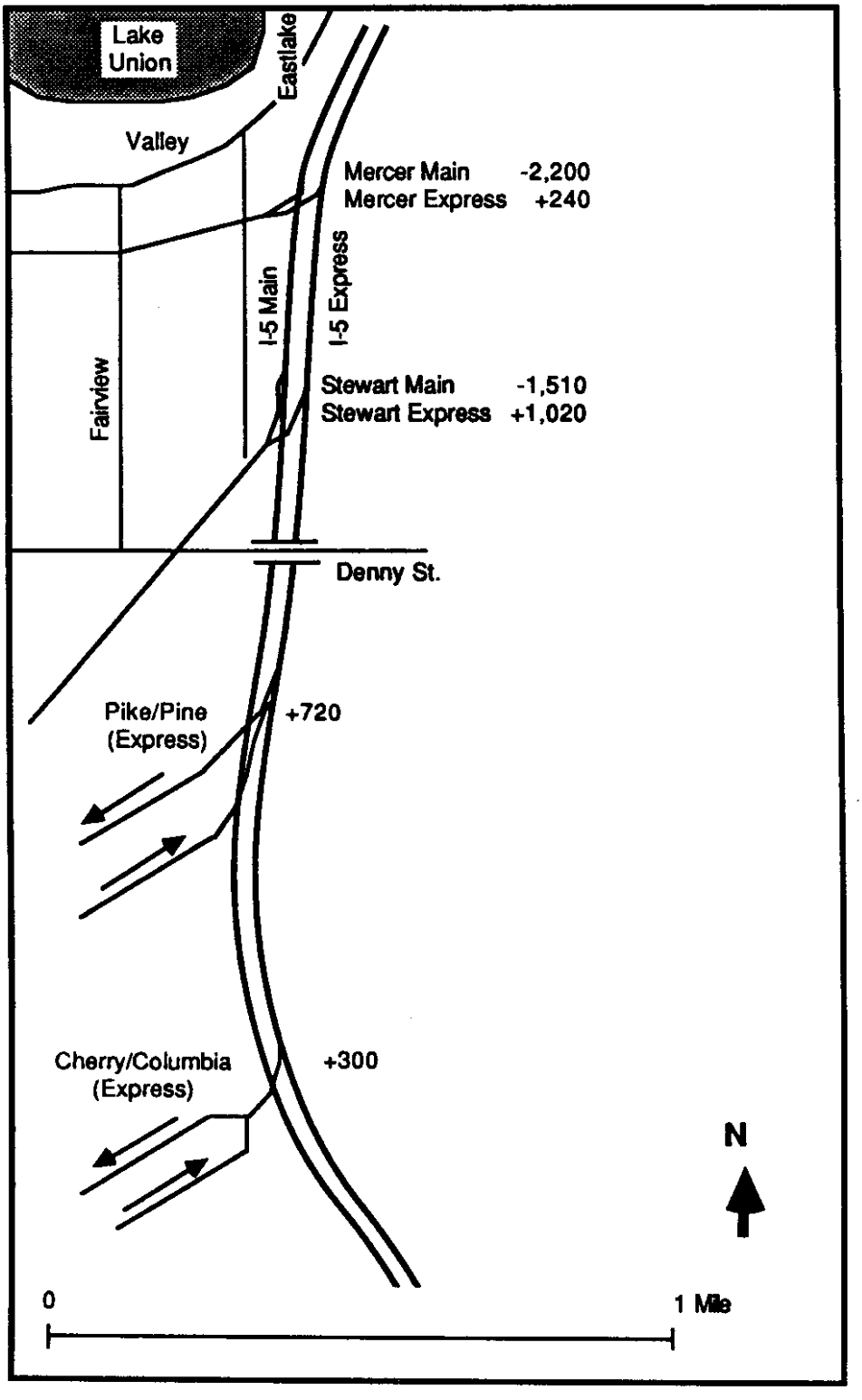
In general, all express lane ramps showed increased AM peak volumes throughout the project (Exhibit E-3). The express lane ramp volumes tended to increase slowly throughout the reconstruction project, and then return to pre-project levels upon completion of the project. Some peak hour congestion effects were noticeable in the growth of the express lane ramp volumes.

The Mercer and Stewart main lane ramps showed a decreased traffic volume throughout the reconstruction effort. Combined, the Mercer and Stewart ramps lost roughly 3,700 vehicles in the three hour peak during all three of the construction phases of the project.

Exhibit E-3

Changes in Three Hour Morning Ramp Volumes

(All ramps open, Phase 4)



Effect of Mercer Ramp Closure

The closure of the I-5 ramp at Mercer had surprisingly little effect on the traffic volumes measured on westbound Valley Street (the second half of the Mercer one-way couplet), east of Westlake Boulevard. While the ramp closure forced the rerouting or mode switching of roughly 3,200 vehicles in the AM peak period (1,300 in the peak hour), the City measured only a 200 vehicle drop in the peak hour volume for Valley, west of Westlake Boulevard. This may have been due in part to the limited number of traffic counts made by the City of Seattle and the high degree of variability in traffic volumes during the reconstruction period.

Of the 3,200 diverted vehicles, roughly 1,000 switched to using the Mercer express ramp from I-5. Approximately 950 other vehicles used the University Bridge and Eastlake to access Valley. Approximately 400 switched to the Stewart ramp (either express or main lane) and continued on Denny Way, and the remainder changed modes or used Aurora Avenue. In terms of average daily traffic, the closure of the Mercer ramp caused a 15.7 percent decrease in traffic on Valley. This represents 5,300 vehicles per day.

Denny Way showed a 200 vehicle increase in the peak hour east of Aurora (25 percent) and a 110 vehicle peak hour increase west of Aurora (13 percent) during this time frame. Average weekday volumes on Denny increased by 31 percent and 14 percent, respectively. This indicates that Denny was not the primary alternative for commuters usually using the Mercer main lane ramp.

Traffic Characteristics

The increases shown in total peak period volumes for the express lane ramps came mostly from an increase in traffic during the early portion of the commute period (6 AM to 7:15 AM). This shift in travel by time of day was also apparent on most city arterials. This indicates a shift in the time of day travel took place, as motorists

attempted to avoid the congestion occurring as a result of the construction. During the 7:15 to 9:00 AM periods, traffic levels on expressway ramps normally approximated their pre-construction levels despite added congestion.

Another change that was apparent was that the day-to-day variation in traffic levels was significantly greater during the construction period than during normal traffic operations. Exhibit E-4 illustrates the changes in this day-to-day variation during the project.

VEHICLE OCCUPANCY

The vehicle occupancy data indicate that in general there was no significant change in automobile occupancy rates during the reconstruction period (see Exhibit E-5). The two locations which did show significant changes in occupancy rates were Eastlake Boulevard, which showed a slight increase in automobile occupancy, and the Mercer express lanes freeway ramp, which showed a slight decrease in automobile occupancy rate. The closing of the Stewart and Mercer ramps did not have a significant effect on the occupancy rate at any of the occupancy count locations.

One other change that was noticeable was an increase in the observed variation in the automobile occupancy rate after the construction project began. The average coefficient of variation (COV) for the automobile occupancy rate before the project was 0.009; for the various phases during the project, the COV jumped to 0.016. It is not known what caused this increased amount of variation, but the most likely causes include instability of newly formed carpools, instability of carpools as a result of the number of vacations being taken in the summer, and/or unusually high amounts of experimentation with carpooling in an attempt to mitigate the traffic conditions.

Note that the occupancy counts were not performed at the Cherry/Columbia HOV exit from the express lanes. This exit did have a 200 to 300 vehicle/peak period increase

Exhibit E-4

90% Confidence Limit Volumes
(Stewart Express Ramp)

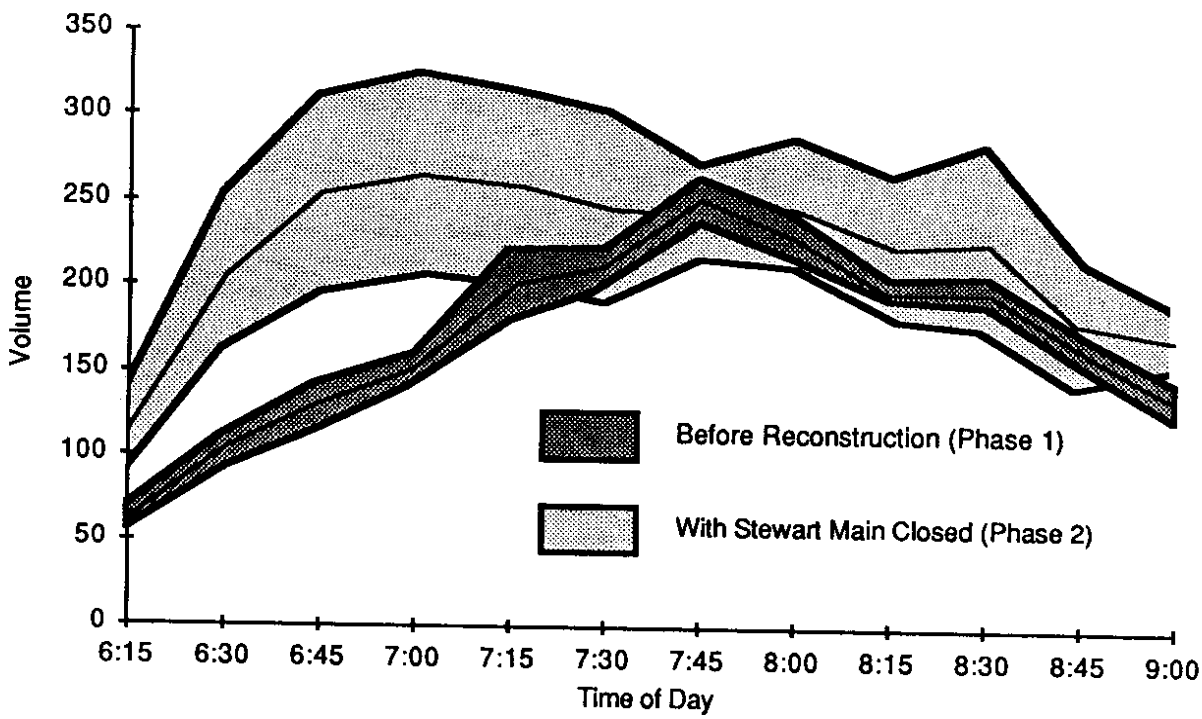


Exhibit E-5

Selected Auto Occupancy Rates

Location	Before	Stewart Ramp Closed	All Ramps Open
Aurora	1.17	1.16	1.17
Mercer Main	1.15	1.15	1.16
Stewart Ex.	1.24	1.21	1.21
Eastlake	1.14	1.16	1.17

in traffic during the construction period. It is highly likely that a large portion of these additional vehicles were not previously carpools, and they thus represent at least some consistent formation of carpools as a result of the efforts of the City, METRO and the Department to encourage ridesharing.

