Research Report
Research Project T9903, Task 81
Hwy Reconstruct—WSDOT

EVALUATION OF THE FULL WEEKEND CLOSURE STRATEGY FOR HIGHWAY RECONSTRUCTION PROJECTS

I-405 TUKWILA TO FACTORIA

by

Phillip S. Dunston
Assistant Professor

Fred L. Mannering
Professor and Chair

Doohee Nam
Research Associate

Jinsun Lee
Research Assistant

Bonnie M. Savage
Research Assistant

Department of Civil Engineering
University of Washington, 352700
Seattle, Washington 98195

Washington State Transportation Center (TRAC)
University of Washington, Box 354802
1107 NE 45th Street, Suite 535
Seattle, Washington 98105-4631

Washington State Department of Transportation
Technical Monitor
Tom L. Nelson
Chief Construction Engineer

Prepared for

Washington State Transportation Commission
Department of Transportation
and in cooperation with
U.S. Department of Transportation
Federal Highway Administration

December 1998

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. WA-RD 454.1	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Evaluation of Full Weekend Closure Strategy for Highway Reconstruction Projects: I-405 Tukwila to Factoria		5. REPORT DATE December 1998 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Phillip S. Dunston and Fred L. Mannering		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Washington State Transportation Center (TRAC) University of Washington, Box 354802 University District Building; 1107 NE 45th Street, Suite 535 Seattle, Washington 98105-4631		10. WORK UNIT NO. 11. CONTRACT OR GRANT NO. T9903, Task 81
12. SPONSORING AGENCY NAME AND ADDRESS Washington State Department of Transportation Transportation Building, MS 7370 Olympia, Washington 98504-7370		13. TYPE OF REPORT AND PERIOD COVERED Research Report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

In August 1997, the Washington State Department of Transportation (WSDOT) adopted a strategy of closing a single direction of freeway over an entire weekend for constructing the overlay on a 5.5-mile (8.85-km) section of I-405. Work was performed over two weekends. Data were collected from field measurements, records, and surveys to assess construction quality, construction costs, and user impacts. Results were compared to historical data from WSDOT and from an NCHRP synthesis study.

Overlay surface smoothness, density, and gradation quality were good, and no difference in consistency was found between night and day paving. Public response from motorists was decidedly positive, while business perceptions were mixed. Traffic simulations indicated that the total closure was preferable to single lane closures over multiple nights.

A decision checklist was developed for use in making the closure strategy decision.

17. KEY WORDS Asphalt overlays, highway reconstruction, highway rehabilitation, weekend closures, weekend paving, user impacts, quality	18. DISTRIBUTION STATEMENT No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report) None	20. SECURITY CLASSIF. (of this page) None	21. NO. OF PAGES	22. PRICE

DISCLAIMER

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 FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

In the summer of 1997, the Washington State Department of Transportation (WSDOT) tested a strategy of closing a single direction of freeway over an entire weekend to accelerate reconstruction on an approximately 5.5-mi. (8.85-km) section of Interstate 405 (from Coal Creek to Sunset Boulevard). For two weekends, all lanes in a single direction—three each—were closed for construction around the clock from Friday evening until Monday morning. The agency expected that these closings would have a significant impact on users and the local residential and business communities because of the few alternative high speed routes in that area. However, the customary practice of frequent night closures of one or two lanes would be likely to extend the period of inconvenience to the public. Therefore, WSDOT requested that researchers from the University of Washington study the project to document benchmark quality and impact data for assessing the weekend closure strategy and to develop recommendations for selecting projects that are suited to the weekend closure strategy.

CONSTRUCTION AND RESEARCH METHODOLOGY

The work, performed over the weekends of August 15 and August 22, 1997, was executed as a portion of project *C4756 Tukwila to Factoria SC&DI Stage I.* The contract specified a 0.15-ft (46-mm) ACP Class A overlay, and mainline tonnages of 16,990 tons (15,410 metric tons) were planned for the southbound lanes and 17,776 tons (16,123 metric tons) for the northbound lanes. The contractor provided AC mix from a mobile rotary drum plant erected in a private business parking lot located about .25 mi. (.4 km) from the southern end of the work zone. Mainline paving was executed with a single paver, and the AC mix was transferred to the paver from a windrow by way of a pickup device. Two roller compactors were used during each weekend. Ramp and shoulder paving was accomplished with a second paver and was not included in the scope of this

study. The contractor's crews worked 12-hour shifts, and traffic control was provided by WSDOT with the assistance of off-duty police officers.

The investigation focused upon issues of construction quality and construction and user impacts. Construction quality was assessed through the collection and analysis of smoothness and in-place density data and through examination of longitudinal joints and other factors. Where possible, results from the I-405 project were compared to data documented from typical projects both within and outside the state of Washington. Production rates, as an indicator of construction costs, were calculated and compared to rates from a comparable nighttime project. User impacts were assessed through surveys of motorists and local businesses. The researchers also conducted a simulation analysis of traffic response to the complete single direction weekend closure versus many nights of single- or multiple-lane partial closure. An additional survey of several state highway agencies was conducted to discover which innovative strategies are being used elsewhere for highway reconstruction or rehabilitation.

RESULTS

Construction

Actual total tonnages for the two weekends were 29,393 tons (38,496 metric tons) on the southbound direction and 19,019 tons (17,250 metric tons) on the northbound direction. The I-405 closure was compared with a similar I-5 project (C4250) from the Nisqually River to the Gravelly Lake Interchange. The I-5 project overlay was constructed with nighttime closures during the 1993 and 1994 paving seasons. The 1994 overlay was constructed with the addition of a mass transfer device. The shift production rates for the I-405 project ranged from 277 tons per hour (251 metric tons per hour) to 413 tons per hour (375 metric tons per hour). The average shift production rate for the I-405 overlay was about 350 tons per hour (317 metric tons per hour). This quantity was 23 percent greater than the shift production from the 1994 overlay on I-5, which utilized the mass transfer device.

Examination of average truck productivity revealed two interesting points. First, the addition of the mass transfer device apparently did not have any effect on truck resource utilization for the I-5 project, despite a marked increase in production rates. The second point was that the paving technique for the I-405 project resulted in esssentially 2 times the truck productivity achieved on the I-5 project. These higher productivities most likely resulted from the close proximity of the mobile asphalt plant and the high degree of access the trucks had to the work site.

Surface smoothness was measured with a California profilograph. Segments measured from sections that were paved during both nighttime and daytime hours revealed no difference in smoothness between night and day paving. Maximum values for the roughness measurements did not exceed a 5 in./mi (80 mm/km) limit taken from a supplemental specification that has been used by one of the WSDOT regions (although not on this project), indicating high quality surface smoothness.

Statistical analysis confirmed that there was no difference between night and day average in-place densities, and variability was also consistent between night and day. The average Rice density of 93.14 percent compared favorably to averages from earlier projects, and the resulting 6.8 percent air voids suggests a satisfactory period of service from the overlay (each percent above 7 means a 10 percent reduction in pavement life).

Gradation and asphalt cement content were both well within the specified ranges, and standard deviations were typically lower than those documented in an NCHRP synthesis study. Problems with the longitudinal joints indicated a need to consider improved lighting and the rate of roller compaction relative to the high speed of paving. No instances of cyclic segregation were noted on this project.

User Impacts

Public response to the weekend closure strategy, obtained via motorist and business surveys, was generally positive. Most motorists (87 percent) were decidedly in favor of the weekend closure strategy over frequent partial closures. About 88 percent

agreed that timely notification enabled most people to make plans to avoid the work zone during the weekends of construction, indicating a successful public information campaign. Specific response strategies related to such factors as age, gender, education, family characteristics, home location, and income were analyzed with binary logit models. Businesses provided more mixed results, although most indicated no impact upon their weekend business operations.

Traffic operational impacts were analyzed through the application of the calibrated traffic assignment model XXE. Both vehicle travel time and distance (vehicle-miles) traveled increased slightly and had only minimal impact on system performance.

Survey of State Highway Agencies

A survey of several state highway agencies (SHAs) indicated that the preferred and most frequently used overlay strategy is single-lane nighttime closures, which generally result in greater variability in densities, a rougher surface, more instances of cyclic segregation, and lower quality longitudinal joints. The I-405 data showed that high performance in these areas can be accomplished with either the nighttime closure or the weekend closure strategies. Innovative approaches the SHAs are considering are most commonly either A+B contracting or lane rental arrangements, both of which tend to put the burden for initiating innovation on the contractor.

Decision Making Checklist

After the positive results gathered during the course of this study had been considered, a decision checklist was developed as an aid to decision makers in determining the appropriate closure strategy for a given project. The checklist is divided into three parts: (1) routing impacts, (2) contractor considerations, and (3) WSDOT functions. The checklist is recommended as a guide for assembling critical information and support for the full weekend closure option versus the nighttime closure option. Because closure policy must ultimately involve qualitative decisions, a deterministic checklist was considered impractical.

CHAPTER 1
INTRODUCTION

Highway reconstruction in congested urban areas is typically performed by partially closing the highway, and often the work is conducted during nighttime hours. The advantage of these nighttime closures is that they avoid huge impacts upon users and the surrounding community during daytime hours when traffic flow is considerably higher. There is a potential downside to nighttime closures, however. The practice may extend the period of inconvenience that is still felt, albeit at different levels, by users and local residents. In addition, and especially true for large projects, the frequent mobilizations and shutdowns that are required inhibit productivity and, in many cases, may even impact construction quality.

As an alternative to frequent night closures, complete shutdown of a single direction of traffic during a weekend is a potentially attractive option. At this time, however, no data exist to use as a guide in deciding between these two closure options. In an attempt to provide initial answers to questions concerning the weekend closure strategy, the goal of the research presented in this report was twofold. One purpose was to document benchmark data on the weekend closure option that can be used in assessing closure strategies for highway reconstruction. The second was to use the documented results in developing a decision making process for choosing the best closure option for future reconstruction projects.

SUBJECT AND SCOPE OF STUDY

The analysis of data collected from this project was designed to assess how the single direction weekend closure strategy compares to the strategy of numerous nighttime closures. As a pilot project, the Washington State Department of Transportation (WSDOT) adopted a weekend closure approach to complete overlay operations on a section of I-405 as part of project *C4756 Tukwila to Factoria SC&DI Stage 1* during August of 1997. All

traffic lanes were closed in a single direction—three each—for two consecutive weekends. The agency expected that these closings would have a significant impact on users and the local residential and business communities because the number of alternative high speed routes in that area is limited.

The contract specified a 0.15-ft (46-mm) ACP Class A overlay and a minimum 0.06-ft (18-mm) ACP Class G prelevel. The project was bounded by the Sunset Boulevard bridge to the south and the Coal Creek Parkway bridge to the north, a distance of about 5.5 miles (8.85 km). Projected total tonnage for the southbound direction was 20,932 tons (18,985 metric tons), and 22,013 tons (19,966 metric tons) was projected for the northbound direction. The southbound overlay was constructed over the weekend of August 15th, while the northbound overlay was constructed during the weekend of August 22nd. Hours allotted for paving were from 8:00 p.m. on Friday to 5:00 am on Monday for each weekend. The prime contractor for the project was Tri-State Construction, Inc., and the paving subcontractor was M. A. Segale, Inc. M. A. Segale is hereafter referred to as the "contractor."

The contractor provided AC mix from a mobile rotary drum plant in Boeing parking lot #6, located .25 mi. (.4 km) from the Park Avenue ramps, the truck access point near the southern end of the project. Mainline paving was executed with a single paver, and the AC mix was transferred to the paver from a windrow by way of a pickup device. Two roller compactors were employed during the first weekend. Although four rollers were made available for the second weekend to better keep pace with the paver, two broke down. Ramp and shoulder paving was accomplished with a second paver. The contractor's crews worked 12-hr shifts.

Traffic control for the project site was provided by WSDOT. Washington State Patrol and City of Renton off-duty police officers assisted with monitoring ramps and flagging through signalized intersections, respectively. An excerpt from the mainline overlay report prepared by the project engineer is included in Appendix E. In addition, a list of

television news story tapings and a collection of newspaper articles are included in Appendix F.

OBJECTIVES

Determination of the more desirable closure option requires identification of key parameters, measurements, observations, and analyses. Focus for this study was placed upon construction quality, construction costs, and user costs. Documentation requirements were met by field data collection, literature review, surveys of the public's opinions, and development of traffic simulations. Specific issues addressed in the performance of this study are cited below.

Construction Site Safety

It was expected that full traffic closure in a single direction would automatically produce a safer construction site. Because an accident in the work area is unlikely for this type of closure strategy, the assessment of work zone safety was based on a review of the literature that provided insight on the relative safety aspects of the two alternative construction strategies.

Construction Quality

The longer periods of uninterrupted work afforded by the weekend closure alternative raised the question of whether consistent quality could be achieved through the night-day cycles. Changes in temperature and lighting might have negative impacts upon the levels of quality that could be achieved in smoothness of ride, density, longitudinal joint construction, and other factors. Offsetting the potentially negative impacts was the fact that the contractor had the luxury of a closed work site and thus the opportunity to reach and maintain a consistent level of production throughout the weekend closure.

Construction Costs

Construction costs are difficult to compare between projects because of the number of variables such as contractor resources, logistics, project size, scope of work, and environment. It is more illuminating to compare performance rates for major work items.

Cost differences between the weekend closure strategy and the nighttime closure strategy were indirectly assessed in this study from examination of paving production rates. The project production rates were also compared with available historical data from a comparably sized nighttime project.

User Impacts

In comparing the partial shutdown of heavily trafficked lanes to a complete weekend shutdown of a single direction of traffic, user costs are an important concern. The most significant costs are the increases in travel time caused by the reduction in system capacity and subsequent route diversion, as well as potential impacts on businesses. The impacts on retail businesses become a critical factor when weekend closures are considered.

In terms of travel time impacts, direct measurement is virtually impossible because of the natural variation in congestion (i.e., incident-induced and variability in recurring congestion) and possible postponement or cancellation of trips. However, an indirect approach can provide valuable insight into user impact. Estimates were made of two components of user costs. First, a series of traffic simulations were created with the traffic assignment software developed at the University of Washington and utilized in previous state-sponsored research with productive results (Trowbridge et al. 1996; Garrison et al. 1989). This simulation model measures delay due to queuing, total vehicle travel time, vehicle emissions, and changes in vehicle-kilometers traveled. Second, because there is always uncertainty with respect to the extent to which travelers will postpone or cancel their trips, the investigators distributed a mail-back survey to ask travelers how their travel patterns had changed in response to the weekend closing of I-405. The sample of travelers was drawn from vehicle license plates observed on the I-405 facility during non-construction weekends. The combination of these two indirect approaches provided a good estimate of the travel-related impacts on users.

Business impacts were measured directly by choosing a representative sample of businesses. Thirty area businesses were polled.

Public Information Campaign

Public opinion data were also collected through the survey of I-405 travelers. In addition to questions relating to changes in travel patterns, travelers were asked to assess the effectiveness of the information campaign conducted to warn the public of the forthcoming closures and about their overall impressions. The information was then analyzed with ordered probability models to determine the factors that underlie the impressions travelers developed.

State Highway Agency Survey

A few state highway agencies (SHAs) were polled for information regarding their closure strategies for constructing ACP overlays. Their responses provided information on current preferences and results, as well as innovations that are being considered for implementation.

Checklist Formulation

An important product of this study is the recommendation of a decision checklist. Formulation of the decision checklist was based on results of the data analysis, opinion surveys, observations, consultation with WSDOT personnel, and insights from literature. The items included in the checklist give careful consideration to the impacts, benefits, and costs associated with the selection of an alternative closure strategy.