Bus Ridership

The analysis of 1985 METRO data shows an increase in July/August morning ridership over that experienced in June for all count locations except the Pine/Pike expressway ramp. This ramp mostly serves buses inbound from the extreme northern boundaries of the METRO service area (Bothell, Woodinville, etc.). Exhibit E-6 shows the total average passenger change that METRO observed at each of its five CBD count locations.

Further analysis showed that these ridership increases were not significantly different from changes measured during similar time periods in 1983. This analysis showed that only the Aurora corridor had a ridership increase that was larger (within statistical confidence limits of 90% $\pm$ 5%) than that observed in 1983.

Person Movements

Changes in person movements during the AM peak period were very similar to changes in vehicle volumes as the occupancy rate of vehicles did not change significantly. For the most part, the main lanes of I-5 experienced a significant decrease in utilization while all other north/south roads experienced some increase. The express lanes of I-5, Aurora Avenue and Eastlake all experienced significant increases in person travel, while Westlake, Montlake and 15th Avenue (the Ballard Bridge) experienced relatively low growth in person travel. These increases in travel occurred throughout the morning, with higher percentages occurring in the early morning hours (6 AM to 7:15) than during the AM peak period.

With the exception of the express lanes and Aurora, almost all person travel growth was directly related to increases in single occupancy vehicle utilization of the roadway. The express lanes and Aurora both experienced a significant increase in the number of bus passengers. Aurora experienced an increase in passengers per bus. The express lanes experienced a small (statistically significant) increase in passengers per bus, but a large influx of buses rerouted from the main lanes and a marginal increase in multi-occupancy vehicles.

Exhibit E-6

Morning Peak Bus Passenger Ridership Change at Metro Locations

(June vs. July/August)

Location	1985 Change	1983 Change
Aurora	+ 131	- 128
Westlake	+ 12	+ 76
Cherry	+ 361	+ 435
Pine	- 64	- 342
Stewart	+ 293	+ 494
TOTAL	+ 733	+ 535
	(5.2%)	(3.8%)

CHAPTER 1
INTRODUCTION

This report documents the investigation of the traffic effects of the reconstruction of Interstate 5, southbound, north of Seattle, during the summer of 1985. This study describes the alternative travel patterns which resulted from the the closure of two to three lanes of the interstate throughout the project, as well as the closure of two different off-ramps that led into the Seattle Central Business District (CBD).

This chapter is divided into three sections. The first will provide the reader with some background on the reconstruction project and travel patterns prior to the disturbance. The second section will describe the objectives of this study more fully, and the third section will describe the content and layout of this report.

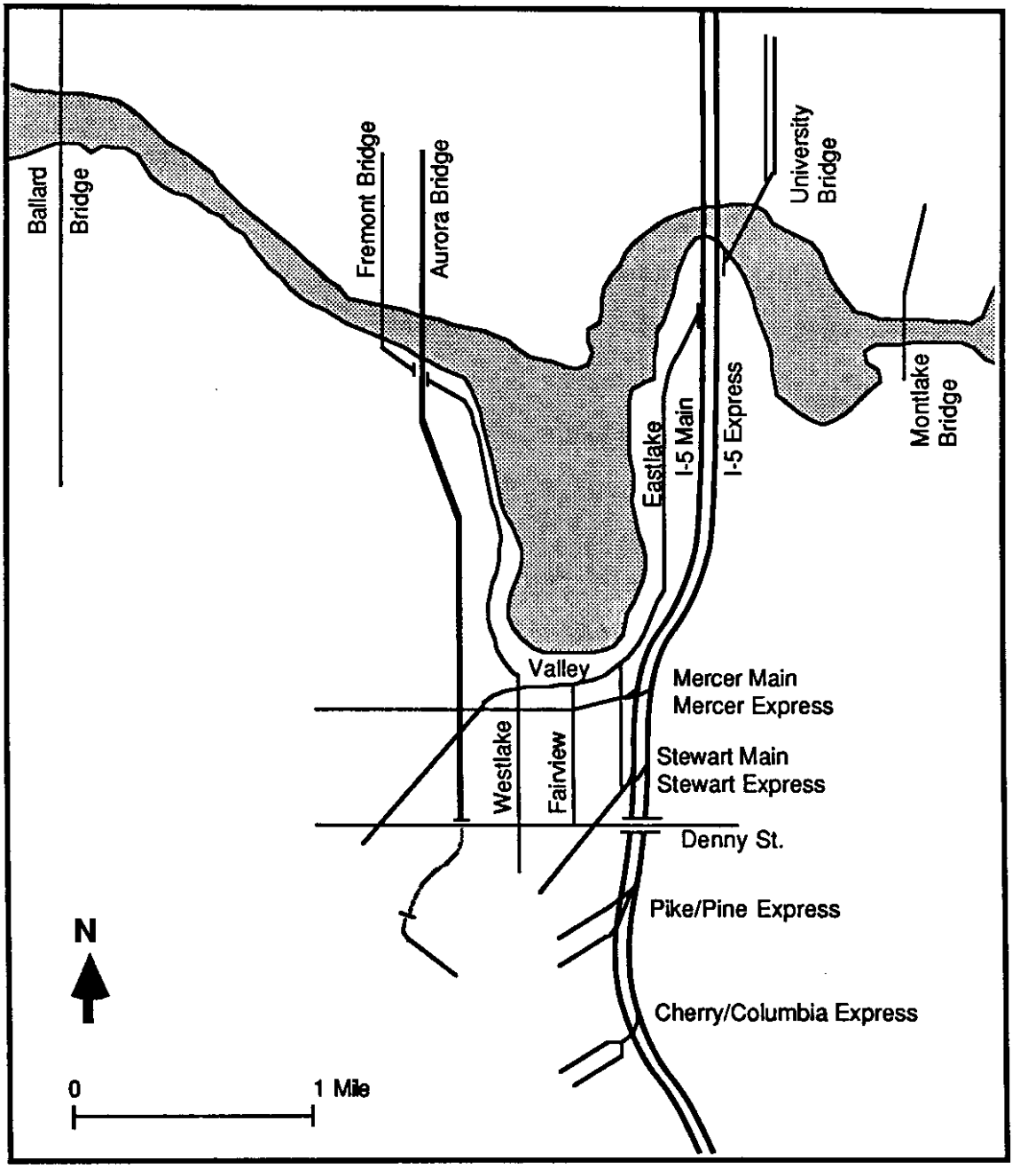
BACKGROUND

During the summer of 1985, the southbound lanes of Interstate 5 north of the Seattle CBD were closed for major reconstruction. All lanes were reconstructed, but two lanes were open at all times during the project. Furthermore, for portions of the reconstruction period, two off-ramps from the freeway to the Seattle CBD and several on-ramps to the freeway north of Seattle were also closed. Exhibit 1 presents a map of the study area and shows the extent of the freeway reconstruction effort.

Exhibit 1 also shows the alternative corridors available to travelers moving into downtown from the northern and northeastern portions of the city. As can be seen, I-5 is the primary north/south corridor on the western side of Lake Washington. Aurora Boulevard (SR 99) is the second major corridor. Both of these routes operated at or near capacity during the peak travel times of the day. In addition to the main lanes on I-5, four reversible express lanes, located in the center of the interstate, were available in

Exhibit 1

Map of Study Area



the peak direction. During normal operation, the express lanes operated from 4:30 AM to 11:30 AM inbound and at all other times in the outbound direction.

Other north/south travel routes must utilize one of four bridges. These bridges (Montlake, University, Fremont and Ballard) were all located on principal arterial roadways that usually experienced below-capacity traffic during the peak periods. However, these roads were signalized, and travel on them was usually slower than on the two express facilities (I-5 and Aurora) during peak periods, except for those travelers living close to the City and having poor access to I-5 and Aurora.

In addition to the traffic from northern Seattle, the reconstruction project also affected travelers from the suburbs east of Lake Washington (Bellevue, Kirkland, Juanita, etc.), whose normal travel path into downtown Seattle crossed the Evergreen Point floating bridge (SR-520) and connected into I-5. These travelers had fewer alternative routes. Their main alternative was to cross the lake using I-90, across Mercer Island. Their other alternatives were to cross on SR-520 and exit either onto Lake Washington Boulevard (entering downtown via Madison Avenue and Capitol Hill) or onto Montlake Boulevard and use the Montlake bridge to reach Capitol Hill and then downtown.

For travelers starting both north and east of the CBD, some high occupancy vehicle (HOV) incentives already existed before the reconstruction project began. Lanes reserved for three or more person carpools and buses existed on both I-5 and SR-520. These lanes provided considerable time savings for HOVs on most morning peak periods.

The Washington State Department of Transportation (WSDOT), the City of Seattle (the City) and the Municipality of Metropolitan Seattle (METRO) took several coordinated steps to reduce the impact of the loss of the ramps and lanes. Among the measures taken by these agencies were the following:

- increases in the amount of bus service provided to corridors affected by the lane closures;
- additional hours of service on the reversible express lanes in the affected direction;
- a significant publicity and informational campaign using printed flyers and brochures, newspapers and TV coverage, and public meetings in areas affected by the project to encourage additional ridesharing and public transportation usage during the construction period;
- a hot-line to provide information to callers on the status of the project and the availability of various ramps;
- close cooperation with airborne radio traffic reporters to assist in the mitigation of the traffic delays experienced by motorists;
- a cross-over ramp was built from the southbound I-5 main lanes to the express lanes;
- several on-ramps in the construction area were either closed or converted to HOV (two-plus people per car);
- placement of highway advisory radio (HAR) transmitters to inform motorists of the construction taking place; and
- retiming of several City arterial traffic signal networks to improve southbound traffic flow.

These steps were similar to those taken during the reconstruction effort for the northbound lanes of I-5 during the summer of 1984. During that reconstruction effort, a total of 32,000 vehicle trips per day were eliminated or shifted from the I-5 main lanes to other routes.

Data collected during the 1984 reconstruction effort, however, was insufficient to tell the WSDOT what happened to the person trips represented by these changes. In

particular, the WSDOT had no idea whether the 6,000 vehicle trips per day that did not appear on alternative routes were not being made, or whether they were being made using high occupancy vehicles (bus or carpool).

OBJECTIVES

This study was developed to more comprehensively examine the changes which occurred in the travel patterns of the people commuting during the morning peak period using the affected traffic corridors. The study was intended to determine the effectiveness of the control measures used for diverting travelers away from the I-5 corridor. Specifically, the study examined how many travelers moved into high occupancy forms of transportation, how many changed travel times or routes, and how many simply stopped traveling as a result of the congestion.

A secondary objective for the study was to provide basic information on the travel patterns of commuters using the study corridors so that the data might be available for future use by the City or WSDOT. Specifically, the study attempted to describe the travel patterns along the study corridors in terms of

- auto occupancy rates,
- transit ridership, and
- traffic volumes.

It attempted to determine how these patterns changed over the course of the reconstruction project. The researchers hope that the information presented here, although not sufficient to meet all needs, may provide enough information to assist other engineers and planners in planning for major traffic disruptions.

To limit the scope of this project, the study looked at the effects of the reconstruction effort only on the AM peak period. This was the time period most significantly affected by the reconstruction effort. Traffic during the remainder of the day was also disrupted, with mid-afternoon traffic jams equaling or exceeding those

experienced during the morning period. Some of the effects of the reconstruction to total daily traffic patterns are also presented in this paper, but discussed only briefly.

CONTENT

This report is broken into five chapters, including this introduction. These chapters include the Executive Summary and Conclusions sections preceding the main document, and the three chapters that follow this introduction:

- Study Design,
- Data Collection, and
- Analysis and Results.

The Study Design chapter describes the task plan used by the project team to perform the project and the methodologies used to analyze the data collected. The Data Collection chapter describes what data was collected, how it was collected, why it was collected, and what difficulties were encountered when collecting it. The Data Analysis chapter discusses the results of the analysis, what conclusions can be drawn from the information, what assumptions were necessary to draw those conclusions, and how the study conclusions impact future efforts of this kind.

CHAPTER 2
STUDY DESIGN

The study was designed as a joint effort between TRAC, the WSDOT, the City and METRO. This was done because each agency had participated in the design of traffic mitigation measures and cooperation reduced the burden of data collection imposed on any one agency. In addition, the study was designed so that each agency would provide the information that it could collect most easily and which it could then use for other purposes. In actuality, some agencies simply collected data that they would normally have collected even if the reconstruction project had not been performed.

TRAC was responsible for the design of the study, the collection of vehicle occupancy information, compilation of data from the other agencies, the analysis of all information, and the production of this report. The other agencies were responsible for collecting data within their jurisdictions. The WSDOT supplied traffic volume data on the Interstate freeway and ramps. The City supplied traffic volumes for city streets, and METRO supplied bus ridership information.

The study was divided into three tasks:

- data collection,
- data analysis, and
- report production.

The data collection task is described in the next chapter. The methodologies used to analyze the collected data are described below.

DATA ANALYSIS METHODOLOGIES

Because the data to be used in the analyses were provided by different agencies and covered several different travel modes and traffic characteristics, the first task of

the project was to reorganize the available data into compatible formats. To do this, the collected data was organized by

- the time of day it was collected,
- the dates on which data were taken,
- the format on which they were stored (computer tape or paper coding sheets), and
- the location at which they were taken (and what corridors those locations represented).

The data were reformatted into five time periods, with each time period corresponding to the availability of ramps and freeway lanes before, during and after the project.

The data available for the analyses did not cover all of the time periods desired. By reorganizing all of the incoming information, however, some missing information was obtained by using data from secondary sources (e.g., the manual vehicle occupancy counts served as secondary vehicle counts, supplementing the machine counts taken by the WSDOT).

In most cases, two statistical tests were applied to the available data to investigate changes in traffic and passenger volumes. These tests were the following:

- the T-test (using both paired and unpaired data), and
- a dummy regression test where a dummy regression variable was used to test for the significance of an event occurring (e.g., closing a ramp).

Both tests normally produced the same results. The results of the T-test are usually presented in this report because they are more descriptive than the results of the dummy regression analysis.

In addition to the statistical tests, graphical displays of data were used in the data analysis. The graphical displays provided better visualization of the changing traffic characteristics than were available using the statistical analysis. This was

particularly useful for examining temporal changes in traffic volumes. Details of the analyses performed in each subject area are described below.

Auto Occupancy Calculations

The automobile occupancy calculations were based on the manual occupancy counts taken by TRAC. Two occupancy rates were estimated. The first excluded buses and the second included buses. To calculate occupancies, the following formulas were used:

$$\text{occupancy w/o bus} = (1 * A1 + 2 * A2 + 3 * A3 + 4 * A4 + 6 * A58 + 10 * A9) / (A1 + A2 + A3 + A4 + A58 + A9)$$

where

A1 = single person vehicles

A2 = vehicles with two occupants

A3 = vehicles with three occupants

A4 = vehicles with four occupants

A58 = vehicles with 5 to eight occupants

A9 = vehicles with 9 or more occupants

Occupancy including bus riders was calculated as follows:

$$\text{occupancy w/bus} = (1 * A1 + 2 * A2 + 3 * A3 + 4 * A4 + 6 * A58 + 9 * A9 + 20 * LHR + 35 * MHR + 25 * LHA + 60 * MHA) / (A1 + A2 + A3 + A4 + A58 + A9 + LHR + MHR + LHA + MHA)$$

where

LHR = standard sized transit coaches operating less than half full

MHR = standard sized transit coaches operating more than half full

LHA = articulated buses operating less than half full

MHA = articulated buses operating more than half full

These bus categories were selected in order to make the greatest use of the limited bus ridership data that could be collected by the individuals performing the vehicle occupancy counts.

Multiple days of vehicle data occupancy collection were available for each of the five project phases. As a result, a standard deviation of the occupancy rate could be calculated for each location and each phase of the project. The T-test was then used to test for the significance of the observed changes in vehicle occupancy rates. Significance tests were performed for changes between all phases and the before (initial) occupancy rate, and for changes between any two consecutive phases.

Spatial Volume Changes

Volume information on the various study area arterials and ramps came from three sources: TRAC, the WSDOT and the City. The WSDOT's ramp information was complete enough that statistical tests could be made to test the significance of volume changes observed during the project. The T-test and dummy regression test were used along with the measured standard deviation of ramp volumes to determine the significance of observed volume changes.

Not enough arterial volume information was available to allow statistical tests for measured changes in city street volumes for the majority of the project phases. In some cases (University Bridge, Aurora Avenue), the volume changes were large enough to indicate their significance even without the aid of statistics. In other cases (Ballard and Montlake bridges), changes were so small that significance probably could not have been shown even had sufficient information been available. The observed changes are described more fully in the Data Analysis Chapter.

Temporal Volume Changes

Estimation of temporal changes were primarily made on the basis of the WSDOT's ramp data. The multiple days available for counting during four of the five project

phases provided enough information to determine changes within the 6 to 9 AM time frame. In addition to the usual T-test and dummy regression tests, a graphical display of the results was used to examine the statistical precision of the observed changes.

Exhibit 2 shows a typical graph used in the analysis. This graph shows the mean and 90 percent confidence lines representing the expected traffic volumes per fifteen minute period for the Stewart Express lanes ramp during periods 1 and 4. The graph shows where the volume changes were significant (from 6:00 to 7:15) and where the observed changes fell within the regularly occurring traffic patterns.

Bus Ridership

Two sources of bus ridership estimates were available to calculate changes in transit patronage. The data collected by TRAC as part of the vehicle occupancy data collection provided a large number of data points, but the accuracy of the estimated per bus occupancy was insufficient for use in determining changes in ridership. METRO data were sufficiently accurate on a bus by bus basis for these measurements, but represented, at most, four days of data collection at each location. This small number of days for counting severely reduced the ability to test the statistical significance of the changes that were measured.