CHAPTER 2
LITERATURE REVIEW

A general literature review of construction operations on major highways did not yield information directly related to full weekend closures. The sources most relevant to this study described factors that contribute to differences between daytime and nighttime paving and, in a more general sense, the issue of motorist accident rates near the work zone. Although the literature does not address the specific situation being studied, this body of information may be useful for identifying potential key issues in the day-night cycles of weekend paving. Topic areas where this literature review might be reasonably relevant are construction productivity, construction quality, construction and user costs, and public safety.

PRODUCTIVITY

Hinze and Carlisle (1990) outlined many of the factors related to nighttime paving productivity and evaluated their relevance. They held that traffic volume, type of work, material delivery, lighting, supervision, communication, and worker morale were among the factors that affect nighttime versus daytime paving productivity. Price (1986) compared the quality and cost of daytime and nighttime projects in Colorado and postulated that the material delivery rate will increase because of less traffic, which normally contributes to idle time. He also stated that temperature extremes could have an adverse effect on crew and equipment performance. Ellis and Kumar (1993) examined differences in cost and productivity between nighttime and daytime paving in Florida and found that nighttime paving production rates were no better than those for daytime paving.

QUALITY

A significant question to be answered is whether continuous paving produces an appreciable difference in paving quality. Researchers have acknowledged that nighttime paving introduces the potential for effects from numerous factors related to supervision,

material quality, and worker effectiveness (Read 1996; Hinze and Carlisle 1990; Price 1986). Temperature gradient effects may have an impact on the quality levels achieved with compaction, longitudinal joints, and cyclic segregation. Read (1996) suggested that cyclic segregation is a function of temperature gradients within the AC mix that could be addressed with attention to material handling, especially the use of transfer devices. Although rationalizations of the impacts on construction quality are generally accepted, quantification of these impacts has been elusive (Ellis 1993). An NCHRP synthesis report by Hughes (1996) presented a compilation of standard levels of quality measures for pavement construction reported by various agencies across the nation. Such information may be useful for benchmarking quality measures for any new closure strategy.

MOTORIST SAFETY

The topic of motorist safety typically comes to mind first when highway construction safety is considered. It is often the most prominent safety concern because traffic impacts are the most easily observed change at the site (other than the construction itself). The motorist encounters a change in traffic routes, patterns, and sometimes driving conditions. Traffic control measures are designed to guide the traffic to modified or alternative routes in as safe and efficient a manner as possible. Historical research shows that not only does this not always happen but that work zone safety continues to be a significant concern (Pal and Sinha 1996a, 1996b; Wang et al. 1996; Hall and Lorenz 1989; Pigman and Agent 1990; Paulsen et al. 1978). No historical data are available on weekend closures, so the safety of available alternative routes would need to be evaluated on a case by case basis. Ultimately, for motorist safety the type and quality of traffic control and the choice of alternative routes should be compared for the two scenarios of weekend and nighttime paving.

CONSTRUCTION COSTS

The numerous variables in construction make direct cost comparisons between projects difficult to validate. Comparisons of daytime construction costs with costs from nighttime work, even on the same project, may be difficult because of the limited number of comparable job conditions and methods. Ellis and Kumar (1993) felt that construction costs of nighttime and daytime paving construction may be compared by looking at major work item (unit) costs rather than total project costs. By using this approach, the two investigators concluded that, in the state of Florida, total program costs for nighttime construction were lower than those for daytime construction, although there was no difference in unit costs. They further concluded that specific job conditions had a greater influence upon unit costs of items than did the type of shift. Because construction costs are a function of numerous contract variables and the unit costs may not reveal a distinction, production rate may be a more sound measure, which can in turn be linked to relative cost.

USER COSTS

As stated previously, the most significant user costs stem from increases in travel time caused by the reduction in roadway capacity and subsequent route diversion, as well as from potential impacts on businesses. User costs related to vehicle delays were shown by Price (1986) to be an order of magnitude lower for nighttime paving than for daytime paving. Because the natural variation in congestion makes direct measurement of user costs related to travel time virtually impossible, measurements or assessments may be accomplished through traffic flow analysis and business community and motorist surveys. While this indirect approach does not provide a dollar figure, it can provide valuable insight into user impacts related to the weekend closure.

LIGHTING

Surprisingly little research has been done on the subject of lighting for nighttime construction. Having determined lighting to be one of the most important elements of

nighttime construction, Ellis and Amos (1996) conducted a study aimed at developing work zone lighting standards. Parameters of illumination level and lighting configurations were examined, as was hazard glare-control. A successful demonstration project resulted in "only minor modifications to the contractor's equipment" at an additional cost of $1,628 to the contractor for the lighting upgrade. Modifications consisted of additional lamps (with spares) for the paver and roller compactors and glare control shades for the portable light tower. Three illumination categories were established corresponding to increasing need for visual clarity.

SUMMARY

Because an important question of this study is whether the weekend closure strategy can provide a consistent quality product between nighttime and daytime shifts, the same factors that influence the differences between daytime and nighttime highway construction may be expected to influence the cost and productivity of the complete weekend closure. Relevant data from Hughes' synthesis report were used as a basis for comparison with the data collected from the I-405 project. The important quality parameters were surface smoothness, in-place density, gradation (including AC content), longitudinal joints, and cyclic segregation.

In the face of limited alternative high speed routes, as with the I-405 closure, documentation and analysis of crash rates should provide valuable decision making information. One might try to monitor the level of traffic accidents along the alternative routes. Such monitoring was beyond the scope of this report, but an examination of accident reports may prove valuable when such information is available.

Because a direct measurement of construction costs is not useful for comparison with other projects, production rates are recommended as an indirect measure of relative costs between projects. This approach is reasonable because the central task of overlay construction is the laydown operation; however, total program costs are still an important consideration when closure strategies are chosen.

Rather than attempting to directly measure user costs, the assessment of user impacts may be a more meaningful approach. Such an approach requires an analysis of traffic response to the weekend closure, as well as the collection of motorist and business feedback.

Proper lighting is a major factor in the successful execution of nighttime construction. It follows that it would play significantly in the level of consistency achieved between the nighttime and daytime shifts of the weekend closure. Lighting levels and configurations are beyond the scope of this study, but observations of light level effects on such highly visible features as longitudinal joints may be readily noted.

CHAPTER 3
COMPARISON OF PRODUCTION RATES

Initial projections for paving production were 20,932 tons (18,985 metric tons) for the southbound direction and 22,013 (19,966 metric tons) for the northbound direction (*SR405 Mainline Overlay Report* in Appendix E). The actual total tonnage for the two weekends was 39,412 tons (35,747 metric tons)—20,393 tons (18,496 metric tons) on the southbound section and 19,019 tons (17,250 metric tons) on the northbound section. These totals included the mainline, shoulders, and ramps. The following discussion focuses on mainline production rate comparisons between the weekend closure project and a comparable nighttime closure project.

Cost comparisons between paving projects are difficult to validate because of the numerous variables that create dissimilarities between projects. However, production rates are an important factor in assessing the relative value for the dollar between paving projects. Historically, researchers have assumed that paving production rates during night closures should exceed those that can be achieved during daylight hours (Price 1986). Ellis and Kumar (1993), however, determined no statistical difference between night and day production rates, assuming a 95 percent confidence level. While production was not monitored on the I-405 project with the idea of doing a statistical comparison, it seemed beneficial to note how the I-405 paving compared to overlay projects of similar size under nighttime closure conditions.

COMPARISON WITH I-5 NIGHTTIME PRODUCTION RATES

Production quantities from I-405 are tabulated in Table 3-1, and production rates are compared to rates from project C4250 on I-5 from the Nisqually River to the Gravelly Lake Interchange in Table 3-2. The I-5 project was a nighttime project that was comparable in paving quantity to the I-405 project. The total tonnage for the I-5 project was 37,888.2 tons (34,364.6 metric tons), with 22,338.7 tons (20,261.2 metric tons) in the northbound

direction and 15,549.5 tons (14,103.4 metric tons) in the southbound direction. The large difference in paving quantities between the two directions resulted from longer project limits in the northbound direction. The northbound overlay was constructed during 14 nights in 1993 and three nights in 1994. The southbound overlay was constructed during 11 nights) in 1994. The northbound overlay constructed during 1993 was characterized by numerous instances of cyclic segregation. During the second year a mass transfer device (remixer) was used to complete the northbound lanes and to construct all of the southbound lanes. The strategy was successful in eliminating the cyclic segregation problem.

Paving production totals were estimated for the number of hours of paving operations for each shift. Table 3-1 lists the number of mainline paving hours for each shift and the total amount of ACC mix placed in that time for the I-405 project. I-405 data were extracted from the truck tickets. The I-405 production was divided by the 12-hr shifts used by the contractor minus the non-paving time at the beginning and end of each shift. Comparisons between IDRs and the truck ticket information for delivery time and station made reasonable shift production estimates feasible. Data for the I-5 project were supplied by the Midland Office of WSDOT.

Table 3-2 shows how the range of production rates achieved during the I-405 weekend closure compared to those of the I-5 nighttime-only paving. On the surface, the effect of the full closure condition seems to yield greater paving quantities. Note that the production for the Saturday night shift for the I-405 southbound paving (see Table 3-1) was uncharacteristically low. This may be explained by considerable worker fatigue, as noted on the IDRs, and also by an interruption in the work when specified course thickness was exceeded. A slightly less dramatic slowdown is noted for the northbound Saturday night paving, but no explanations were indicated in the IDRs. It appears that average paving rates of about 350 tons per hour (317 metric tons per hour) or more may be achieved with the full weekend closure strategy when the asphalt plant is in close proximity to the construction site and traffic-free access is ensured.

Table 3-1. Production by Shift from I-405 Project

Shift	Southbound Paving Production		Northbound Paving Production	
	Time Length for Mainline Paving Work (hrs)	Production [tons (metric tons)]	Time Length for Mainline Paving Work (hrs)	Production [tons (metric tons)]
Friday Night	10.5	3716.5 (3370.9)	11.25	4105.45 (3723.6)
Saturday Day	12	4955.85 (4495.0)	10.5	4181.65 (3792.8)
Saturday Night	11.5	3185.58 (2889.3)	11	3498.35 (3173.0)
Sunday Day	2.5	849.45 (770.4)	0.5	167.1 (151.5)

Table 3-2. Production Rates for I-405 in Comparison with Nighttime Project on I-5

Project	Transfer Method	Average Shift Duration (hrs)	Maximum Production Rate [tons/hr (metric tons/hr)]	Minimum Production Rate [tons/hr (metric tons/hr)]	Average Production Rate [tons/hr (metric tons/hr)]
I-5 Northbound 1993	Conven-tional	6.4	280(254)	135(122)	220(200)
I-5 Northbound 1994	Mass transfer	7.1	331(300)	288(261)	313(284)
I-5 Southbound 1994	Mass transfer	6.0	323(293)	149(135)	267(242)
I-405 Southbound 1997	Pickup	9.1	413(375)	277(251)	346(314)
I-405 Northbound 1997	Pickup	10.9	398(361)	318(288)	354(320)

By comparison, it may be more appropriately stated that the results indicated that the continuous, unobstructed paving operation resulted in an approximate 21 percent increase in production rates over paving executed without the same protective conditions.

TRUCK PRODUCTION RATES

Truck productivity serves as an additional basis for comparison between the two projects and further confirms the value of unobstructed material delivery, as shown in Table 3-3. The number of tons per hour per truck for each shift was calculated from the shift production and the average number of trucks hauling hot mix for that shift. All shifts with either a total production of less than 300 tons (272 metric tons) or a duration of less than 4 hours were deleted from the comparison to provide a more reasonable estimate of truck productivity. Note that available data for truck sizes was inadequate for calculating truck numbers on a size-equivalent basis. The values for average shift production from Table 3-2 are repeated in Table 3-3 to elucidate the comparison.

Table 3-3. Truck Productivity for I-405 in Comparison with I-5 Nighttime Project

Project	Transfer Method	Average Production Rate [tons/hr (metric tons/hr)]	Maximum Truck Productivity [tons/hr (metric tons/hr)]	Minimum Truck Productivity [tons/hr (metric tons/hr)]	Average Truck Productivity [tons/hr (metric tons/hr)]
I-5 Northbound 1993	Conven-tional	220(200)	26(23.6)	14(12.7)	19.4(17.6)
I-5 Northbound 1994	Mass transfer	313(284)	30(27.2)	21(19)	26(23.6)
I-5 Southbound 1994	Mass transfer	267(242)	22(19.9)	11(10)	19.6(17.7)
I-405 Southbound 1997	Pickup	346(314)	63.5(57.6)	39.6(36)	51.2(46.4)
I-405 Northbound 1997	Pickup	354(320)	60.8(55.1)	45.4(41.2)	54.4(49.3)

Examination of average truck productivity reveals two interesting points. First, the addition of the mass transfer device did not have any effect on truck resource utilization for the I-5 project, despite an apparent increase in production rates. The second point revealed by the data is that the paving technique for the I-405 project resulted in esssentially 2 times the truck productivity achieved on the I-5 project. These higher truck productivities most likely resulted from the close proximity of the mobile asphalt plant and the protected access the trucks had to the work site. This insight underscores the benefit derived from the establishment of secure and uninterrupted site access for the hot mix delivery trucks.

CHAPTER 4
QUALITY CHARACTERISTICS OF THE OVERLAY

The evaluation of the quality of the AC overlay included both quantitative and qualitative assessments. Surface smoothness, in-place densities, aggregate gradation, and asphalt cement content were quantitatively assessed. Qualitative assessments encompassed the condition of the longitudinal joints, the presence of cyclic segregation, and other factors. All evaluation was focused on the mainline paving. The evaluation addressed two broad questions: (1) whether differences existed between nighttime and daytime paving quality and (2) whether the overall characterization of the project compared well to other paving jobs, especially nighttime paving. Results of the analysis between night and day cycles are presented and discussed below. Where historical data were obtained, they are compared to this project.

SURFACE SMOOTHNESS

Smoothness was measured with a California profilograph, model CS 8200 Version 1.0, manufactured by James Cox and Sons, Inc. This particular model uses a first order low pass filter for smoothing the data. The use of the first order filter has been noted to produce readings that are less sensitive than earlier manual approaches and higher order filters (Huft 1992; Scofield et al. 1992). For the purposes of this study, consistency in the smoothness of the riding surface was of primary importance; therefore, the sensitivity of the measurement technique was of less significance. Note that although the contractor was aware that smoothness would be measured and that a continuous smooth ride was desirable, smoothness measurements were not a requirement of the contract.

Tables 4-1 and 4-2 summarize the smoothness measurements that were taken during the two weekend closures. For each lane, the PRI represents a continuous

segment of the lane. Measurements were first taken from the prelevel surface to isolate the improvement of the overlay course.

Table 4-1. Southbound Profilograph Summary

Lane	Wheel Path	Prelevel PRI [in/mi(mm/km)]	Overlay PRI [in/mi(mm/km)]	Improvement in PRI [in/mi(mm/km)]	When Paved
1	Inside	4.3(68)	3.4(47)	+0.9(14)	N
2	Outside	6.7(106)	1.8(28)	+4.9(77)	D
2	Inside	1.8(28)	1.7(27)	+0.1(2)	D
2	Outside	5.0(79)	1.4(22)	+3.6(57)	D
1	Inside	4.2(66)	5.0(79)	-0.8(13)	D

Table 4-2. Northbound Profilograph Summary

Lane	Wheel Path	Prelevel PR [in/mi(mm/km)]	Overlay PRI [in/mi(mm/km)]	Improvement in PRI [in/mi(mm/km)]	When Paved
1	Inside	11.5(182)	1.3(20)	+10.2(161)	Night
3	Outside	7.8(123)	2.4(38)	+5.4(85)	Day
2	Inside	6.2(98)	1.3(20)	+4.9(77)	Day

The profilograph measurements can be put into perspective by considering the smoothness specification for AC pavements that is currently utilized in the Southwest Region. The supplement specification for Section 5-04.3(13) of the standard specification stipulates that the contractor should employ methods that produce a riding surface that has a profile index of 5 in. per miles (80 mm per kilometer), as measured with a California-type computerized profilograph. Reference to this specification indicates that the contractor for the I-405 project produced smoothness appropriate to a high quality

pavement. Only the PRI for the last section listed for the southbound direction came close to exceeding 5 in./mi (80 mm/km). Investigation did not reveal why the PRI for this section was so much rougher than that of the other sections.