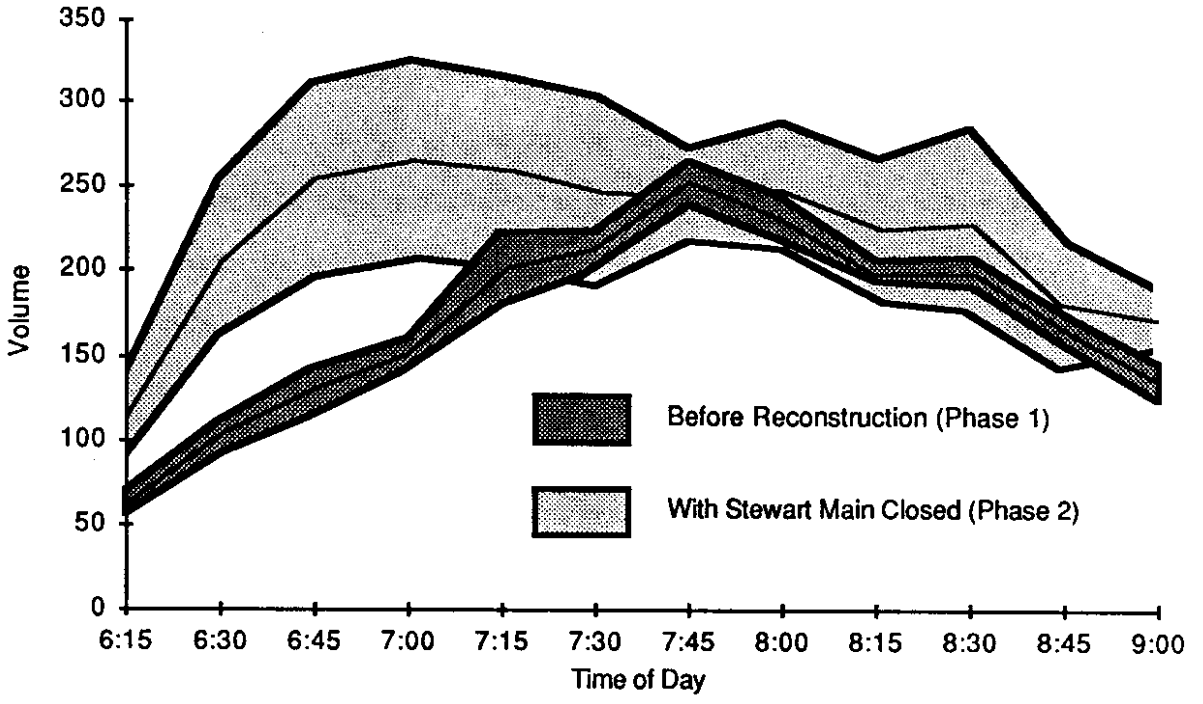
METRO transit data collected during the reconstruction project were also compared to data from a previous year to determine whether changes observed in 1985 were the result of the reconstruction or whether they resulted from seasonal fluctuations in transit patronage. For this analysis, a paired T-test was performed, comparing June to July/August ridership changes observed in 1985 with similar data collected in 1983.

Person Travel

The person travel estimates were made based on a combination of all of the above data. Vehicle occupancy rates from the TRAC data were applied to the volume information collected by the WSDOT and the City. For the Cherry/Columbia and

Exhibit 2

Stewart Express Ramp Volumes
(Graphical Analysis)



Pike/Pine off-ramps, where TRAC did not collect data, vehicle occupancy rates were assumed. For the HOV ramp at Cherry, an occupancy rate of 3.0 was selected because new carpools being formed would most likely meet but not exceed the normal minimum requirements for using an HOV facility. For the Pike/Pine off-ramp, the Stewart Express ramp occupancy rate was used, as this ramp most closely resembled the Pike/Pine ramp in terms of the destination of the vehicles using the ramp.

Changes in person travel were computed by calculating total person travel before and during the project, and then subtracting these values. Person travel was computed as follows:

person travel = automobile occupancy * volume + bus ridership.

Statistical tests were not applied to the estimates of person travel changes due to the wide variety of travel estimates (of varying quality) used in the calculations.

CHAPTER 3
DATA COLLECTION

This chapter describes the data collection activities for this project. The data collection was divided into two subtasks:

- data to be collected by TRAC, and
- data to be collected by other agencies.

TRAC DATA COLLECTION

TRAC was responsible for the collection of vehicle occupancy information. This information was collected by manual observation at eight locations. The locations chosen covered the two freeway ramps that would be closed at some time during the reconstruction period, the express lane ramps onto those same arterials, and the arterials which served as the most likely diversion routes for commuters avoiding the reconstruction. The eight locations are shown in Exhibit 3.

Data was collected during five separate phases of the reconstruction project. These phases corresponded to the following times and project events:

Phase 1) Before the reconstruction began (before June 28);

Phase 2) Initial reconstruction, Stewart Ramp closed (June 28 through July 14);

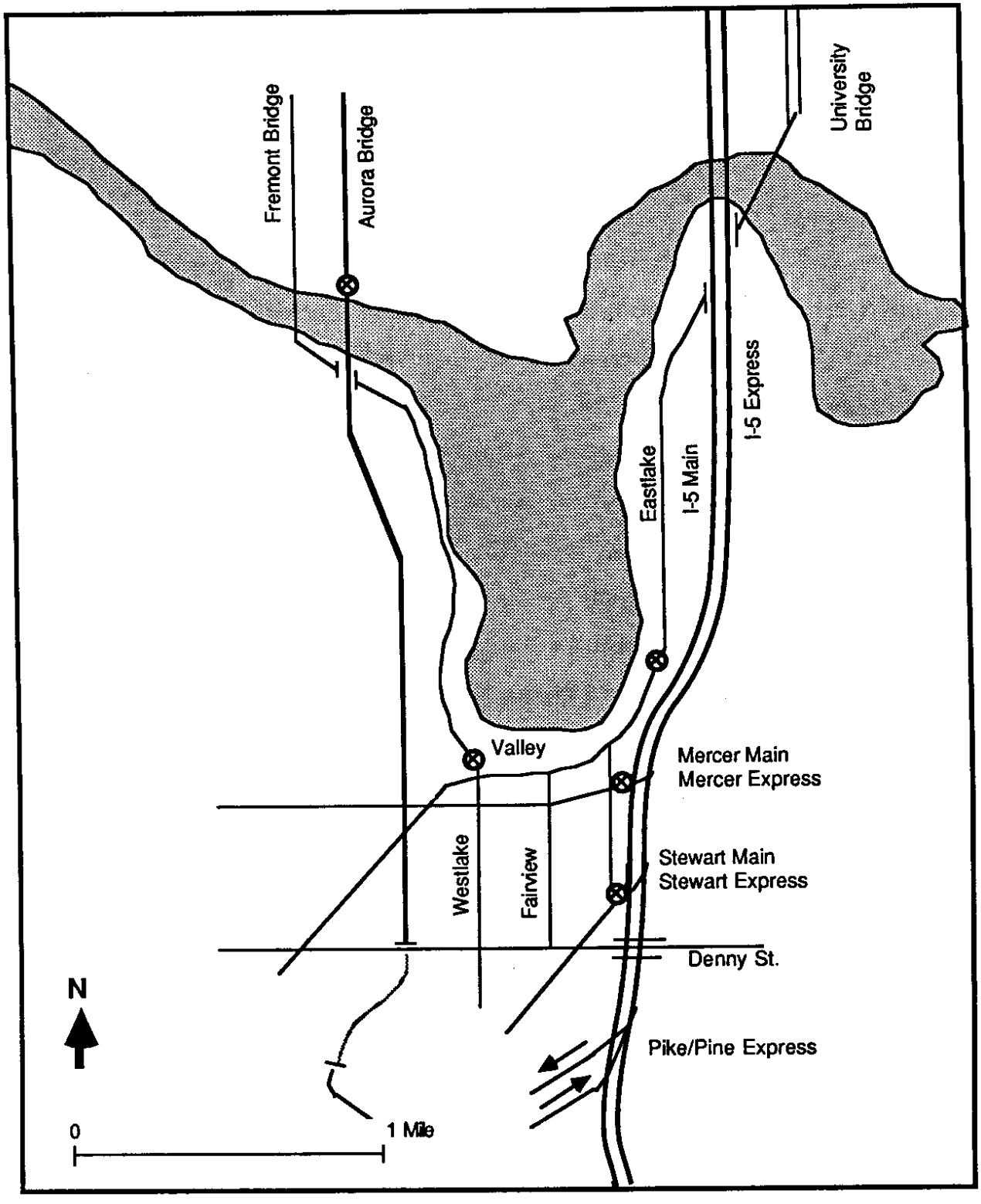
Phase 3) Mid reconstruction, Stewart Ramp open, Mercer Ramp closed (July 15 through July 29);

Phase 4) Final Reconstruction, All ramps open, but two main lanes still closed (July 30 through August 20, the completion of the reconstruction effort); and

Phase 5) After reconstruction was completed.

Exhibit 3

Location of Vehicle Occupancy Counts



These time periods were chosen so that the volume effects of the different ramp closures could be monitored, as could the effects of time on the commuters' choices of travel modes (i.e., as the project progressed, would the vehicle occupancies change as people experimented with carpooling, either forming more as the construction progressed or eliminating carpools that did not save them sufficient amounts of time?). Finally, we were interested in whether the act of closing freeway ramps would have a measurable effect on occupancy rates.

Data were collected at each ramp for two hours during the weekday, morning peak period for at least three days during each of the five periods listed above. Most observations were made on Mondays, Tuesdays and Wednesdays, although some counts were made during the later days of the week.

Vehicle occupancies were collected using the form shown in Exhibit 4. Counts were made in five minute intervals for two hours between 7 and 9 AM on weekday mornings. In addition to counting automobiles by occupancy category, buses passing these count locations were broken into four categories:

- standard size buses less than half full,
- standard size buses half or more than half full,
- articulated buses less than half full, and
- articulated buses half or more than half full.

These categories were chosen to provide a quick estimate of bus ridership change during the early portions of the project. It was not possible for the staff collecting vehicle occupancy data to provide a better estimate of bus ridership than that noted above, as the traffic volumes at all locations prevented an observer from concentrating on any one vehicle for a significant amount of time. METRO transit ridership counts served as the primary basis for estimating transit patronage. The effects of the reconstruction on bus ridership is described later in this report.

EXHIBIT 4

VEHICLE OCCUPANCY DATA COLLECTION FORM

Time:_____ Location:_____

Date:_____ Name of Observor:_____

1 Person Car & Trucks	2 Pers. Car	3 Pers. Car	4 Pers. Car	5-8 Pers. Car	9-11 Pers. Car	Reg Half Bus	Reg Full Bus	Art. Half Bus	Art. Full Bus	
										7:30-7:35
										7:35-7:40
										7:40-7:45
										7:45-7:50
										7:50-7:55
										7:55-8:00

OTHER AGENCY DATA COLLECTION

All three of the agencies collected data before the project began, and then at least once more during the project. In most cases, data could not be collected throughout all five time periods of the project. As a result, it was not possible to track all traffic characteristics and patterns across all of the time periods indicated above.