Statistical analysis of the PRIs revealed no differences between nighttime and daytime paving shifts, nor between southbound and northbound lanes. Note, however, that the number of samples that were obtainable on this project was small and included many more daytime shifts than nighttime shifts. A larger database would be desirable for drawing firm, statistically supported conclusions.

IN-PLACE DENSITIES

The results obtained from measurements of in-place density were compared for differences between daytime and nighttime paving and between weekend closures. Comparisons were also made with historical data, and correlations with pay factors were examined. The first two analyses are discussed below, while the last is discussed in Chapter 5.

Overview of Density Results

Mat density measurements were taken in sequence with the paving operations along the length of both the southbound and northbound lanes with a calibrated nuclear densometer. In accordance with WSDOT Test Method No. 716, five measurements were taken from sublots of each 400-ton lot and an average density was calculated for each lot. Average Rice density percentages were found to be normally distributed (see Figure 4-1). Average densities over the entire worksite ranged from 91.46 to 94.98 percent, with an average density of 93.14 percent and a standard deviation of 0.72 percent. The range for all individual sublots was from 90.1 to 96.4 percent (see Figure 4-2).

Statistical tests indicated that there were no significant differences in the average (mean) densities between the two weekends (directions). The mean density in the northbound direction was 93.13 percent, and that in the southbound direction was 93.14 percent, virtually the same. However, the statistical variation about the mean densities

was significantly different. As seen in Figure 4-2, the range of densities for the northbound direction (91.46 to 94.98 percent) was somewhat greater than the range for the southbound direction (92.0 to 94.28 percent).

Figure 4-3 shows a plot of densities measured as paving operations progressed through each respective weekend. The time is expressed in terms of the day and night intervals, which coincided with shift changes occurring at 8:00 am and 8:00 pm each day of the closures. F-tests for statistical differences in variation revealed that the difference in variation between the two weekends of paving could be isolated to the "First Day" of paving. That is, the variation in average in-place densities was shown to be different between the Saturday daytime shifts. No other source of variation difference was statistically supported.

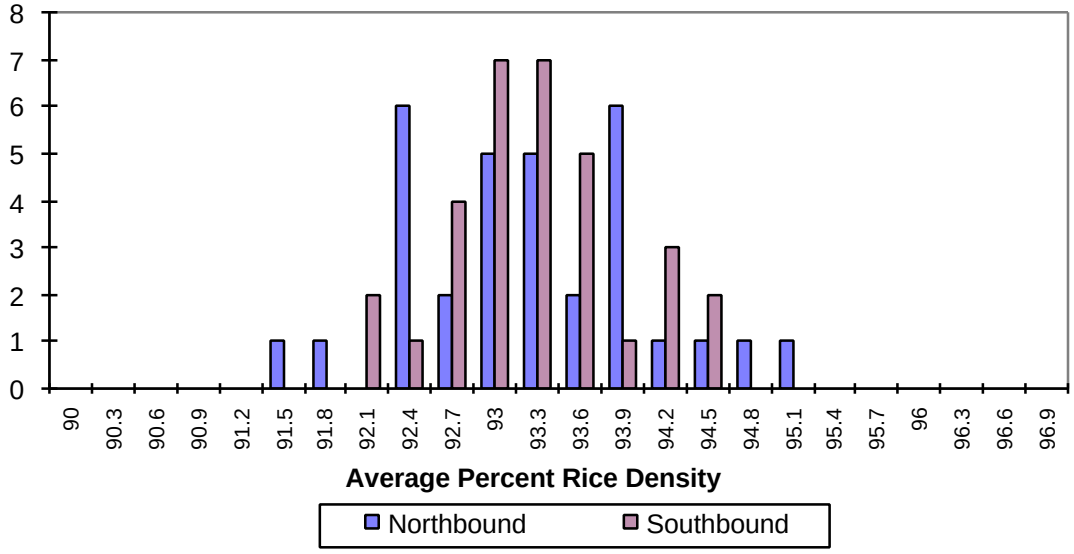


Figure 4-1. Frequency Histogram of Average Rice Density Percentages for Each Direction

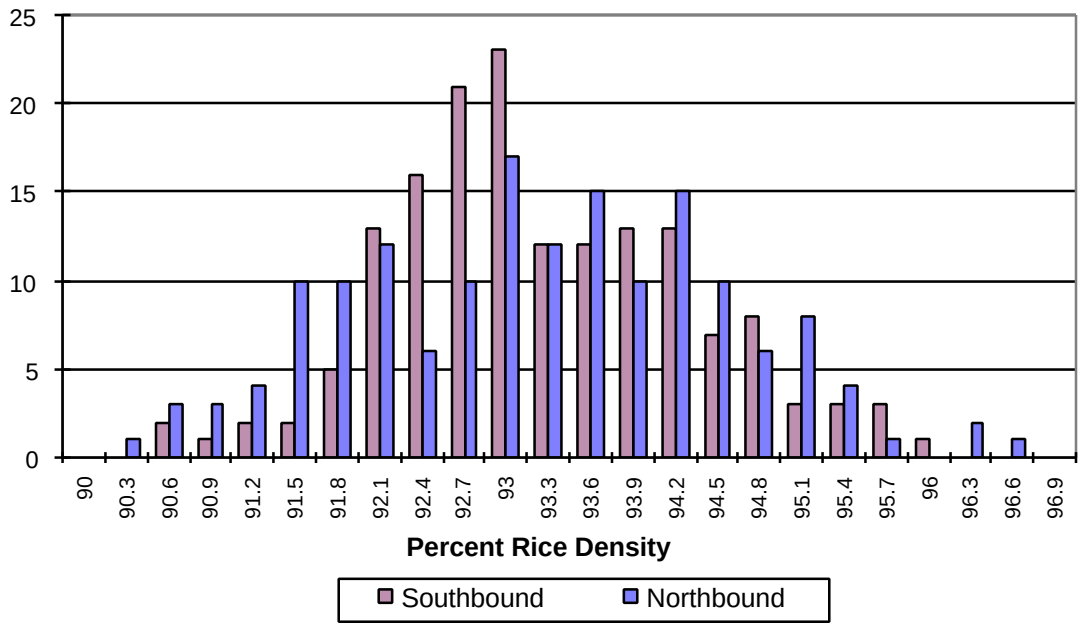


Figure 4-2. Frequency Distribution of Rice Density Percentages for all Mainline Paving

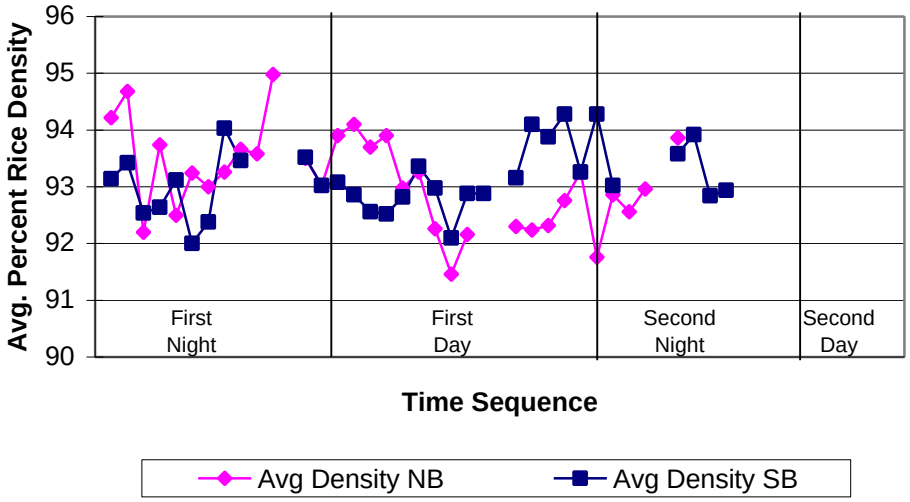


Figure 4-3. Average Rice Density Throughout Paving Operations

A trend line drawn through the data from the southbound direction indicates a slight general increase in average densities as paving operations progressed (refer to Figure 4-4a). This trend implies that paving operations became more effective as the first weekend proceeded. On the other hand, a slight decrease in average densities was apparent for the northbound direction (refer to Figure 4-4b), indicating a loss of effectiveness. Such an apparent trend may be attributed to growing human fatigue after the first weekend or to a faster paving rate and thus more pressure on the compaction operation to keep pace with paving. (Although four compactors were devoted to the second weekend of paving, two of the four roller compactors broke down.) However, explanations for the apparent trends cannot be guaranteed because of limited data and questionable assumptions. For example, the validity of connecting the shifts in sequence is questionable.

No significant differences in pavement densities were found between lots paved in the daytime and those paved in the nighttime. This was true for both northbound and southbound directions, individually and as a whole.

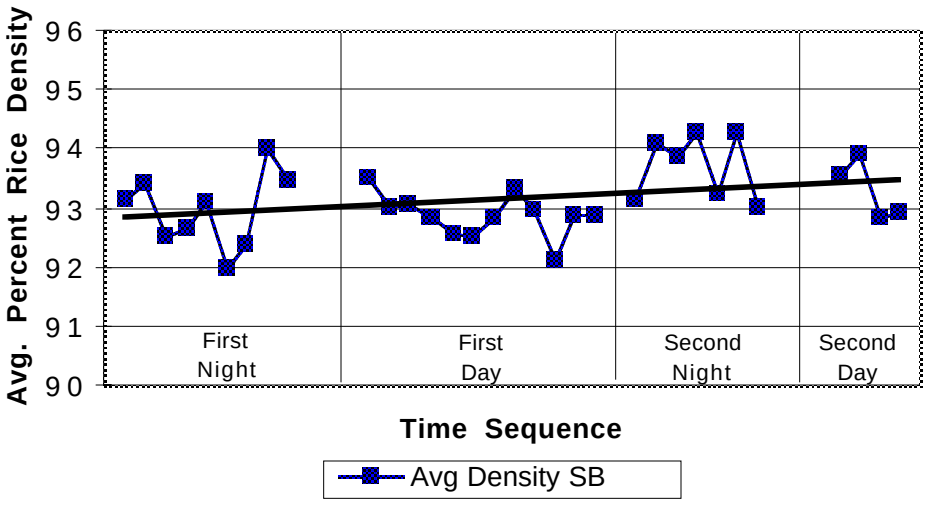


Figure 4-4a. Trend for Southbound Average Rice Densities

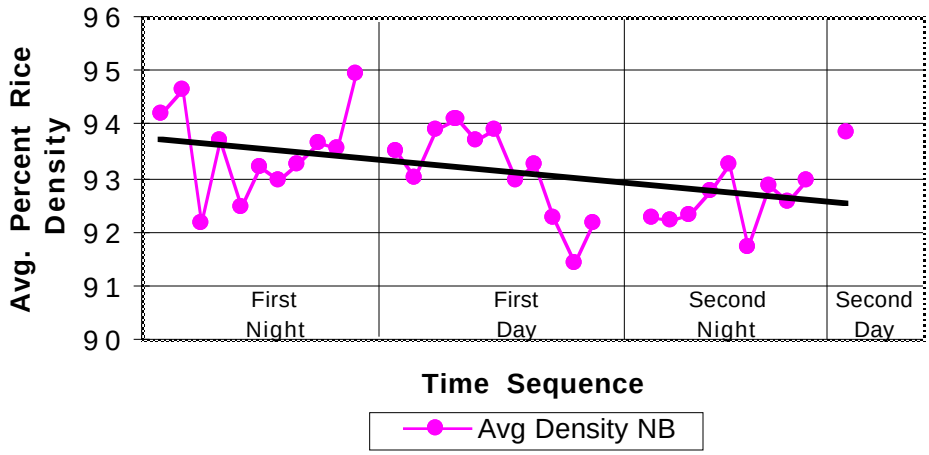


Figure 4-4b. Trend for Northbound Average Rice Densities

Densities in Perspective

Comparison with historical data helps to put the average Rice densities into perspective. When Markey et al. (1994) studied the initial impact of the WSDOT quality assurance (QA) specification, they included three QA projects. In Table 4-3, the statistical parameters for density from those jobs are compared to those from the mainline paving for the I-405 project. The I-405 project compares quite well. Its mean average density is exceeded by only one of the other three projects (3522), and all but one of the other projects (3587) have greater variability.

Table 4-3. Comparison of I-405 Average Rice Density Percentage Parameters to Early QA Projects from Markey et al. (1994)

Job	# Lots	Mean	Max.	Min.	Range	Standard Deviation	Variance
I-405	64	93.14	94.98	91.46	3.52	0.716	0.513
3522	46	93.34	95.52	91.24	4.28	1.035	1.070
3587	24	92.87	94.82	91.66	3.16	0.694	0.482
3636	131	92.49	94.42	88.64	5.78	0.867	0.756

Further examination of construction quality included comparison of the air voids in the compacted ACP with values quoted in the literature. Notwithstanding differences between measurement methods, the I-405 project variability was found to be distinctly less than those reported from the several sources included in Table 4-4.

Table 4-4. Comparison with Reported Standard Deviation of Asphalt Concrete Air Voids for Roadway Compacted Mixtures (adapted from Hughes 1996)

Source	Year	Method	AV%
I-405	1997	Nuclear	*0.73*
California	1995	Cores	*1.9*
New Jersey	1995	Cores	*1.5*
Ontario	1995	Cores	*1.6*
Colorado	1993	Cores	*1.0*
Washington	1993	Nuclear	*0.9*
Virginia	1984	Cores	*1.3*

The effect that air voids in the compacted mix have upon pavement quality is worth noting. Linden et al. (1989) conducted a study wherein they confirmed a basic rule of thumb that for every 1 percent above 7 percent of air voids in the compacted roadway mix, pavement life decreases by 10 percent. The average percentage of air voids for the project was 6.8, which suggests a satisfactory period of service from the overlay.

GRADATION

Areas of quality performance that were explicitly specified in addition to density were the aggregates gradation and the asphalt cement content. Table 4-5 shows how favorably the mix of aggregate and asphalt cement fractions for this job compared to the job mix formula. For each aggregate size and for the asphalt cement content, job gradation fell well within the specified range limits. Even two standard deviations (95 percent of cases) from the job average would still have fallen within specified range limits in all cases except the 1/4-inch (6.33 mm) size.

Table 4-5. Gradation Summary for I-405 Project

Item	JMF%	Job Average %	Standard Deviation %	One Standard Deviation %	Specified Range Limits %
3/4 (19 mm)	100.00	100.00	0.00	100.00	100.0
1/2 (12.5)	98.00	98.00	0.83	97.17 - 98.83	90.0 - 100.0
3/8 (9.5 mm)	86.00	86.71	1.64	85.07 - 88.35	75.0 - 90.0
1/4 (6.33 mm)	69.00	67.19	2.19	65.00 - 69.38	63.0 - 75.0
No. 10 (2.00 mm)	35.00	33.00	1.43	31.57 - 34.43	30.0 - 40.0
No. 40 (425 μm)	14.00	13.69	0.92	12.77 - 14.61	11.0 - 18.0
No. 200 (75 μm)	5.00	4.87	0.41	4.46 - 5.28	3.0 - 7.0
% AC	5.30	5.18	0.18	5.00 - 5.36	4.8 - 5.8

Table 4-6 helps to put the gradation variability into perspective. Aggregate gradation variability data published by Hughes (1996) is shown here for direct comparison to the I-405 gradation results. Note that the variabilities from the I-405 project were consistently less than those reported from the four most recent sources presented from Hughes' synthesis study. The Washington State data from 1993 were obtained from a project that was executed under the then newly developed statistical quality assurance (SQA) specification.

Table 4-6. Comparison with Typical Asphalt Concrete Aggregate Gradation Variability from Extraction Tests (adapted from Hughes 1996)

Size	Percent Passing Standard Deviation				
	I-405	Washington 1993	Arkansas* 1993	Pennsylvania 1982	Virginia 1968
3/4 or 1/2 (19 mm or 12.5 mm)	0.83	1.6	1.7	2.3	-
3/8 (9.5 mm)	1.64	2.5	2.6	4.4	1.9
1/4" or #4 (6.33 mm or 4.75 mm)	2.19	3.0	2.8	3.4	3.3
#8 or #10 (2.3 mm or 2.00 mm)	1.43	2.4	1.7	2.5	3.2
#40 or #50 (425 µm or 300 µm)	0.92	1.6	1.3	1.5	1.6
#200 (75 µm)	0.41	0.5	0.6	1.0	0.9
*Data from questionnaire responses.					

The asphalt cement content variability can also be compared with some typical standard deviations. Table 4-7 shows how the variability from the I-405 project compares to data previously published from several sources and condensed by Hughes (1996). Only data from the last ten years are presented. It is important to acknowledge that variation between measurement procedures may exist. However, the I-405 project compares favorably with other data if the measurement procedure is disregarded.

Table 4-7. Comparison with Typical Asphalt Cement Content Variability (adapted from Hughes 1996)

Source	Year	Test	Std Dev, %
I-405	1997	Nuclear	0.18
Arkansas*	1994	Extraction	0.21
Virginia	1994	Extraction	0.18
Virginia	1994	Nuclear	0.21
NCAT	1994	Nuclear	0.19
NCAT	1994	Centrifuge	0.44
NCAT	1994	Ignition	0.30
Washington	1993	Extraction	0.24
Colorado	1993	Extraction	0.15
Kansas	1988	Nuclear	0.27
Virginia	1988	Extraction	0.19
*data from questionnaire responses.			

LONGITUDINAL JOINTS

Longitudinal joints were expected to be of good quality since the unfinished mat had not been exposed to normal traffic. However, there were noted difficulties in matching the longitudinal joints. This problem was indicated by both waviness in the joint line and deep cracks or tears near and parallel to the joint. Several instances of poor longitudinal joints were noted during both weekends. Because of concern over the quality of the longitudinal joints during the first weekend of paving (southbound), instructions were given to apply a fog seal to the joints. The joints still appeared wavy in the northbound direction, but no sealing was deemed necessary.

Without direct observation, causes for flaws in the longitudinal joints are speculative. However, consultation with the contractor's supervisors and reference to the literature (*Hot Mix …*; *Asphalt Construction Handbook* 1992) revealed three potential explanations for the problems with the longitudinal joints. The first possibility is that the wide drums of the large rollers may have extended too far beyond the free edge of the

mat, thus creating an improper edge on the cold mat side of the joint. The second possibility is excessive rolling of the joint, especially during the cooler nighttime hours when the AC mat temperature may have been too low. A final possibility is that too much of the width of the vibratory roller extended onto the cold mat.

Finally, note that flaws in the longitudinal joints were more extensive because nighttime visibility inhibited recognition of the problem, a case for better lighting. In addition, the relatively high speed of the paving operation often meant that the compaction operations were too far behind (confirmed by IDR comments), thus giving the AC mat more time to cool before compaction.

CYCLIC SEGREGATION

Experiences with other projects raised the issue of cyclic segregation on the I-405 project. It was determined, however, that the continuous paving with a pickup device, combined with no expectation of prolonged nighttime cooling of the HMA in the truck, would preclude any problem with cyclic segregation. Visual inspection of the pavement by both the investigators and WSDOT personnel revealed no evidence of cyclic segregation.

OTHER SURFACE DEFECTS

There were numerous tears in the ACP mat throughout the outside lane (#1) in the northbound direction. The contractor's supervisors thought the tack coat might have been inadequate, perhaps through removal by heavy truck traffic. The resulting lack of adhesion between the prelevel surface and the overlay may have allowed the mat, which was unrestrained on the shoulder side, to slide and therefore to tear easily during the rolling operations. This problem, along with the assessment of the longitudinal joints, indicates a need to pay closer attention to the interaction between temperature, the speed of paving, and the paving plan lane sequence.

SUMMARY

The overall level of quality in the overlay was good with respect to smoothness, density, gradation, and cyclic segregation. Comparisons with historical data from Washington State, as well as a few other states, were quite favorable, indicating that the quality of the I-405 project with respect to these parameters was decidedly better than average. Not only were commendable mean values achieved, but variabilities were notably minimized.

For the measured quality parameters, no statistically substantiated differences appeared between night and day paving. However, more samples between night and day shifts would be desirable to draw a solid conclusion. Data from future weekend closures should be combined with the data from the I-405 project to allow a more comprehensive evaluation of the quality achieved with the closure method.

Roller operations seem to be the major area of difficulty during weekend closures. This was evident in problems with the longitudinal joints and in surface tears in one lane of the northbound direction. Several IDR notations also referred to this problem. The high speed of the laydown operation demands substantial effort by the roller operators to keep up with the paver. An adequate number of rollers must be available. Based upon the experience of the first weekend, the contractor did begin the second weekend with four rollers, but did not replace two of the four when they broke down. Close attention to this vital construction operation is recommended for future weekend closure projects.

CHAPTER 5
ANALYSIS OF PAY FACTORS

An analysis of the pay factors that were earned by the contractor for the I-405 project was conducted as an outgrowth of consultation with WSDOT personnel after the in-place density and gradation records had been examined. The objective of the analysis was to examine the trends revealed by a comparison of the calculated pay factors with their corresponding parameter measures, not to perform an in-depth examination of WSDOT's SQA procedures. This chapter discusses the results obtained from examining pay factors for uncompacted AC mix and in-place AC pavement. The reader is referred to WA-RD 326.1 (Markey et al. 1994) for an explanation and sample calculation of pay factors, as outlined in the WSDOT statistical quality assurance specifications.

IN-PLACE DENSITY

Figures 5-1 and 5-2 show plots of the pay factors versus the average percentage of Rice densities for the southbound and northbound paving, respectively. Each plot indicates that, with few exceptions, average densities at or above 93 percent typically resulted in maximum pay factors of 1.05. The practical target for the contractor is 92 percent of Rice density, while the statistically specified minimum as noted in Section 5-04.3(10)B of the *1994 Standard Specification*, is 91 percent. None of the average densities were below 91 percent. Points of interest are those that fell between 92 percent and 93 percent.

In both figures 5-1 and 5-2, average or lot densities between 92 percent and 93 percent yielded a scatter of corresponding pay factors, including maximum values. The northbound direction had the widest range. Even at and slightly above 93 percent, a few pay factors were calculated at less than maximum for the southbound direction. Figures 5-3 and 5-4 convey a better perspective of the relation between these densities and the calculated pay factors. Each column, measured from the left vertical axis (ordinate), represents the average percentage Rice density for the sequence of lots that were measured.

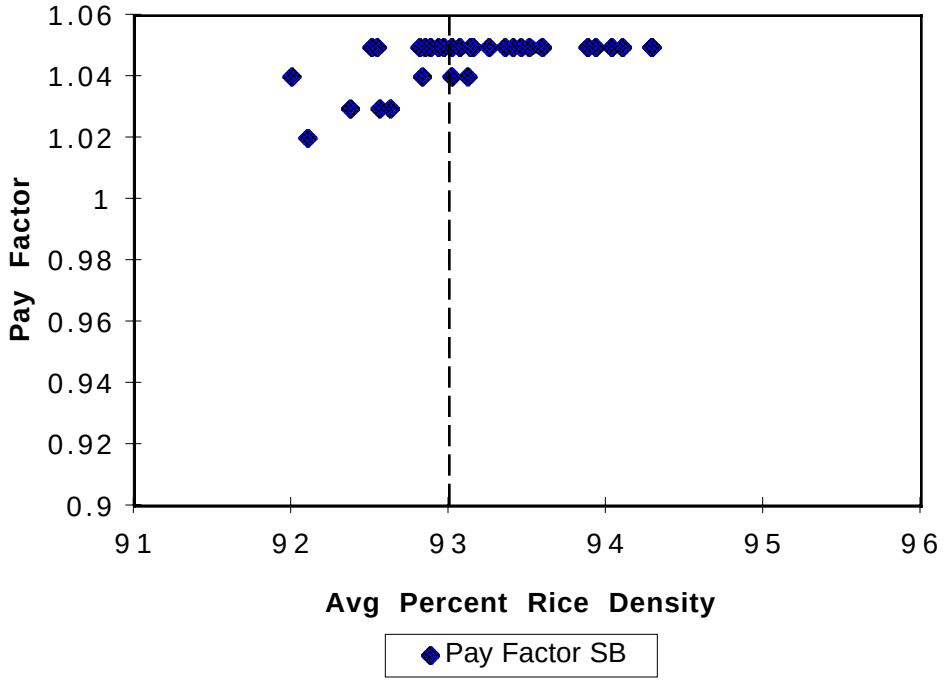


Figure 5-1. Pay Factors versus Average Densities for Southbound Paving

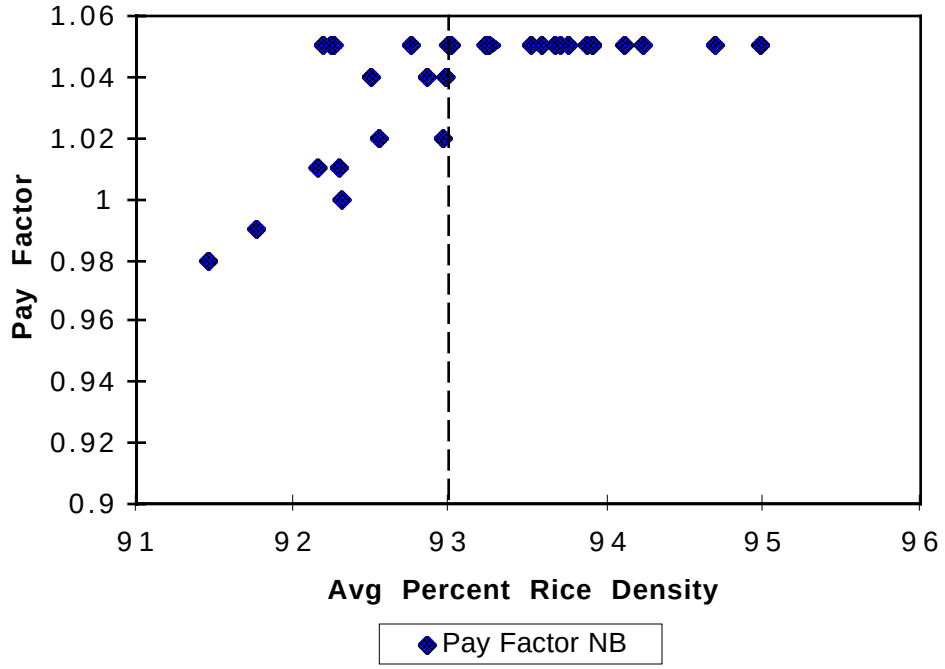


Figure 5-2. Pay Factors versus Average Densities for Northbound Paving

The triangles represent the corresponding pay factors, which are scaled on the right ordinate. The southbound sequence of pay factors conveys the picture of a relatively steady performance, which is consistent with the generally lower variability noted for that weekend closure. The northbound sequence, however, which was visually (although not statistically) characterized by greater variability in density measurements, only shows a corresponding variability in pay factors from Saturday night (August 23) through Sunday morning (August 24). Close examination of both figures reveals several instances of lower average densities associated with the maximum pay factors, while some slightly higher average densities are associated with lower pay factors. It is evident from these charts that the variation in pay factors did not consistently follow the variation in average measured densities.

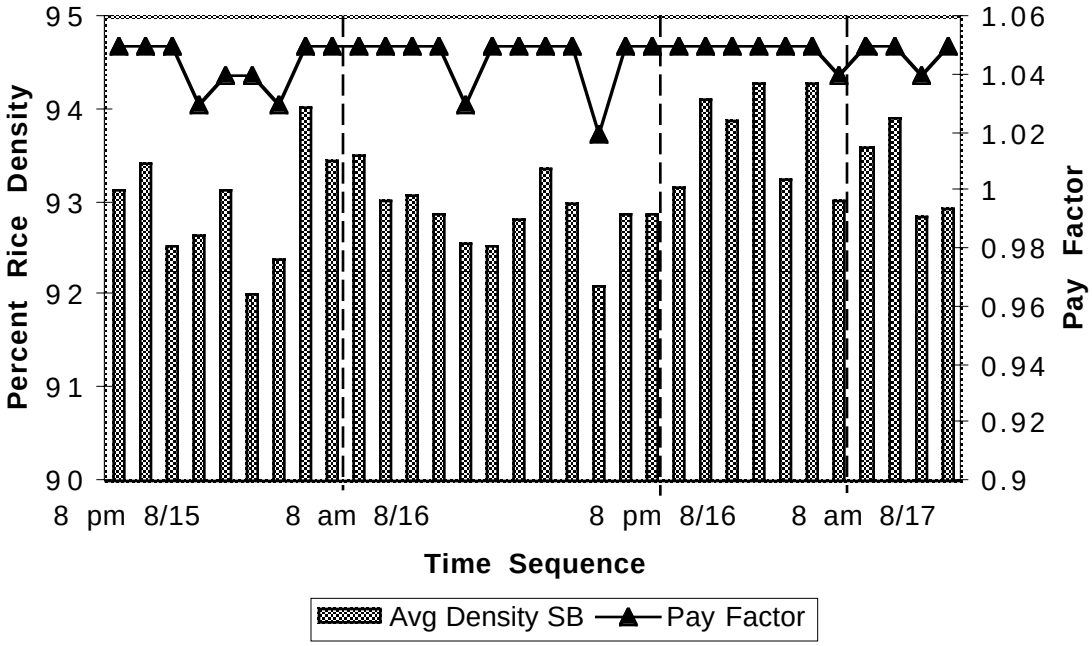


Figure 5-3. Plot of Pay Factors and Average Densities for Southbound Paving

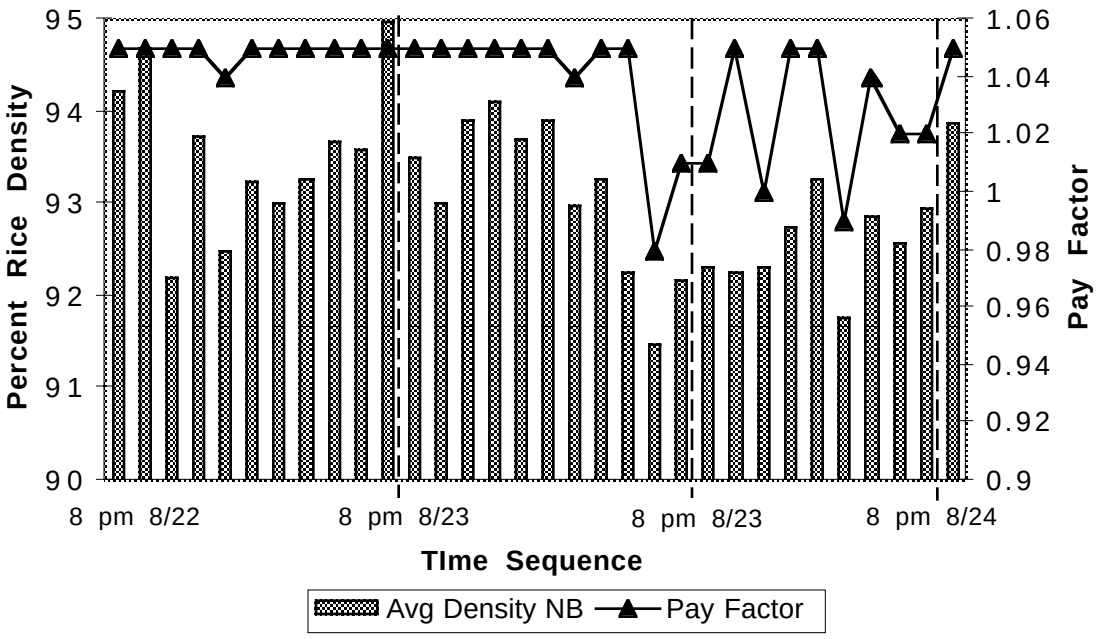


Figure 5-4. Plot of Pay Factors and Average Densities for Northbound Paving

The explanation for the apparent inconsistency between lot density patterns and pay factor patterns is shown in figures 5-5 and 5-6, which display the same pay factors as they correspond to the ranges of sublot in-place densities that are represented by each average density. What is noted upon comparison with the two preceding figures is that lower densities that yielded maximum pay factors were calculated from smaller ranges of sublot densities. A specific example of this occurrence is the sixth lot taken from the Saturday (8/16) daytime shift for the southbound paving. Series of lots that corresponded to maximum pay factors were characterized by notably smaller ranges of sublot densities for both weekends of paving. Conversely, the last night (8/23) of paving for the northbound direction, which was characterized by a considerably smaller percentage of maximum value pay factors, was characterized by wider ranges in sublot densities. The recorded values