The Washington State Department of Transportation collected traffic counts at freeway main lane and express lane on- and off-ramps. Exhibit 5 indicates the location of the WSDOT's ramp counts and the number of counts made at each location during the various project time periods. As can be seen in this exhibit, WSDOT data was available for all time periods except for after completion of the project. The researchers assumed that after the reconstruction period ended, traffic returned to the same levels seen before the project began. Such a conclusion is supported by the volume and vehicle occupancy information compiled by TRAC.

The WSDOT's traffic data was obtained for 15 minute periods, and summarized for each 24 hour day. These data were extremely useful in determining the shift of traffic volumes across time periods, for estimating the increases in traffic volumes on freeway ramps not included in the TRAC vehicle occupancy data collection, and for comparing with the manual vehicle counts collected by TRAC as part of the vehicle occupancy data collection.

City of Seattle volume counts on bridges were used to estimate the changes in volumes on City arterials. The City was able to provide the counts shown in Exhibit 6. Because the counts taken by the City did not cover the various reconstruction time periods, much of the analysis on changing travel paths during the different project periods was prevented; however, there was enough information to determine the general change in the distribution of vehicles trying to reach the CBD during the reconstruction period as a whole.

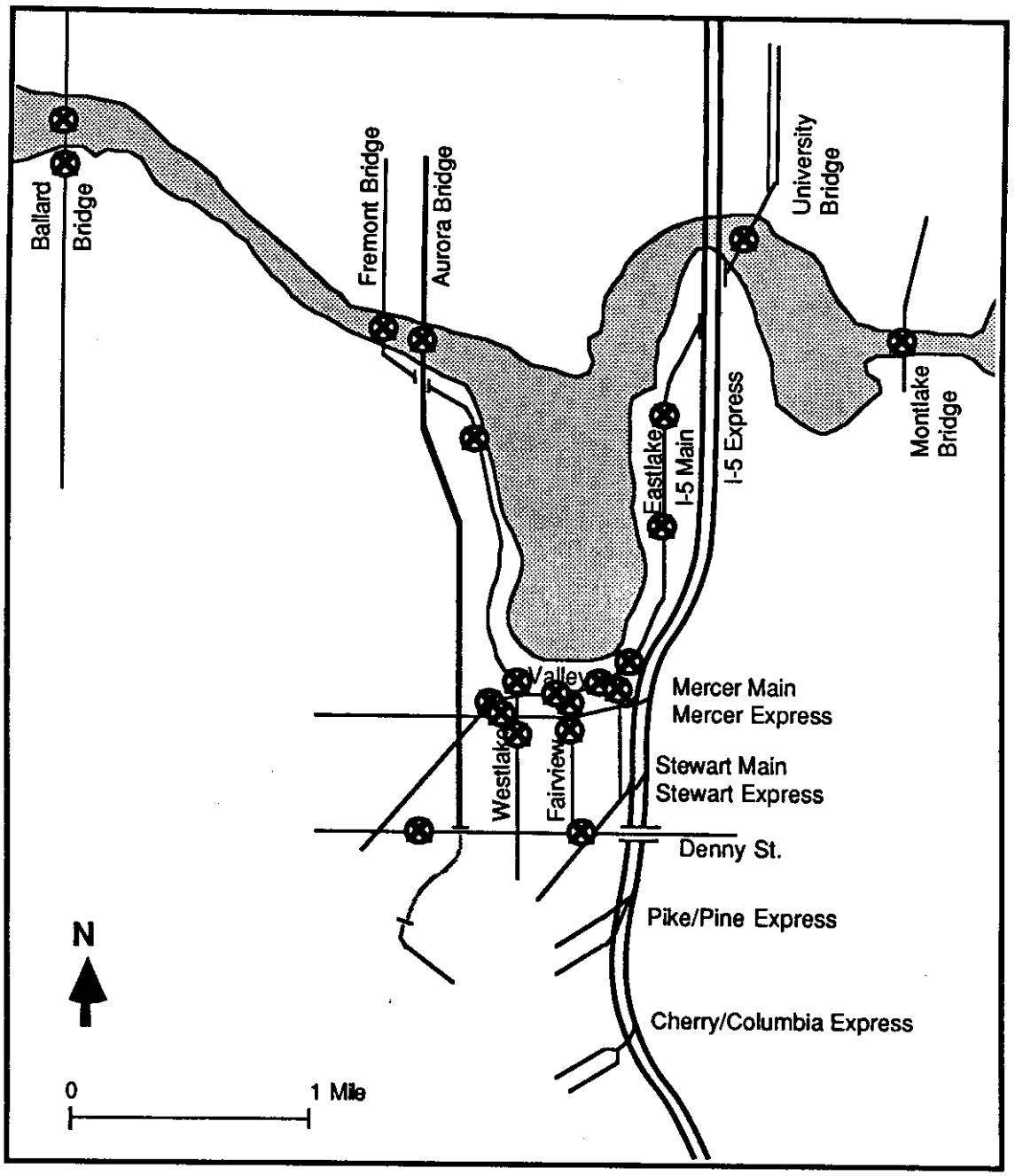
EXHIBIT 5
LOCATION AND NUMBER* OF WSDOT RAMP VOLUME COUNTS

	Time Period (Phase)				
Location	Before (1)	Stewart Closed (2)	Mercer Closed (3)	Ramps Open (4)	After (5)
Cherry/Columbia Express Ramp	5	2	0	9	0
Pike/Pine Express Ramp	5	6	10	11	0
Mercer Mainlane Ramp	6	6	0	8	0
Mercer Express Ramp	6	5	10	8	0
Stewart Mainlane Ramp	4	0	11	13	0
Stewart Express Lane Ramp	5	7	3	14	0
42nd Street Express Ramp	5	7	11	13	0
50th Street Express Ramp	0	8	6	12	0
Ravenna Express Ramp	0	0	3	8	0
Total	36	43	54	96	0

* Number of count days

Exhibit 6

Location of City of Seattle Counts*



* Additional counts were made on roads not shown on this map.

METRO transit passenger volumes were mostly available for two time periods, before the reconstruction and during the reconstruction project. Exhibit 7 shows where and when passenger load counts were taken during the project. As with the arterial volume data, this lack of information prohibited the analysis of changes in transit ridership by reconstruction time period, but did allow the analysis of changes over the reconstruction period as a whole.

METRO data normally consisted of two to four days' worth of load point passenger counts. One or two days of information was supplied during June (before the construction) and then again at some point during the construction period. Each count location provided information about ridership on several bus routes.

This amount of data was sufficient to estimate the general trends in ridership before and during the project period, but it did not provide for a high level of statistical confidence in the changes measured and the conclusions drawn from this information. For example, at the Westlake location, two load counts were performed during the reconstruction (July 25 and August 19). These two data points showed markedly different transit patronage. In the July count, ridership increased almost 13 percent from June, while in the August count it decreased almost 3 percent.

In addition to the data described above, METRO provided TRAC with ridership counts taken at similar times of the year during 1983. The year 1983 was chosen because it was the first year available when major construction was not taking place in the Seattle freeway network. During 1984 WSDOT was reconstructing the northbound lanes of I-5. This reconstruction effort would have caused changes in transit ridership similar to those being examined, and it was TRAC's intent to compare those changes to changes that might have normally occurred simply as a result of the time of year.

EXHIBIT 7
TRANSIT RIDERSHIP COUNT LOCATIONS AND DATES

Name	Location	Dates Counted	Routes Observed
Aurora	Aurora Bridge	June 27, 1985 July 25, 1985	5, 6, 29, 360, 403, 406
Westlake	7th and Westlake	June 25, 1985 July 25, 1985 August 19, 1985	26, 28
Cherry	5th and Cherry	June 17, 1985 June 18, 1985 July 8, 1985 July 9, 1985	16, 41, 71, 72, 73, 74, 75, 303, 304, 317, 355, 377, 416, 477
Stewart	Stewart and Eastlake	June 17, 1985 June 18, 1985 July 8, 1985 July 9, 1985	25, 32, 71, 72, 73, 74, 250, 251, 253, 254, 255, 256, 257, 258, 259, 260, 262, 267, 268, 311, 401, 402, 404, 405, 408, 409, 410, 411, 414
Pine	Pine I-5 Ramp	June 17, 1985 June 18, 1985 July 8, 1985 July 9, 1985	65, 301, 305, 306, 307, 308, 309, 310, 311

CHAPTER 4
ANALYSIS AND RESULTS

This chapter describes the changes that occurred in travel patterns, vehicle occupancies, time of travel, transit ridership and total person travel as a result of the reconstruction project. These various aspects of travel will each be discussed separately and will then be combined to describe the total changes that occurred as a result of the reconstruction lane closures and mitigating measures.

TRAFFIC VOLUME CHANGES

Three different types of traffic volume changes occurred during the study period. These changes included

- shifts in the travel paths used to reach the CBD,
- shifts in the time periods used for commuting into the CBD, and
- shifts in the number of people using their own automobiles to reach the CBD.