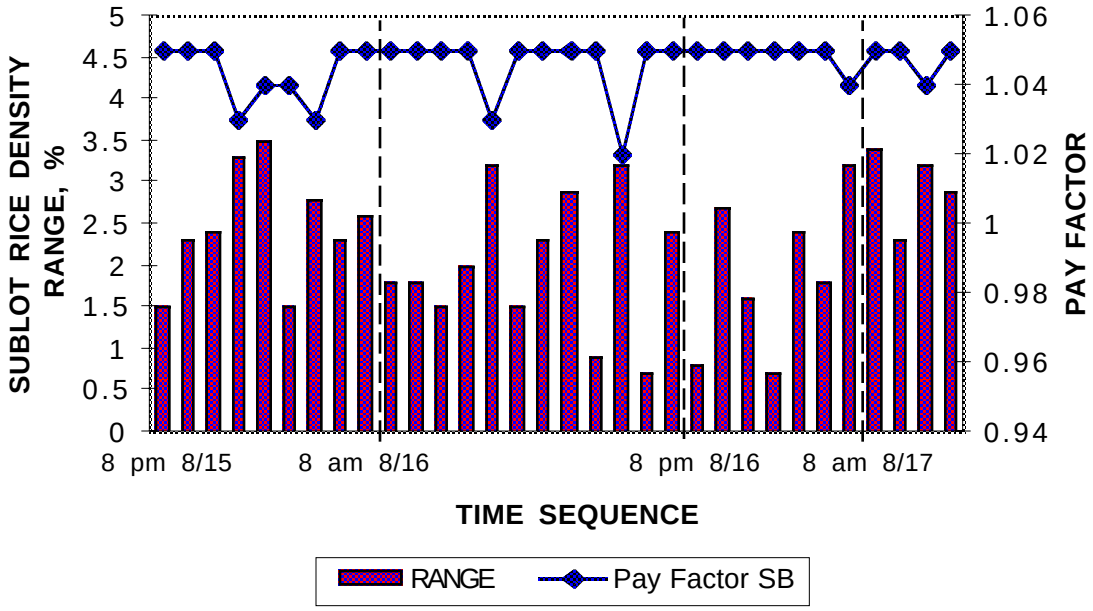


Figure 5-5. Pay Factors and Range of Rice Density Percentages for Southbound Direction

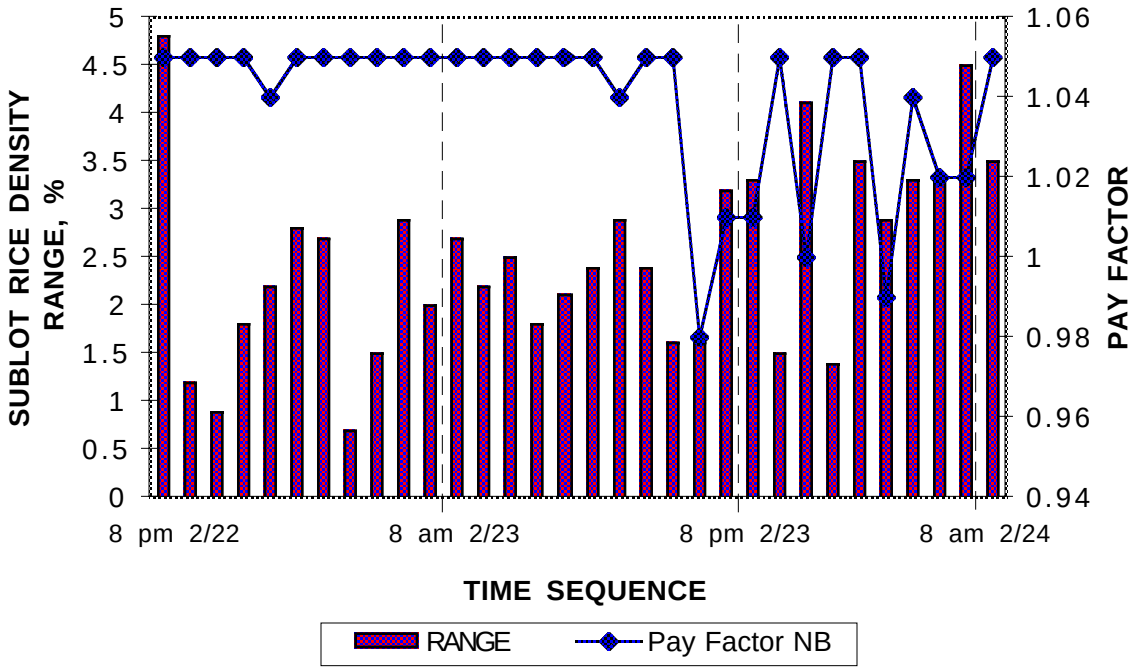


Figure 5-6. Pay Factors and Range of Rice Density Percentages for Northbound Direction

also revealed that some sublot values were lower than 91 percent of Rice density, which also contributed to less than maximum pay factors for the corresponding lots.

In summary, the contractor was successful in achieving maximum pay factors for in-place densities through most of the project. Instances in which the contractor was not successful in spite of reasonably high lot densities were explained by either below-minimum sublot density measurements or wide ranges of sublot densities. Therefore, the pay factors clearly tempered the reward that would accompany higher average densities with a penalty for lower individual sublot densities and for inconsistency.

GRADATION PAY FACTORS

Comparison of pay factors with corresponding parameters is not as straightforward for aggregate gradation and asphalt cement content as it is for in-place densities. Pay factors for aggregate gradation and asphalt content for the I-405 project are listed in Table 5-1. Each pay factor represents 42 sublots of 800 tons each. The composite pay factor was 1.043. Each item pay factor is a function of specified range limits, the average percentage, and the standard deviation achieved for the specific item. Therefore, no significant insights may be derived from comparisons between pay factors and any measured parameters for aggregate gradation and asphalt content for any single project. It can only be stated that lower variabilities were rewarded with higher pay factors. Comparisons between projects with identical specified range limits would be of greater relevance, as they would reveal the impact of standard deviation variability.

Table 5-1. Pay Factors and Standard Deviations for AC Mix Items

Item	Pay Factor	Standard Deviation (%)
3/4 (19 mm)	1.05	0.00
1/2 (12.5)	1.05	0.83
3/8 (9.5 mm)	1.04	1.64
1/4 (6.33 mm)	1.04	2.19
No. 10 (2.00 mm)	1.04	1.43
No. 40 (425 µm)	1.05	0.92
No. 200 (75 µm)	1.05	0.41
% AC	1.04	0.18

CHAPTER 6
SURVEY RESULTS: PUBLIC FEEDBACK

A survey was conducted to ask travelers how their travel patterns had changed in response to the weekend closing of I-405. Questions related to the effectiveness of the information campaign and the travelers' overall impressions.

The sample of travelers was drawn from license plates of vehicles observed using the I-405 facility during the three weekends preceding construction. In all, 2170 Washington state license plate numbers were collected and matched with addresses through the Washington State Department of Licensing. After irrelevant data had been excluded, such as rental cars and out-of-state addresses, 1,940 surveys were mailed to vehicle owners in early September 1997. Of those, 378 valid surveys were returned (a response rate of 19.4 percent). Data were coded and analyzed with the LIMDEP statistical package (Greene, 1995).

DESCRIPTIVE STATISTICS

Table 6-1 has summary statistics for respondents' socioeconomic attributes. The average respondent was about 45 years old; about 57 percent were male; and almost 69 percent were married. The average household contained 2.77 members, with 1.53 working people and 2.28 vehicles.

Figure 6-1 shows the distribution of age; most respondents were between 31 and 60. Figures 6-2 and 6-3 show the distribution of income and education level of respondents. The income of more than half of the households was over $50,000/year, and over 50 percent of respondents had a college and/or post graduate degree.

Table 6-1. Summary of Respondents' Socioeconomic Attributes

Gender	Male	213	(56.50%)
	Female	164	(43.50%)
Marital status	Married	259	(68.88%)
	Single	69	(18.35%)
	Separated	4	(1.06%)
	Divorced	34	(9.04%)
	Other	10	(2.66%)
Average age		44.8	
Average household size		2.77	
Average number of working people		1.53	
Average number of motor vehicles		2.28	

Figure 6-1. Distribution of Age

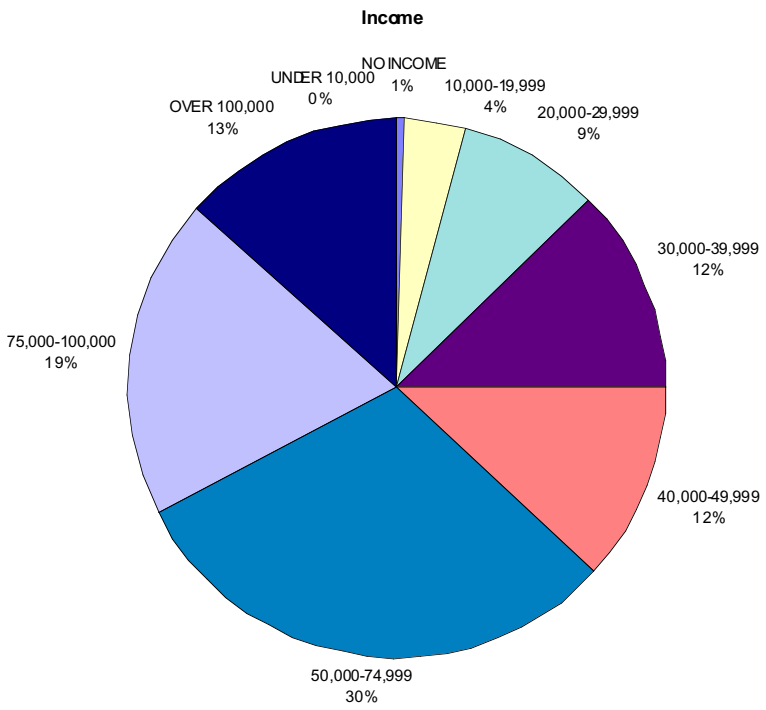


Figure 6-2. Income Distribution of Respondents

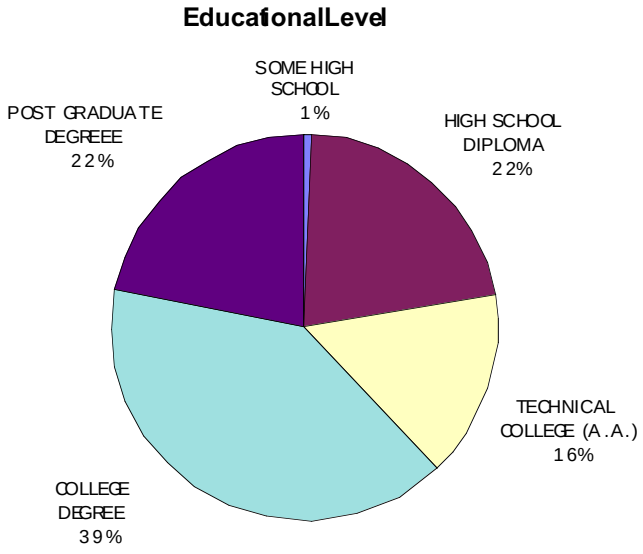


Figure 6-3. Educational Level of Respondents

Table 6-2 shows the respondents' traffic-related behavior during the closure. About 85 percent of respondents were in the Seattle area during the closure on either August 15th through 18th or August 22nd through 25th, and 18 respondents arranged a schedule to be out of the area because of the I-405 closure. About 53 percent said that the weekend closure of I-405 affected their travel plans in some way. About 70 percent of respondents changed their routes, 42 percent altered their departure time, 9 percent canceled their trips, 8 percent shopped at different places, and 6 percent spent less money. Ninety-three percent of respondents said that they knew of the weekend closures in advance. More detailed analysis is presented in subsequent sections.

In terms of trip types canceled because of the I-405 closure: 37 percent of visiting trips, 24 percent of shopping trips, 15 percent of business trips, 12 percent of recreation trips, and 12 percent of other types of trips were canceled. The distribution of alternative routes taken because of weekend closure showed that most respondents took I-5 (39 percent) and I-90 (27 percent) as alternative routes.

The distribution of the sources from which respondents gained information about the I-405 closures showed that 32 percent of respondents learned about the I-405 closures from radio, 28 percent from television, 26 percent from road signs, 6 percent from word of mouth, 4 percent from newspapers, and 4 percent from other sources. For comparison, the ways that people usually acquire traffic-related information in the Puget Sound region are 36 percent from radio, 26 percent from road variable message signs, 21 percent from television, 8 percent from newspapers, 5 percent from word of mouth, and the rest from other means.

Table 6-2. Summary of Respondents' Travel-Related Behaviors

Question	Yes	No
Were you in the Seattle Area during the weekends of either August 15-18 or August 22-25?	319 (84.62%)	58 (15.38%)
↳ If no, did you arrange your schedule to be out of the area because of the I-405 weekend closure?	18 (22.22%)	63 (77.78%)
Did the weekend closure of I-405 affect your travel plans in any way?	178 (53.45%)	155 (46.55%)
Did you use a trip route that you would not have normally taken because of the weekend closure of I-405?	179 (69.11%)	80 (30.89%)
Did you change the departure time of any of your trips because of the weekend closure of I-405?	109 (41.76%)	152 (58.24%)
Did you cancel a trip that you would have normally taken because of the weekend closure of I-405?	23 (8.78%)	239 (91.22%)
Did you spend less money shopping because of a weekend closure of I-405?	15 (5.68%)	249 (94.32%)
Did you shop at different places because of a weekend closure of I-405?	20 (7.58%)	244 (92.42%)
Were you aware of the I-405 closures before they happened on August 15-18 or August 22-25?	353 (93.39%)	25 (6.61%)

ESTIMATION RESULTS

An ordered probit model was appropriate to use because the data were ordinally ranked (i.e., disagree strongly, disagree, neutral, agree and agree strongly), as discussed earlier. The ordered probit model results of the opinions about each statement are presented in Appendix B with the resulting coefficients, t-statistics, and marginal effects.

Travel Impacts

Figure 6-4 shows the distribution of responses to the statement that the weekend I-405 closures had a major impact on their travel plans. About 70 percent of respondents said that they experienced no major impact on their travel plans. For comparison, in answer to a previous similar question, 54 percent of respondents said that the weekend closure of I-405 had affected their plans anyway.

The estimation results in appendix Table B-1 show that respondents younger than 30 were more likely to believe that the closure had had a major impact on their travel plans. This may be because younger people usually participate in more outdoor activities during the weekend than older people. Households with less than $30,000 in income and respondents who were highly educated were less likely to agree with this statement. Seattle and Bellevue residents were less likely to believe that the I-405 closure had a major impact on their travel plans. This may be because they have easy access to alternative routes such as I-90 and I-5.

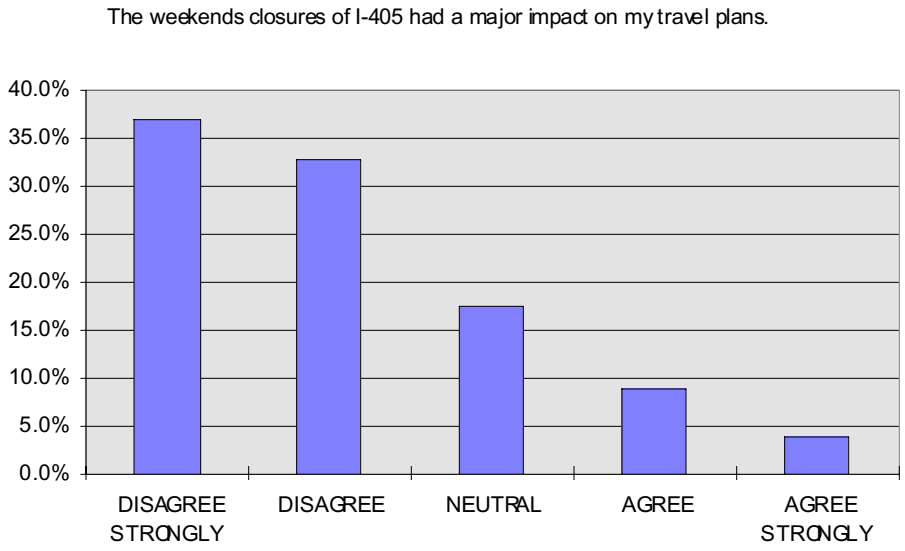


Figure 6-4. Responses to the Statement That the Weekend Closures of I-405 Had a Major Impact on Travel Plans

Information Dissemination

The state and the media were apparently successful at informing the public of the I-405 closures. About 88 percent agreed that the state and the media allowed most people to plan ahead. However, middle age respondents between 30 and 54 were less likely to believe that information about I-405 was properly disseminated by the state or media. (See appendix Table B-2.) As the number of working people in households increases, the likelihood that respondents would support this statement increases. Bellevue residents were more likely to agree with this statement than Seattle or Kirkland residents.

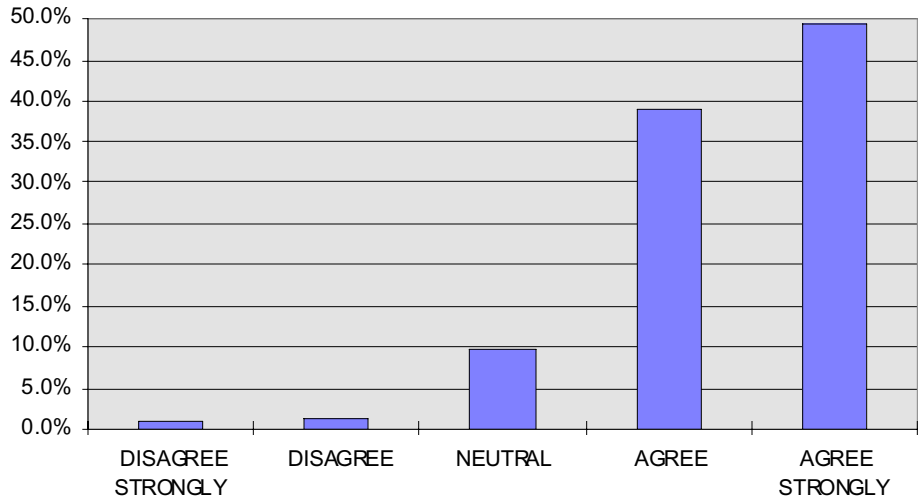


Figure 6-5. Responses to the Statement That the State and the Media Did a Good Job of Making the Public Aware of the I-405 Closures

Effectiveness of Plan

Given that transportation planning is a political process, public perception is as important as the program itself. The statement that closing highways completely for a weekend is better than closing a few lanes during the day for several days was overwhelmingly supported by 87 percent of respondents. The results in appendix Table

B-3 show travelers' opinions, depending on socioeconomic characteristics. Middle age respondents and Kirkland or Mercer island residents were more likely to disagree with this statement. People in higher-income households and respondents who were highly educated were more likely to believe that closing highways completely for a weekend is better than closing a few lanes during the days for several days. As the number of working people in a household increased, the likelihood that respondents would support this statement increased.

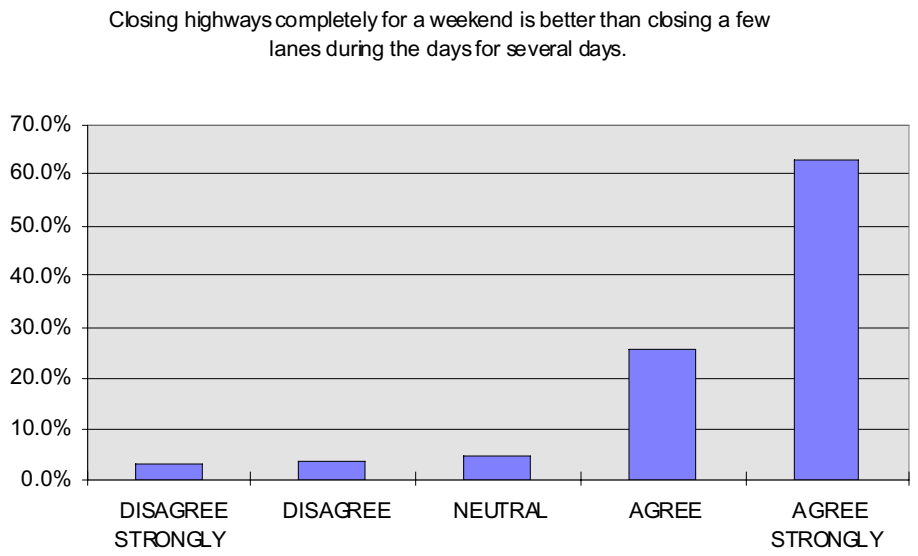


Figure 6-6. Responses to the Statement That Closing Highways Completely for a Weekend Is Better Than Closing a Few Lanes During the Day for Several Days

Business Impacts

For the statement that the weekend closures of I-405 had a significant, negative impact on area businesses, 47 percent of respondents disagree, 46 percent were neutral, and 7 percent agreed (Figure 6-7). Appendix Table B-4 presents the ordered probit estimation results. Middle age respondents were more likely to think that the closure had a significant, negative impact on area businesses. Those with a high school diploma or higher education were less likely to agree with this statement. As the number of

household people increased, the likelihood that respondents would support this statement decreased. Redmond and Bellevue residents were also less likely to agree with this statement.

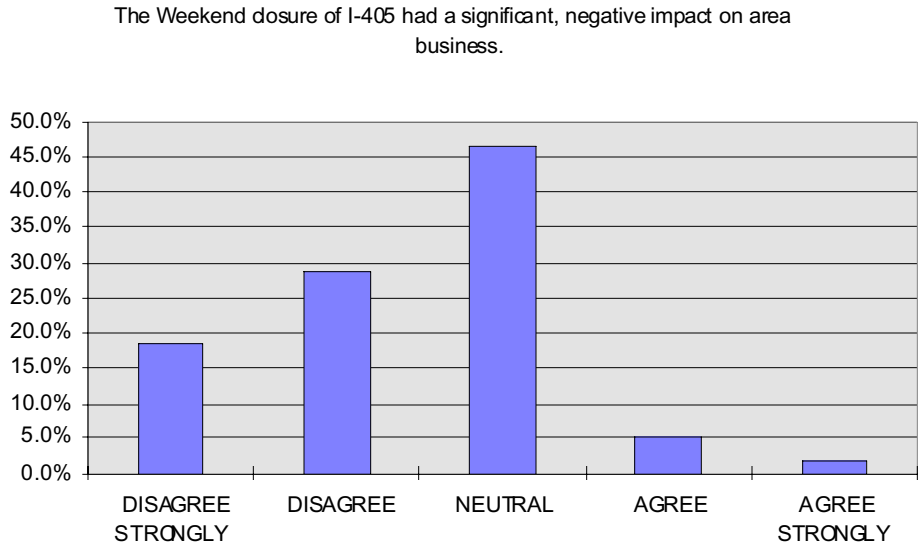


Figure 6-7. Response to the Statement That the Weekend Closure of I-405 Had a Significant, Negative Impact on Area Businesses

MODELING RESULTS: DISCRETE CHOICES

Impact of Travel Plan by the Weekend Closure of I-405

The binary logit model estimates of whether the weekend closure of I-405 affected respondents' travel plans are presented in appendix Table B-5. Respondents less than 30 years old were more likely to consider themselves affected by the closures, but those 55 or over were less likely to believe that their travel plans had been affected. In addition, as household income increased, travel plans were more likely to be affected. Respondents with college degrees were less likely to think that their travel plans had been affected. As the number of children under 6 years old increased, the likelihood of agreeing increased. Bellevue, Renton, and Kent residents were more likely to be affected by the closure than Seattle residents.

Route Selection

Appendix Table B-6 shows binary logit model results for estimating whether respondents used routes that they normally would not have taken. As respondents' age increased, they were less likely to change from routes usually taken. However, as household income increased, the likelihood of route change increased. Respondents with college degrees were less likely to use other routes. Similarly, as the number of children under 6 years old increased, respondents were less likely to use other routes. Respondents with a higher number of operable vehicles were more likely to reroute. Respondents' geographic locations affected their travel behaviors, as expected. Bellevue, Renton, Kent, and Kirkland residents were more likely to use other routes than Seattle residents because Seattle residents were not severely affected by the closures.

Departure Time

The model estimates for whether departure time was changed because of the weekend closures of I-405 are presented in appendix Table B-7. Estimation results show that married people, older respondents, and respondents from low income households (less than $20,000) were less likely to change departure times. People in higher income households (more than $50,000) were also less likely to change departure times. However, as the number of children age 6 to 16 increased, respondents were more likely to change their departure time because of the closures. The greater the number of operable vehicles, the less the likelihood of departure time change. As expected, Seattle residents were less likely to change their departure time.

Trip Cancellation

Appendix Table B-8 presents the estimates of whether respondents canceled trips that they would normally have taken because of the weekend closures of I-405. Single people were more likely to cancel their trips. Respondents younger than 30 and respondents with high school diplomas were less likely to cancel their trips. In addition,

as the number of operable vehicles increased, the likelihood of trip cancellation decreased. Renton residents were more likely to cancel their trips.

Shopping Behavior

The estimates for whether respondents shopped at different places because of the weekend closures of I-405 are presented in appendix Table B-9. Single people were less likely to shop at different places. Also, as the number of people in a household increased, the likelihood of this statement decreased. Male respondents were more likely to shop at different places. People younger than 30 had a similar tendency. Respondents with a college degree were more likely to shop at different places, and as the number of children between 6 and 16 increased, the likelihood of this statement increased. Bellevue area residents had positive likelihoods, unlike Seattle area residents.

Awareness of the I-405 Closures

Appendix Table B-10 shows whether respondents were aware of the I-405 closures beforehand. The positive coefficient of the constant term indicates that overall, the public was aware. Middle aged respondents were less likely to be aware of the closures, and higher income household people also the same tendency. However, as education level increased, respondents were more likely to be aware of the closures. Also, as the number of working people in a household increased, respondents were more likely to be aware of the closure plan. It may be that working people were more sensitive to road closure because it might affect their work activities. Bellevue residents were also more likely to be aware of the I-405 closure, perhaps because Bellevue is in and around I-405.

CHAPTER 7
BUSINESS AND RETAIL IMPACTS OF CLOSURES

Data were collected from area businesses during the last week of August to determine the impact of the two weekend closures on businesses. Businesses were contacted by telephone and asked how their business was affected during the two weekend closures. Their response was recorded on a scale of 1 to 5, with 1 being a strong negative impact, 3 being no impact, and 5 being a strong positive impact. The average response, on this scale, for all businesses was exactly 3.0 (indicating no impact on average). Of the 30 businesses, 1 indicated a strong negative impact, 4 indicated a mild negative impact, 22 indicted no impact, and 3 indicated a mild positive impact. Figures 7-1 and 7-2 give some summary information on the survey.

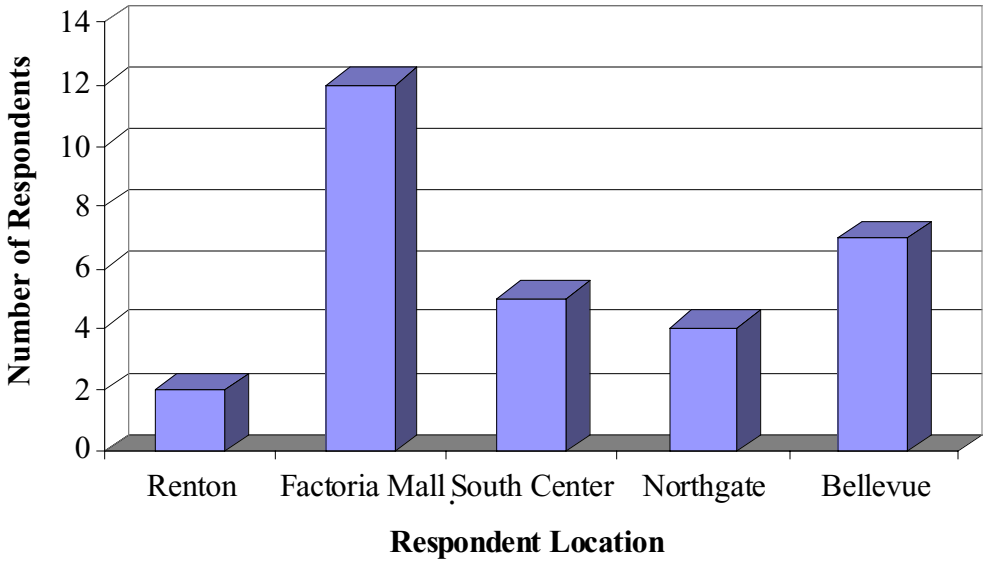


Figure 7-1. Number of Respondents from Specified Locations.

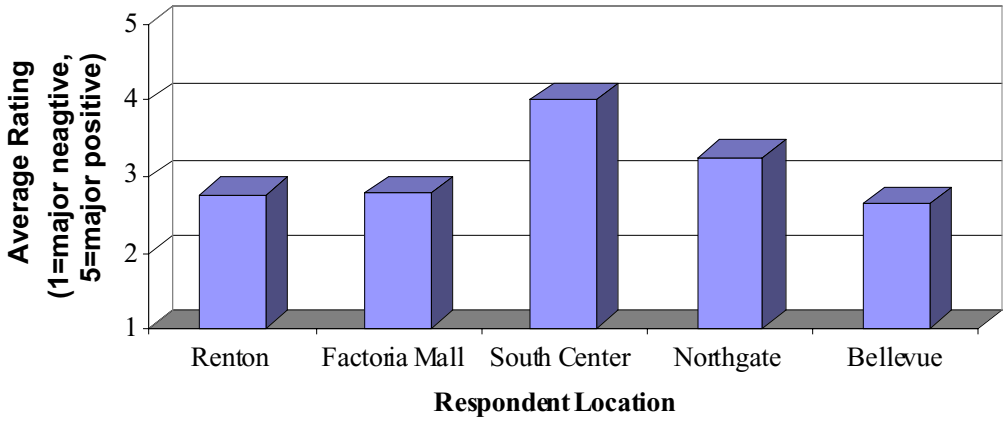


Figure 7-2. Average Ratings of Business Impacts Attributable to Closures by Respondent Location.