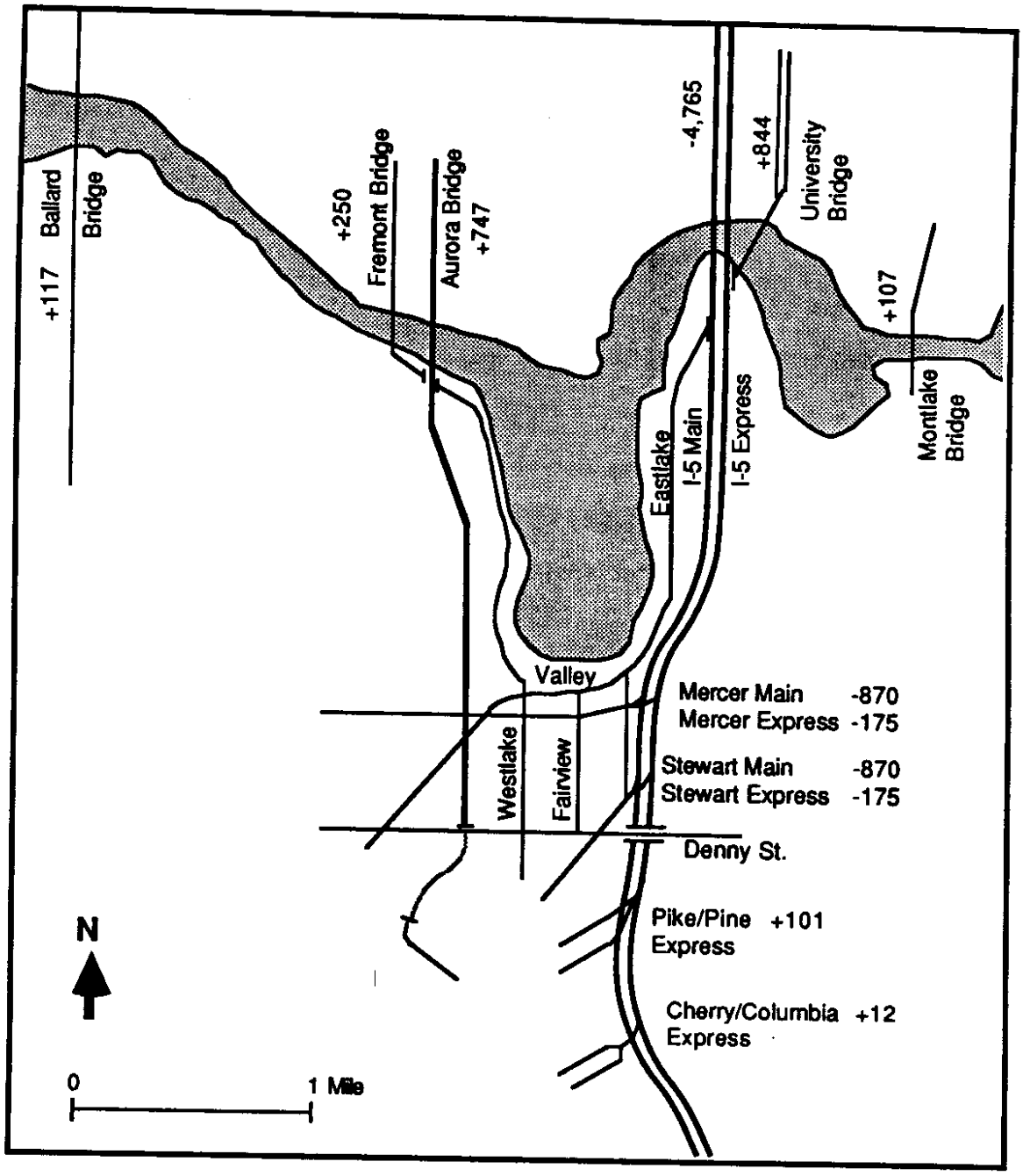
This section will describe the first two categories of change as measured by the collected data. Later sections of this chapter will describe the change in automobile usage.

Travel Path Changes

As was expected, significant shifts occurred in the travel paths used by morning commuters. With the reduction of two lanes on the interstate, I-5 (main and express lanes combined) carried roughly 4,700 fewer vehicles in the peak hour than normal. As can be seen in Exhibit 8, about half of these vehicles switched to alternative arterials during the peak hour. The majority of the travelers who changed routes chose Aurora Avenue (747 additional vehicles in the peak hour) and Eastlake (844 additional vehicles in the peak). These roads showed even higher percentage increases in vehicles during the early morning time periods (i.e., 6:00 AM to 7:15 AM). For the morning period from

Exhibit 8

Changes in Peak Hour Travel Volumes



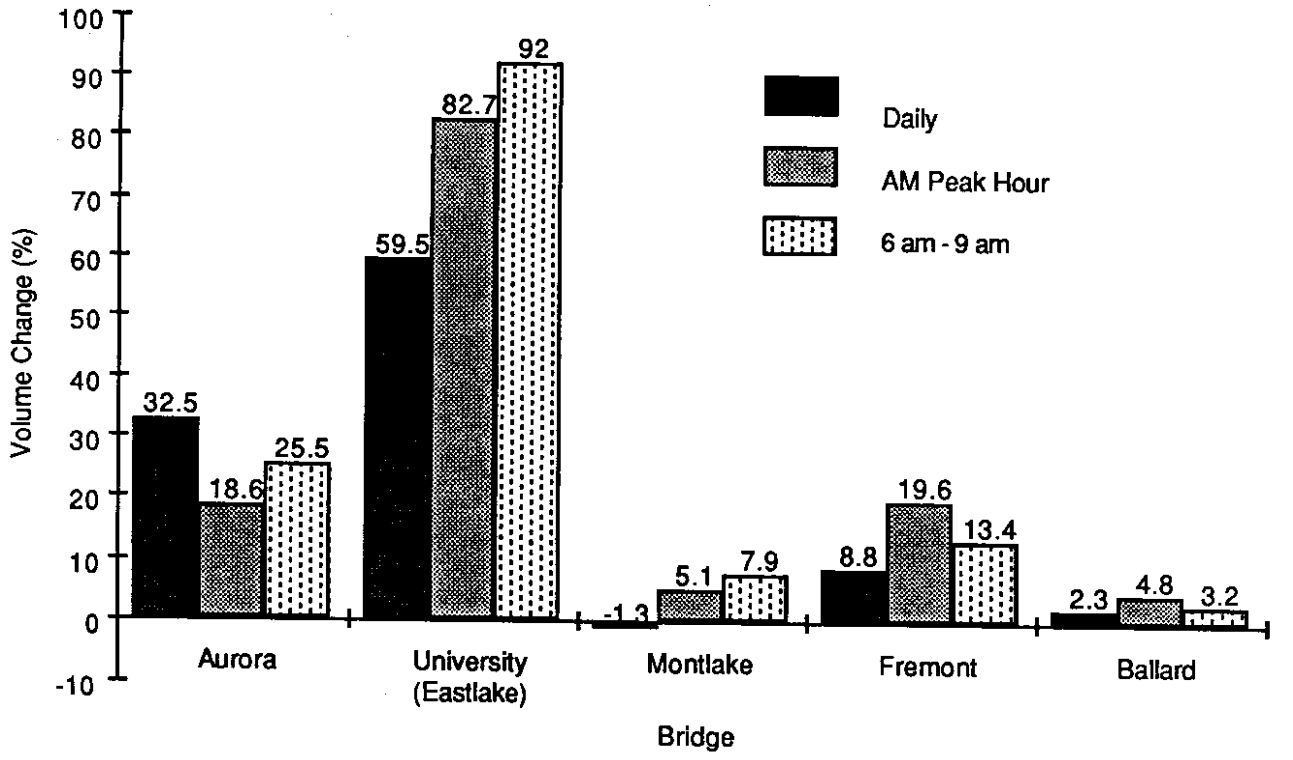
6 to 9 AM, Eastlake showed an increase in traffic of 92 percent (1,894 vehicles). Its peak hour volume increase was only 83 percent (see Exhibit 9). Similarly, Aurora volumes increased over 25 percent for the three hour period and only 18.5 percent during the peak hour. On Aurora, the higher percentage increase during the three-hour morning commute resulted from the fact that the roadway was near capacity during the peak hour even without the I-5 construction project. On Eastlake, the greater percentage increase was more likely due to the low volumes normally present on that road at that time of day.

Both of these traffic increases were expected. Aurora Avenue provides the most direct and fastest alternative to Interstate 5 for travel from the northern edges of the metropolitan region. Eastlake received an extra large amount of travel because the Montlake entrance to Westbound SR-520 and the 45th Street entrance onto I-5 were closed. These closures severely restricted access to the already congested freeway for those travelers living in the University District, Sandpoint, Laurelhurst, and Ravenna areas. With the loss of I-5, Eastlake was the fastest route into downtown from most of these areas.

The Ballard and Montlake bridges showed the lowest increases in volumes, both in percentage and absolute terms. The Ballard Bridge was not significantly affected by the reconstruction effort, probably because it was far enough west that it was difficult to access for the majority of travelers who might have wanted to avoid either I-5 or Aurora. The fact that the Montlake Bridge's volume did not increase significantly during the peak hour indicates that the majority of the traffic that might have used Montlake and 23rd avenues instead used the University Bridge and Eastlake. This may have been due to the sometimes heavy congestion which can occur on Montlake during peak periods, or it may indicate that Eastlake was a faster travel path than using Montlake (with or without congestion) and passing through Capitol Hill. However, during the

Exhibit 9

Daily and AM Percentage Volume Changes



three-hour AM period, Montlake traffic levels rose considerably more than during the single peak hour (377 versus 107). This indicates that at least some congestion-related restrictions to volume increases on Montlake occurred during the peak hour.

Lake Washington Boulevard from SR-520 to Madison Avenue did not show a substantial increase in traffic despite the fact that it serves as an alternative route into the CBD for vehicles crossing the Evergreen Point Floating Bridge. This is somewhat surprising in that the congestion at the connection between I-5 and SR-520 was fairly heavy throughout the reconstruction effort, and residents of the community surrounding Lake Washington Boulevard have often complained to the City that motorists from downtown use the Lake Washington ramp rather than using I-5 to get to and from SR-520.

Daily changes in traffic volumes were as significant as AM peak changes. I-5 southbound experienced a 37,200 vehicle decrease in total daily weekday traffic. This represents a decrease of 31 percent. Of these vehicles 21,700, or 58 percent, switched to SR-99 (Aurora) or city arterials to cross the Lake Washington Ship Canal. The remaining 42 percent either used I-405, switched modes (i.e., used carpools or the bus) or did not make the trip.