Some of the businesses surveyed offered detailed information on the impacts of the closure. One Renton business owner said, "Business was down slightly the first weekend, but not the second. We were not really affected." (Lermond's of Renton).

Seven of the Factoria Mall businesses gave the following responses:

"Probably due to back-to-school shopping, business actually increased. People are going to find a way to get to Target." (Target)

"The closure inconvenienced managers who live in Tacoma, but we were very busy." (Old Country Buffet)

"Business was helped on the southbound closure and hurt on the northbound closure." (Big 5)

"We were very slow." (Torero's Restaurant)

"No problem, no complaints. The following weekend would have been bad if the closure had occurred then, due to back-to-school shopping." (Beanpod Restaurant)

"The southbound closure had no effect. Business during the northbound closure was down 20 percent." (Petco)

"With the sale and it being a new store it is hard to tell." (Nordstrom)

Two Bellevue businesses responded as follows: “The weekend of the southbound closure, business was half of normal. During the northbound closure business was down but not by as much.” (Scandia Down):

“Business was very slow, but it is hard to differentiate the reason. People have complained, however.” (Kitchen Kitchen)

Businesses at Northgate and South Center did not provide detailed comments.

Eleven trucking firms were surveyed by telephone in Seattle, Tukwila, Kent, and Bellevue and asked whether the weekend closures had an effect on their operations. Responses were measured on a scale of 1 to 5, with 1 being no effect, 3 being some effect, and 5 being a significant effect. The results of the survey are summarized in Figure 7-3. This figure shows that about 64 percent indicated very small or no effect, while 27 percent indicated a significant effect. These results are similar to the business findings, with most firms not being significantly impacted but some indicating significant impacts. While some firms were clearly affected by the closure of a major route in the highway network, overall impacts were surprisingly low.

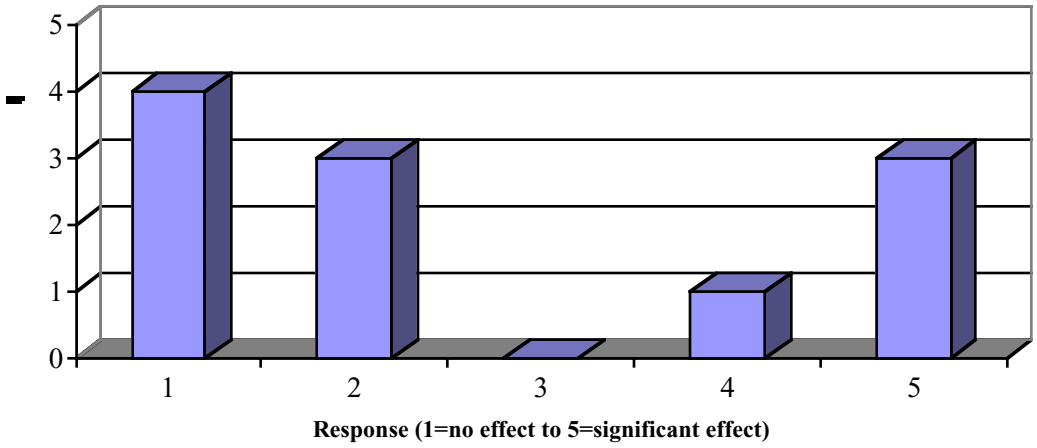


Figure 7-3. Ratings of Impacts upon Trucking Firms

CHAPTER 8
TRAFFIC OPERATIONAL IMPACTS OF CLOSURES

The intent of this chapter is to evaluate the traffic-related impacts of I-405 closure during construction. WSDOT closed traffic in a single direction for two consecutive weekends, August 15 through 17 and August 22 through 24, 1997. This approach was evaluated to determine its impact on vehicle travel time, vehicle miles traveled by single-occupant vehicles (SOV), and vehicle miles traveled by high occupancy vehicles (HOV). Also examined were total emissions, including carbon monoxide (CO), oxides of nitrogen (NOx), and volatile organic compounds (VOC).

SIMULATION OF I-405 CLOSURES

I-405 closure was evaluated through the application of the calibrated traffic assignment model XXE (as described above). An overview of the model application procedure is presented in Figure 8-1.

The impacts of this approach on traffic congestion in the Seattle area were estimated by using the calibrated XXE traffic assignment model and measured in terms of vehicle travel time and total vehicle-miles-traveled. Table 8-1 summarizes the results, and Figure 8-2 gives the percentage changes in travel times and total vehicle miles traveled.

Table 8-1 shows that closing I-405 from Southcenter to Coal Creek had minimal impact on system performance. However, as expected, all of the measures of system performance increased.

In interpreting the results, it is important to recognize the limitations of the traffic simulation approach. First, the weekend Origin-Destination matrix had to be estimated. Although the researchers were confident that the matrix was reasonably close to the actual conditions, some caution must be used in interpreting the results. Second, our model assigned travel on the basis of expected travel time and assumed that travelers

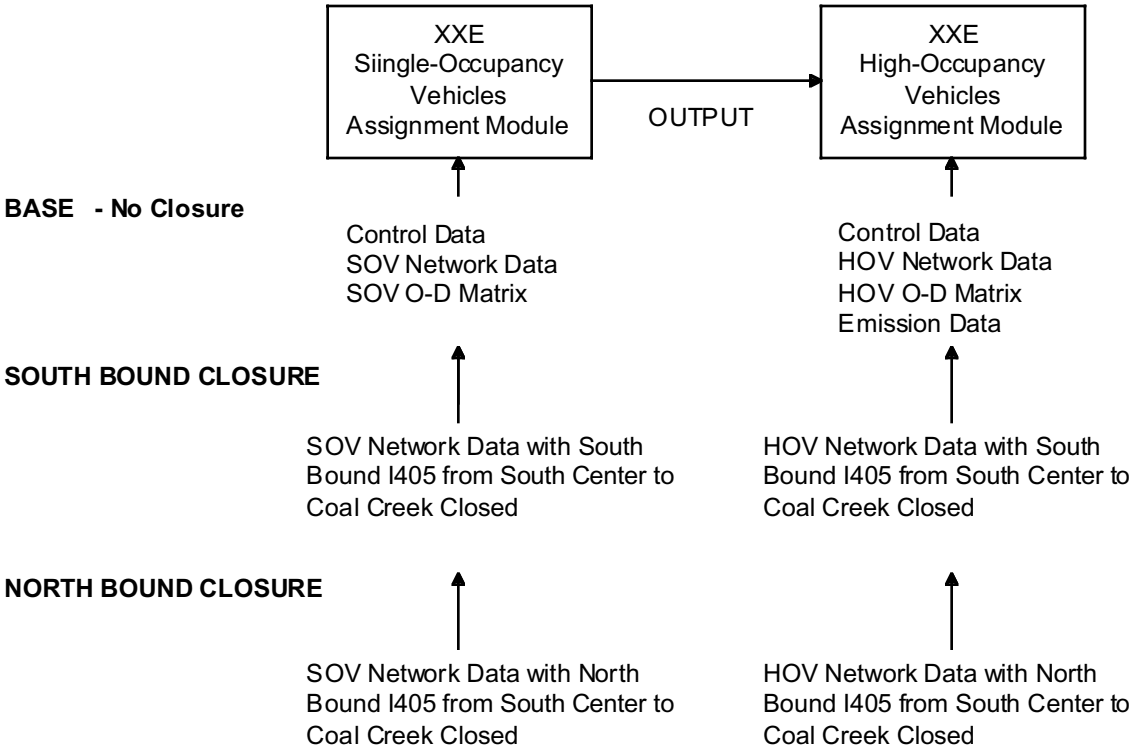


Figure 8-1. Simulation Process

Table 8-1. Simulation Results (weekend peak hour)

	Total Travel Time (veh-hours)	Total Vehicle Miles Traveled	Avg. Congestion (Non-zero links)	Total CO Emission (grams/sec)	Total NOX Emission (grams/sec)	Total VOC Emission (grams/sec)
Base (No Closure)	43,000	1,200,000	0.48	9046.19	1234.08	1283.99
South Bound Closed	48,600	1,220,000	0.52	9809.57	1253.13	1371.44
North Bound Closed	49,300	1,220,000	0.51	10069.10	1259.47	1406.43

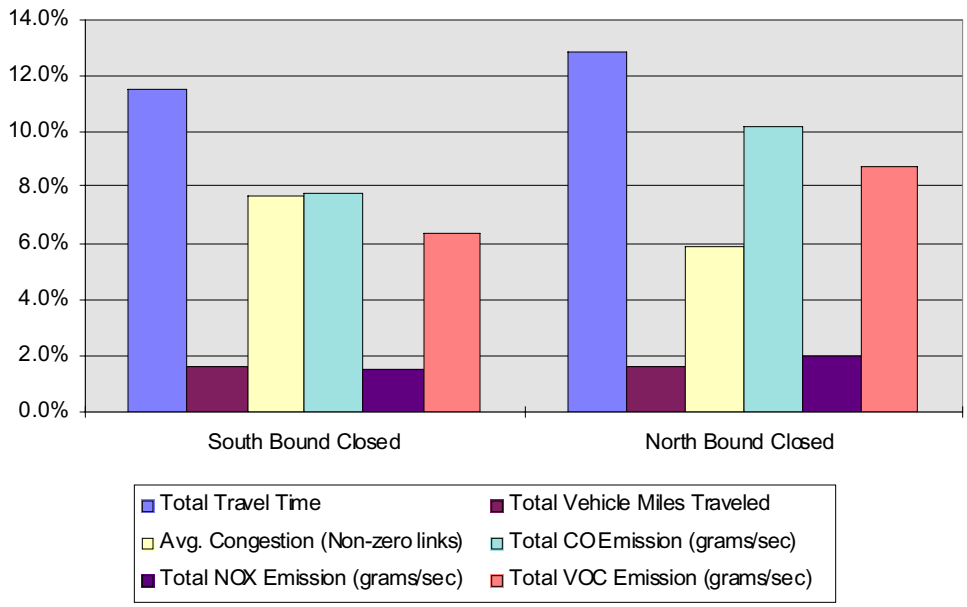


Figure 8-2. The Percentage Change Resulting from the Closures

do not change their trip-departure times or modes in response to congestion. The complete shut-down of I-405 almost certainly would have had great effects on travel characteristics (i.e., departure time and mode choice) that would need to be considered. Nevertheless, in spite of these limitations, the results presented in this chapter provide a good idea of the range of impacts that could be observed.

SCENARIO: HALF CLOSURE

Another possible scenario, closing the half of lanes, was simulated. Table 8-2 summarizes the results, and Figure 8-3 gives the percentage changes in travel times and total vehicle miles traveled. As expected, all of the measures of system performance decreased in comparison with the results of complete closure.

Table 8-2. Simulation Results with Half Closure (weekend peak hour)

	Total Travel Time (veh-hours)	Total Vehicle Mile Traveled	Avg. Congestion (Non-zero links)	Total CO Emission (grams/sec)	Total NOX Emission (grams/sec)	Total VOC Emission (grams/sec)
Base (No Closure)	43,000	1,200,000	0.48	9046.19	1234.08	1283.99
South Bound Closed	44,100 (2.5%)	1,200,000 (0%)	0.49 (2%)	9178.56 (1.4%)	1230.45 (-0.3%)	1299.31 (1.2%)
North Bound Closed	43,900 (2.1%)	1,200,000 (0%)	0.5 (4%)	9228.98 (2.0%)	1234.52 (0.0%)	1303.51 (1.5%)

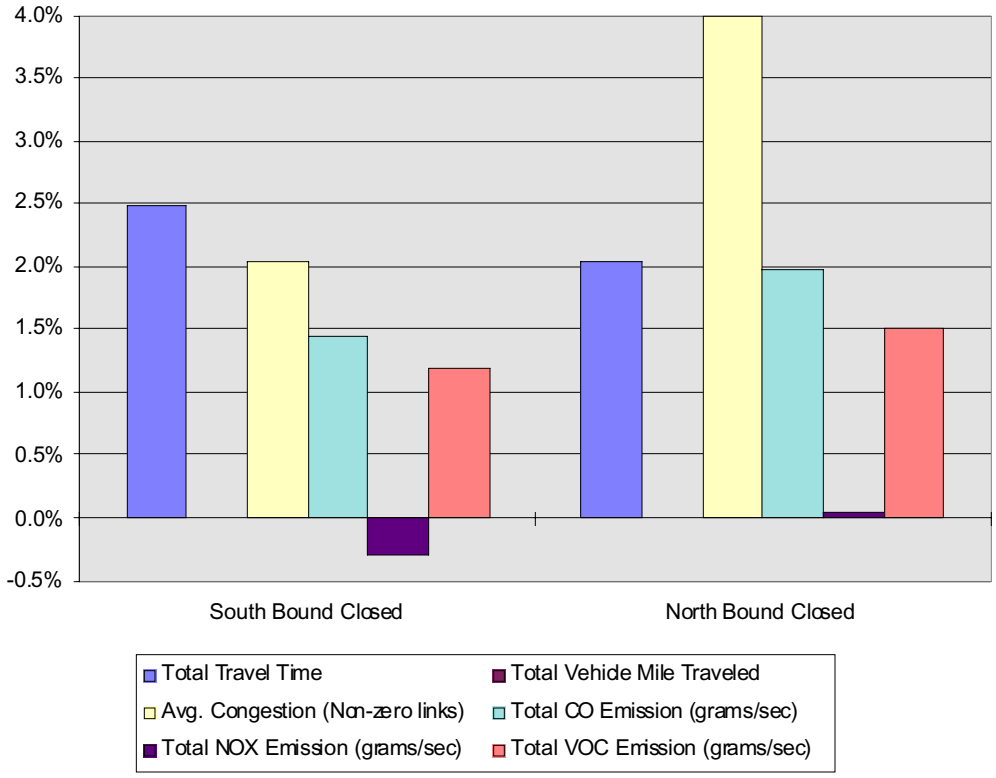


Figure 8-3. The Percentage Change Resulting From Half Closure

CHAPTER 9
EXPERIENCES OF OTHER STATE HIGHWAY AGENCIES

While the researchers knew at the outset of this study that the full weekend closure strategy was unique, learning what other selected states were planning for or had experienced with various closure strategies was deemed valuable. Nine state highway agencies were contacted, and six provided responses to a brief survey, which is included in Appendix C.2. The responding states were among those considered to have heavily populated areas that would require innovative approaches for accomplishing large highway reconstruction or rehabilitation projects. The responding states were Illinois, California, Georgia, Massachusetts, Texas, and Florida.

NUMBER OF PROJECTS

Table 9-1 indicates the amount of highway reconstruction work that the responding states were involved in executing. Only projects exceeding 25,000 tons are included in the counts that are shown for past and future projects. The state of Texas appeared to have a much larger program than the other participating states, although it was not apparent from the survey how any of the states were physically dividing their work.