For the city arterials, only Aurora Avenue showed a larger (percentage) increase in daily volumes than in AM peak period volumes. Exhibit 9 shows these comparisons. The large increase in daily volumes on Aurora indicates that a large number of travelers from the north end of Seattle switched to Aurora. The lack of a similarly large increase on other city arterials most likely indicates that travelers starting closer to the city were more likely to switch to transit because transit service to those areas in the middle of the day was considerably more convenient than it was to northern Seattle. It is also possible that Aurora picked up much of the "through" travel normally on I-5, and that much of the discretionary travel to the Seattle CBD was not made during the reconstruction period.

Off-Ramp Usage

The usage of I-5 ramps which lead into the Seattle CBD is discussed separately because of the impact such information might have on future traffic routing during construction efforts downtown. The ramps into downtown were affected by two separate phenomenon:

- the loss of main lane freeway capacity from the north; and,
- the loss of the two exits (Stewart first, then Mercer) for the early stages of the project.

In general, all express lane ramps showed increased AM peak volumes throughout the project. Average AM volumes (6 AM to 9 AM) for the CBD ramps are shown in Exhibit 10. As can be seen in this exhibit, the express lane ramp volumes tended to increase slowly throughout the reconstruction project and then returned to pre-project levels upon completion of the project, although the Mercer ramp did show some congestion induced volume decreases towards the end of the project. The peak hour usage of the Mercer express ramp actually decreased slightly in phase 4 of the construction project, due to increased congestion on the express lanes themselves.

The Mercer and Stewart main lane ramps showed decreased traffic volumes throughout the reconstruction effort. Combined, the Mercer and Stewart ramps lost a total of roughly 3,700 vehicles in the three-hour peak during all three of the construction phases of the project.

Note that both ramps carried similar volumes while the other ramp was closed. When Stewart was closed, the Mercer ramp carried 2,290 vehicles per peak. With the Mercer ramp closed, the Stewart ramp carried 2,060 vehicles per peak period. With both ramps open, Stewart carried an average of 1,190 vehicles per morning, while Mercer carried 970 vehicles.

EXHIBIT 10
AVERAGE MORNING (6 AM TO 9 AM) RAMP VOLUMES

Ramp	Before Construction	Stewart Closed	Mercer Closed	Ramps Open
Mercer Main	3,170	2,290	C.L.	970
Mercer Express	2,720	3,270	3,710	2,960
Stewart Main	2,700	C.L.	2,060	1,190
Stewart Express	2,040	2,640	3,060	3,060
Pike/Pine (Express Ramp)	3,940	3,430	3,490	3,660
Cherry/Columbia (Express Ramp)	750	970	N/A	1,050

C.L. Ramp closed

N/A Data not available

Effect of Mercer Ramp Closure

The closure of the I-5 ramp at Mercer had surprisingly little effect on the traffic volumes measured on westbound Valley Street (the second half of the Mercer one-way couplet), east of Westlake Boulevard. While the ramp closure forced the rerouting or mode switching of roughly 3,200 vehicles in the AM peak period (1,300 in the peak hour), the City measured only a 200 vehicle drop in the peak hour volume for Valley, west of Westlake Boulevard. This result is rather surprising, and may be in part due to the limited number of days of data collection the City of Seattle was able to collect at this location, and the high degree of variation existing in traffic volumes during the reconstruction project.

Of the 3,200 diverted vehicles, roughly 1,000 switched to using the Mercer express ramp from I-5. Approximately 950 other vehicles used the University Bridge and East-lake to access Valley. Approximately 400 switched to the Stewart ramp (either express or main lane) and then Denny Way, and the remainder changed modes, used Aurora Avenue, or did not make the trip. In terms of average daily traffic, the Mercer ramp closure caused a 15.7 percent decrease in traffic on Valley. This represents 5,300 vehicles per day.

With Mercer closed, Denny Way showed a 200 vehicle increase east of Aurora (25 percent) in the peak hour and a 110 vehicle peak hour increase west of Aurora (13 percent). Average weekday volumes on Denny increased by 31 percent and 14 percent, respectively.

Traffic Characteristics

The increases shown in total peak period volumes for the express lane ramps came mostly from an increase in traffic during the early portion of the commute period (6 AM to 7:15). This indicates a shift in the time of day travel took place, as motorists attempted to avoid the congestion occurring as a result of the construction. During the

7:15 to 9:00 AM periods, traffic levels on expressway ramps normally approximated their pre-construction levels despite added congestion. Exhibit 11 graphically illustrates the increase in ramp volumes early in the morning commute period.

Ramp volume data was not collected for 1983. This information would have allowed the determination of whether this shift was caused exclusively by the reconstruction effort, or whether there was some seasonal component (i.e., commuters shift their work hours earlier to allow them to take more advantage of the light present in the evenings).

Another change that was apparent was that the day to day variation in traffic levels was significantly greater during the construction period than during normal traffic operations. As can be seen in Exhibit 12, this was particularly true for the freeway ramp volumes. This increase in traffic volume variability was undoubtedly due to a combination of two factors:

- the greater effect accidents and disabled vehicles had on I-5 capacity as a result of the loss of two lanes and reduction in available shoulders; and
- the difficulty drivers had in knowing when the Stewart and Mercer ramps would be open.

While the information put out by the WSDOT was for the most part accurate, the TRAC data collection team did find that on at least one occasion the Mercer ramp was not open to traffic despite the fact that the reconstruction hotline told travelers that the ramp was open. Motorists may very well have waited until they knew for sure that particular ramps were open again before attempting to use them. This would have resulted in a slowly increasing usage of the ramps after they were reopened. On top of this, morning commuters may have experimented with alternative morning routes to find the fastest path for reaching downtown during the construction period. Such experimentation could have significantly altered the day-to-day travel patterns that were

Exhibit 11

Stewart Express Ramp Volumes

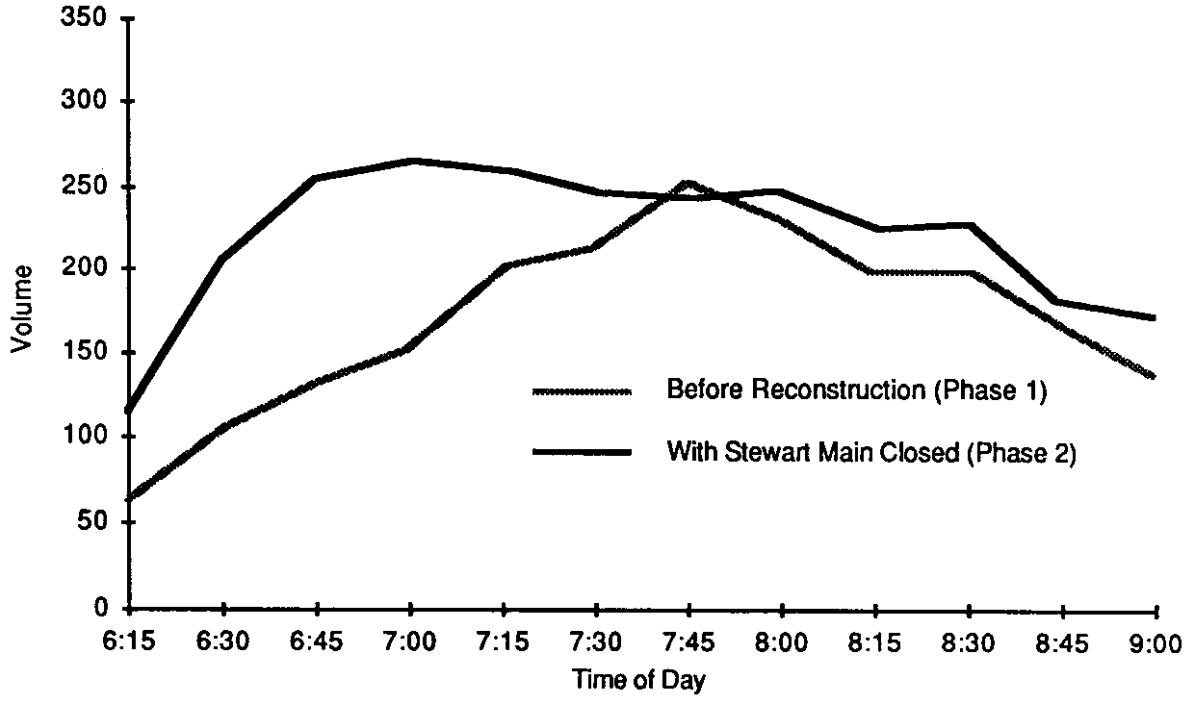
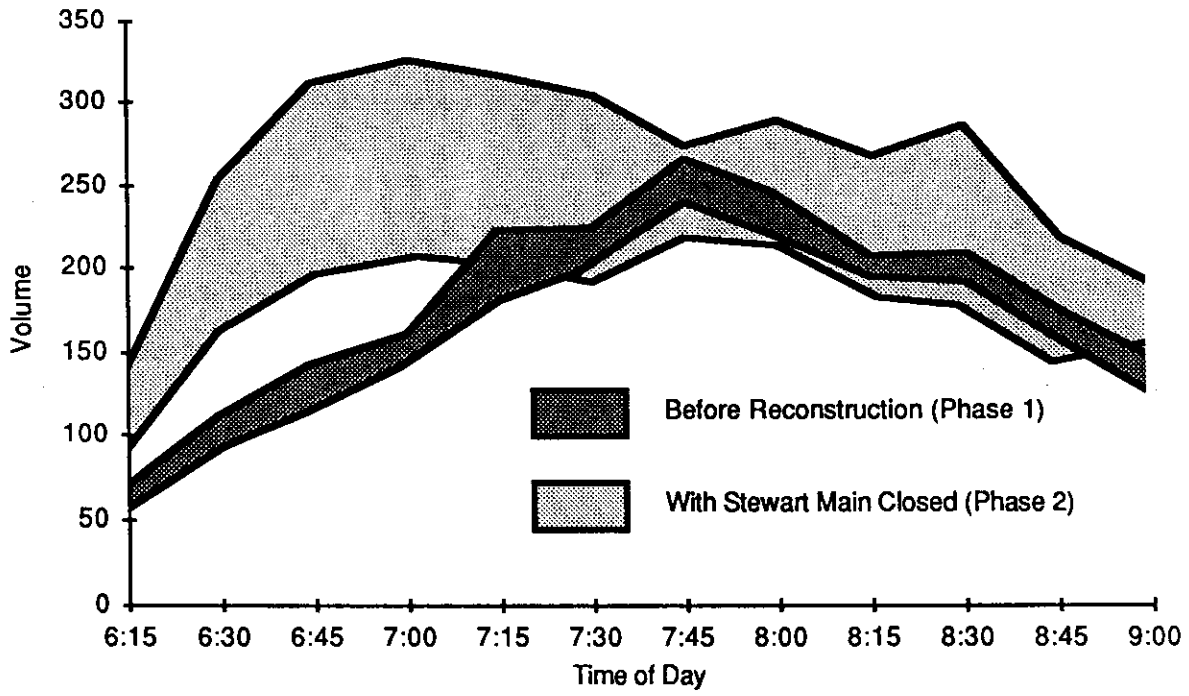


Exhibit 12

Stewart Express Ramp Volumes
(90% confidence interval)



observed. Add these factors to the further significant reductions in capacity that a disabled vehicle would have caused during the peak period, and it is not surprising that the vehicle volume observed on any given day varied more than in the pre-reconstruction period.

VEHICLE OCCUPANCY

Carpooling

As was indicated earlier, vehicle occupancy data was collected at eight locations. This data indicates that in general, there was no significant change in automobile occupancy rates during the reconstruction period. As shown in Exhibit 13, one arterial and one ramp showed significant changes in automobile occupancy during the project, but the system averages as a whole did not change.

The two locations which did show significant changes in occupancy rates were Eastlake Boulevard, which showed a slight increase in automobile occupancy, and the Mercer express lanes freeway ramp, which showed a slight decrease in automobile occupancy rate. The closing of the Stewart and Mercer ramps did not have a significant effect on the occupancy rate at any of the count locations.

One other change that was noticeable was an increase in the standard deviation of the automobile occupancy rate after the construction project began. It is not known what caused this increased amount of variation, but the most likely causes include the following:

- instability of newly formed carpools,
- instability of carpools as a result of the number of vacations being taken in the summer, or
- unusually high amounts of experimentation with carpooling in an attempt to mitigate the traffic conditions.

EXHIBIT 13
AUTOMOBILE OCCUPANCY RATES DURING THE PROJECT

	Time Period (Phase)				
Location	Before (1)	Stewart Closed (2)	Mercer Closed (3)	Ramps Open (4)	After (5)
Westlake	1.14	1.15	1.15	1.15	1.07*
Aurora	1.17	1.16	1.15	1.17	1.16
Stewart Mainlanes Ramp	1.19	N/A	1.20	1.24	1.18
Stewart Express Ramp	1.24	1.21	1.20	1.21	1.21
Mercer Mainlanes Ramp	1.15	1.15	N/A	1.16	1.15
Mercer Express Ramp	1.19	1.19	1.16*	1.17*	1.17
Eastlake	1.14	1.16*	1.17*	1.17*	1.16

* Indicates a statistically significant change from Phase 1 at the 90 percent confidence level.

One final note needs to be made about automobile occupancy rates. Occupancy counts were not performed at the Cherry/Columbia HOV exit from the express lanes. This exit did have a 200 to 300 vehicle/peak period increase in traffic during the construction period. It is highly likely that a portion of these additional vehicles were not previously carpools (previous studies determined violation rates between 17 and 40 percent), and they thus represent at least some formation of carpools as a result of the efforts of the City, METRO and the WSDOT to encourage ridesharing.

Average Vehicle Occupancy

A second analysis was made of average vehicle occupancy (as opposed to the automobile occupancy analysis described above, which excluded buses). At first glance, this analysis showed slightly different results than those stated above (i.e., as shown in Exhibit 13). After careful examination, however, it became apparent that the inclusion of buses into the occupancy calculation merely distorted the true picture of occupancy rates.

In Exhibit 14, the most noticeable change in occupancy rates is the decrease in occupancy on Eastlake, the opposite of the change calculated for automobiles only. What actually occurred on this road is that automobile occupancy increased slightly, but automobile volumes increased tremendously (almost 100 percent) while the number of buses stayed relatively constant. As a result, the average number of passengers per vehicle decreased because of the lower percentage of high occupancy vehicles (buses) in the traffic stream. Thus, while Eastlake actually performed as desired (more vehicles utilized it than normal, and those vehicles carried more passengers than they normally did), the numerical average appeared to show a negative response to the construction effort (lower vehicle occupancy).

A second problem the vehicle occupancy equation encountered was the rerouting of METRO buses. METRO rerouted 27 bus routes serving downtown at various times

EXHIBIT 14
VEHICLE OCCUPANCY RATES DURING THE PROJECT INCLUDING BUSES

	Time Period (Phase)				
Location	Before (1)	Stewart Closed (2)	Mercer Closed (3)	Ramps Open (4)	After (5)
Westlake	1.41	1.33*	1.44	1.44	1.28*
Aurora	1.30	1.27	1.26*	1.29	1.28
Stewart Mainlanes Ramp	1.28	N/A	1.31*	1.84*	1.41
Stewart Express Ramp	1.95	1.89	1.39*	1.46*	1.98
Mercer Mainlanes Ramp	1.19	1.20	N/A	1.16	1.21
Mercer Express Ramp	1.20	1.20	1.17	1.18	1.17
Eastlake	1.70	1.55*	1.54*	1.39*	1.69

* Indicates a statistically significant change from Phase 1 at the 90 percent confidence level.

during the summer to allow them to avoid the reconstruction congestion and closed ramps. As a result, TRAC data collection personnel counted those buses at some times, but at other times the buses "disappeared." The reduction in the number of buses observed tended to cause a statistically significant drop in the number of people being transported on a road, and thus caused a drop in the average occupancy rate. This phenomenon is easily seen in Exhibit 14 for the Stewart Street Express ramps during periods 3 and 4.

Bus Ridership

Bus ridership estimates were based on data provided by METRO for the morning commute periods before and during the construction project and for similar periods in 1983. These time periods were chosen so that changes in bus ridership could be observed not simply with respect to the construction caused changes, but also in relation to seasonal changes which occurred during the last year that reconstruction did not affect bus ridership. With this information, TRAC could differentiate between those changes apparently caused by the reconstruction congestion and public information campaign, and those changes which normally occurred during the summer season.

Exhibit 15 shows the total average passenger change that METRO observed at each of its five CBD count locations. The analysis of data for 1985 showed an increase in July/August morning ridership over June ridership for all locations except the Pine/Pike expressway ramp. This ramp mostly serves buses inbound from the extreme northern boundaries of the METRO service area (Bothell, Woodinville, etc.). An insufficient number of count days for each bus route was available to indicate whether most of the observed passenger ridership increases between June and July were statistically significant or simply fell within the range of normal daily variation.

When broken down by corridor, the available information (see Exhibit 16) showed measured increases in passengers on all corridors. Only the increases on Aurora

Exhibit 15

AM Bus Passenger Ridership Change at Metro Count Locations

Location	1985 Change	1983 Change
Aurora	+ 131	- 128
Westlake	+ 12	+ 76
Cherry	+ 361	+ 435
Pine	- 64	- 342
Stewart	+ 293	+ 494
TOTAL	+ 733	+ 535
	(5.2%)	(3.8%)

Avenue can be called statistically significant given the available data. The 447 rider increase on I-5 looks large, but is not statistically significant because of the large number of buses on I-5, and the fairly high variation present in the ridership data.

When the ridership increases in 1985 were compared with ridership changes measured during similar time periods in 1983, the analysis showed (see Exhibit 16) that only the Aurora corridor had a ridership increase that was larger (within statistical confidence limits of 90% ± 5%) than that observed in 1983. Only one other corridor (I-5 from northern Seattle) showed an increase in passenger ridership when compared with 1983 levels. The remaining corridors showed minor decreases in ridership changes between 1983 and 1985. None of these changes was statistically significant.

It is not clear whether these results are observed because of the limited number of ridership counts available from METRO (i.e., with high daily variation in passenger ridership one or two days of ridership information can give misleading results), or whether the ridership levels on many routes actually did rise more slowly in 1985 than they did in 1983.

When initially asked for ridership information, METRO's "ballpark" ridership estimate showed a 6 percent rise in passengers, while they indicated the summer months usually represented a 4 percent decrease in ridership. Available data support the 6 percent rise in 1985, but do not show the "normal" 4 percent decrease. Some of the differences may be due to the limited data available to TRAC (i.e., morning ridership for a limited number of routes).

Person Movements

Changes in person movements during the AM peak period were very similar to changes in vehicle volumes as the occupancy rate of vehicles did not change significantly and bus ridership changes were small compared to vehicle volumes. For the most part, the main lanes of I-5 experienced a significant decrease in utilization while all

Exhibit 16

AM Bus Ridership Change By Corridor

Corridor	1985 Change	1983 Change
Westlake	12	76
Aurora	131	-128
Eastlake	48	112
I-5	447	161
Sr-520	72	226

other north/south roads experienced some gain. The express lanes of I-5, Aurora Avenue and Eastlake all experienced significant increases in person travel, while Westlake, Montlake and 15th avenue (the Ballard Bridge) experienced relatively low growth in person travel. These increases in travel occurred throughout the mornings, with higher percentage changes occurring in the early morning hours (6AM to 7:15) than during the AM peak hour.

With the exception of the express lanes and Aurora, almost all person travel growth were directly related to increases in single occupancy vehicle utilization of the roadway. The express lanes and Aurora both experienced a large increase in the number of bus passengers. Aurora experienced a significant increase in passengers per bus in addition to an increase in the number of automobiles. The express lanes experienced an apparent moderate increase in passengers per bus, a large influx of buses rerouted from the main lanes, an increase in multi-occupancy vehicles, and a sizable increase in single occupancy vehicles.