PREFERRED LANE CLOSURE STRATEGIES

Choices for lane closure strategies were characterized by number of lanes and time of day. Single lane closures were used most often by five of the six states (Table 9-2). As expected, the majority also employed night closures most frequently. There was no consensus on the second or third choices. However, single lane closure was the overall leading choice for number of closure lanes, whereas the choice between night and day was roughly even. The notion of multi-lane closures did not appear significant until the fourth level of frequency was reached. In addition, each state preferred to use the multi-lane strategy first during night hours before selecting it as a daytime option.

Table 9-1. Survey Responses—Number of Projects Exceeding 25,000 Tons

State	Reconstruction Projects >25,000 tons	
	Last 3 Years	Next 3 Years
Illinois	-	-
Georgia	>25	12
Florida	50	50
California	45	50
Massachusetts	45	30
Texas	330	330

Table 9-2. Survey Responses—Preferred Closure Strategies

State	Alternatives Ranked by Frequency of Use			
	First	Second	Third	Fourth
Illinois	Single day	Complete day	Single night	Complete continuous
Georgia	Single night	Single day	Multi-lane night	Multi-lane day
Florida	Single night	Single day	Single continuous	N/A
California	Multi-lane night	Single night	Single day	Multi-lane day
Massachusetts	Single night	Multi-lane night	Single day	Multi-lane day
Texas	Single night	Single day	Multi-lane night	Multi-lane day

QUALITY FROM PREFERRED STRATEGIES

Each state respondent was asked to indicate any quality trends associated with the most frequently used closure strategy. Table 9-3 contains the responses from SHAs that responded with answers other than "no noted difference" (NND) for any of the quality parameters that related directly to the condition of the overlay. None of the respondents noted any differences in gradation, so that category is omitted from the table. Also, the survey did not indicate whether the ride quality was judged by measurement or by inspection.

Table 9-3. Survey Responses—Overlay Quality Parameters

State	Most Frequent Closure Strategy	Densities	Longitudinal Joints	Ride Quality	Cyclic Segregation
Florida	Single night	NND	NND	Worse ride	Higher rate of occurrence
California	Multi-lane night	—	Lower quality	NND	—
Massachusetts	Single night	Lower with greater variability	NND	Worse ride	Higher rate of occurrence
Texas	Single night	Greater variability	Lower quality	Worse ride	Higher rate of occurrence

Because each of the states represented in Table 9-3 utilized the nighttime option most frequently, Table 9-3 may be expected to provide a picture of the type of quality that is often achieved through nighttime paving. The responses indicated that nighttime paving tends to result in greater variability in densities, a rougher ride, more instances of cyclic segregation, and lower quality longitudinal joints. It is encouraging that this study found that the three former difficulties can be overcome.

Table 9-4 contains the results of other performance parameters that are not directly related to the overlay condition. Illinois was the only state that cited no noted difference for all of the parameters. For the two states that noted a change in safety, safety incident rates were lower for both workers and the public. The respondents were almost equally divided on whether pay factors were the same or higher for nighttime paving. Two respondents indicated that traffic control and limited operations for night work resulted in higher pay factors. Because the survey did not query the SHAs on the details of their quality assurance specifications, it is not clear whether they were actually describing higher pay factors or simply higher costs.

Table 9-4. Survey Responses—Performance Parameters Not Related to Overlay Condition

State	Most Frequent Closure Strategy	Safety	Cost Impact	Hourly Production Rates
Georgia	Single night	NND	Higher pay factors for nighttime traffic control	Greater variability
Florida	Single night	NND	NND	Higher rates
California	Multi-lane night	NND	Higher pay factors for limited operations	Greater variability
Massachusetts	Single night	Lower incident rate	Higher pay factors	Lower rates
Texas	Single night	Lower incident rate	NND	Higher rates

Hourly production rates were noted to be different in the form of either greater variability or higher rates. Only one respondent cited lower production rates. The Florida study by Ellis and Kumar (1993) concluded that nighttime paving productivity

(tons/hr) may be as high as for daytime paving, although the total shift production may not be as high. In fact, no statistical difference in paving production rates could be confirmed in their study.

PUBLIC RESPONSE AND FEEDBACK

Public response to closure strategies motivates the search for more innovative strategies. Table 9-5 shows the experiences of the respondents with their most frequently used closure strategy. Respondents said that the public is generally pleased with the approach of partial closures at night. This public response would be expected because conventional views are that the partial night closure is the least disruptive alternative available. As more state highway agencies consider the full weekend closure strategy, more data will become available to gauge user responses and preferences between the full weekend closure and the partial night closure.

Table 9-5. Survey Responses—Reaction and Feedback from Public

State	Most Frequent Closure Strategy	Public Response/Feedback
Illinois	Single day	Businesses prefer
Georgia	Single night	Motorists adjust with little complaint; businesses prefer
Florida	Single night	Motorists adjust with little complaint; businesses prefer; mostly positive feedback
California	Multi-lane night	Motorists adjust with little complaint
Massachusetts	Single night	Mostly positive feedback
Texas	Single night	Mostly positive feedback

APPROACHES UNDER CONSIDERATION

The survey queried respondents on new or innovative closure strategies that would be a departure from current practice for reconstruction projects. Table 9-6 shows the responses and indicates a general trend (four of the six) toward contractual arrangements such as A+B contracting and lane rental. In both of these approaches the responsibility for innovations to minimize impacts to the public rests primarily with the contractor. Herbsman (1995) showed that a significant number of states have taken this approach, namely A+B bidding. He listed 15 states (including California and Georgia) that had used the method at least once, and five of the states—California, Maryland, North Carolina, Missouri, and New York—more than ten times.

Table 9-6. Closure Strategies under Consideration

State	Strategy Considered
Illinois	A + B; nighttime closures
Georgia	Lane rental w/ restrictions
Florida	Lane rental
California	Weekend closures (55 hrs)
Massachusetts	More night work in high ADT areas
Texas	Lane rental

State highway agencies appear to be at various points along the spectrum of innovative highway reconstruction strategies. Out of the six respondents to this study, only California is actively considering the weekend closure option. The picture presented by these responses underscores the uniqueness of this approach and the need to gather more comparative data. Two of the respondents, Illinois and Massachusetts, indicated that some SHAs still have not made extensive use of the nighttime paving option.

SUMMARY

It appears from the survey of selected state highway agencies that the partial nighttime closure strategy is still the most popular strategy for minimizing highway reconstruction impacts to the public. Although night closures create problems related to the quality of the overlay and other performance parameters, the public is generally pleased with the relative minimal impact of this closure strategy. One conclusion might be that the desirability of the full weekend closure alternative will develop only as more states find specific motivations to utilize the option and are successful in minimizing user impacts. The general direction of SHAs, however, appears to be toward A+B bidding and lane rental options that make the contractor responsible for initiating innovations within the confines of the more traditional strategies.

CHAPTER 10
DECISION PROCESS CHECKLIST

After the results and observations made during the course of this study were considered, a decision checklist was created as a guide for assessing the suitability of a specific project for a full weekend closure. The checklist was further refined through consultation with WSDOT personnel representing the project development, traffic control, and construction groups of the Northwest Region. The original objective for the checklist was to establish the steps necessary to determine whether a project should be accomplished by full weekend closures or by night closures. Discussion with WSDOT personnel from the aforementioned groups led to the agreement that the closure strategy decision involved issues of policy that made it too complex for a deterministic checklist. Rather, more valuable would be a checklist that would ensure that all of the appropriate inputs were obtained so that decision makers would have the critical information necessary to make the closure decision. Tables 10-1 through 10-3 contain the final version of the decision process checklist, which is broken into three distinct sections.

The format of the checklist is straightforward. It contains a breakdown of critical information or input categories that should be considered. The three major divisions are (1) routing impacts, (2) contractor considerations, and (3) WSDOT functions. The three tables correspond to these divisions.

The intention of the first section of the checklist (Table 10-1) is to consider three categories of impact to the public. The items included in the checklist cover potential impacts to private motorists, residents and businesses that rely upon the relevant section of highway for through passage, as well as for local access. Sensitive businesses such as hospitals, hotels, and others deserve special consideration when paving operations are scheduled because of both traffic access restrictions and noise inconvenience. Local agencies will have a keen interest in the potential impact, especially because of access and noise, upon citizens living in their jurisdictions. Bus transit agencies and private

transporters of goods should be alerted in the event that their normal routes must be altered.

Table 10-1. Closure Strategy Decision Process Checklist for Routing Impacts

CATEGORY	ISSUE	√	COMMENTS
Network Geometry and Traffic Safety	Identify alternative through routes		Planned detours for motorists to pass through area may be necessary.
	Identify alternative local area access routes		Planned detours for access to local businesses and homes may be necessary.
	Identify potential traffic safety impacts		Diverted traffic may increase incidents on lower capacity routes.
	Note number and height of drop-offs		Significant drop-off heights increase safety risks for motorists.
Inconvenience	Contact local agencies early		Local agencies will have a well informed perspective on impact to their respective communities.
	Note number of noise nights required/ available		Extensions may be required and may not be allowable.
	Note local zoning and ordinances		Changes in restrictions may occur along length of project if crossing municipalities.
	Note critical nearby facilities		Sensitive facilities needing secure access or controlled environments such as hospitals, hotels, etc. should be considered.
Transit Impacts	Contact public transportation agencies		Bus routes may be impacted.
	Contact private carriers/transporters		Trucking distribution firms will need to select alternative routes.

The focus of the second division of the checklist (Table 10-2) is issues that will affect the ability of the contractor to perform satisfactorily. Although most of the activities that are listed should be considered and ultimately determined by the contractor, it would serve the project development team well to analyze these project parameters ahead of time to gauge feasibility. Early consideration by the WSDOT personnel may help facilitate contractor planning as the means for owner support of specific logistical options are already established.

Table 10-2. Closure Strategy Decision Process Checklist for Contractor Considerations

CATEGORY	ISSUE	√	COMMENTS
Contractor Logistics	Plan for secure site access		Plan for access security should be worked out with appropriate local law enforcement and businesses.
	Plan for secure alternative routes		Backup routes should be planned in the event of a major traffic incident.
	Note proximity of plant(s) to job site		Even though contractor may not be selected, the location of known permanent mixing facilities that may be used should be identified and considered in route planning.
	Note usage constraints on haul route(s)		Some roads may have load and/or time restrictions.
	Explore multiple access points		Plant location, job site movements, etc. may lend themselves to multiple site entrance/exit points for contractor's trucks.
	Contact contractor associations		Contractor associations such as AGC can provide feedback concerning the attractiveness of a proposed strategy from a contractor's perspective.
Worker Safety	Assign traffic control		Situation may dictate need for WSDOT to handle traffic control instead of contractor, and local law enforcement should be informed.
Product Quality	Note permanent lighting at site		Absence of permanent lighting may dictate need for temporary lighting to be required in contract.
	Note expected day and night temperatures		Cold temperatures or large gradients between day and night may affect the speed of paving as constrained by rolling operations. This fact should be considered in the estimate of required paving time.

Table 10-3. Closure Strategy Decision Process Checklist for WSDOT Functions

CATEGORY	ISSUE	√	COMMENTS
Scheduling	Note number and location of full closures for season		Too many such closures close together in time and/or geography will increase inconvenience to users.
	Note timing of holidays		Travel and festive holidays should be avoided to accommodate motorists.
	Note timing of cultural and sporting events		Major events require that travel alternatives be open.
	Allot contingency time for weather delays		WSDOT estimate of time should include a proper allowance for rain or temperature interruptions to compare against contractor's schedule.
	Select alternate closure time options		Backup full closure times may be impossible to schedule late in season, so night option may be necessary.
	Give contractor options early		When the contractor is known, that contractor's successful performance is enabled by appropriate time to plan and adjust.
Public Information	Announce plan in time for the initial spring press conference		This annual event draws the attention of interested parties and initiates the comprehensive public information campaign for the paving season.
	Determine advance notification time window		Businesses will require more time to adjust plans.
	Coordinate between projects		A paving season overview will outline the potential problems in conducting campaigns for numerous special projects. Effectiveness can be lost if a special closure strategy is used too frequently in one season or if overlapping campaigns are executed poorly.
	Plan multimedia approach (TV, newspapers, web, VMS, radio)		Broadest communication is essential to ensure successful motorist adjustments.

Table 10-3 outlines specific considerations that relate to scheduling a closure and giving the public appropriate advance notification. It is apparent that a major key to success for potentially high impact closure strategies such as the full weekend closure is ensuring that the public is aware of the closure plans well in advance and that diverting traffic during major local community events is avoided. Early communication to the

contractor of closure option considerations also improves the contractor's ability to prepare a successful operation. For example, for the I-405 full weekend closures, the early consultation with the contractor clearly contributed to recognition of the importance of ensuring site access for the truck fleet and resulted in coordination among the contractor, Boeing, and the City of Renton to establish the location of the mobile hot mix facility.

The decision checklist is recommended as a guide for assembling critical information and support for the full weekend closure option versus the nighttime closure option. However, it is acknowledged that such decisions are not simply a matter of technical logistics but of public policy and that closure decisions ultimately require a qualitative judgment. Along those lines, public perception becomes a key factor. Copies of some of the numerous newspaper articles that covered the I-405 closure are included in Appendix F, as is a log of television news coverage.

CHAPTER 11
CONCLUSIONS AND RECOMMENDATIONS

The preceding presentation of data and discussion of results provide a generally positive portrait of the I-405 weekend closure. While only limited generalizations can be made because of the uniqueness of construction projects, it is clear from this study that weekend closure is an attractive option for highway reconstruction. Specific conclusions and recommendations are highlighted below under the categories of construction, user impacts, and decision making.

CONSTRUCTION

The following results and conclusions are noted concerning construction performance:

- Statistical analysis revealed no difference in surface smoothness between night and day shifts of the weekend closure. However, a larger data set is desirable for forming more general conclusions.
- Practically all of the surface smoothness measurements well exceeded the 80-mm/km limit specified in a particular supplemental specification for flexible pavements.
- Statistical analysis revealed no difference in in-place densities between night and day shifts of the weekend closure.
- Levels of quality in density and gradation compared favorably to historical data from across the nation.
- Average shift production rates and hourly production rates per truck for the weekend closure were higher than those documented for a similar nighttime paving project. This result underscores the premium production benefits derived from close proximity of the asphalt plant and traffic-free access for the asphalt delivery trucks. Therefore, the

investigators urge careful consideration of the impact of a remote production facility on projects that utilize the weekend closure option.

- Although contractor performance in reaching specified density and in constructing longitudinal joints appeared to be affected by nighttime temperature gradients, worker fatigue, and loss of visibility, the aggregation of measures of quality indicated a high quality product. These facts support a general impression of success for the weekend closure strategy.
- Other states appear to be leaning toward construction strategies that put the balance of responsibility for minimizing user and community impact on the contractor. The more accommodating weekend closure strategy was only being considered by one of the states that were polled, California.

USER IMPACT AND PUBLIC REACTION

The following results and conclusions are noted concerning impacts to businesses and the motoring public:

- The awareness of the closures was very high, indicating that media work and the overall marketing effort was well done.
- Given the high level of awareness, individuals were able to plan around the closures, and the public's perception was that the closures had a minimal impact on their travel patterns.
- The public felt that the impact on businesses was minimal, and this perception was corroborated by their indication that few shopping trips were altered from standard travel patterns.
- The comments on the closure and the construction approach were generally very favorable. This is strong evidence of the public's acceptance of the repaving effort.

- The survey of businesses indicated some mixed results, with some businesses gaining and others losing. It is difficult to distinguish such variations from the normal variation that is likely to occur from week to week. However, the business survey results showed clearly that the strong negative impacts many had predicted (see Appendix F) did not materialize. Similarly, the survey of trucking companies indicated that the impacts on freight movement were minimal.
- Traffic simulations showed a relatively modest increase in overall congestion and emissions as a result of the closure. The simulations also showed that in terms of overall impact on congestion, total closure was preferable to single/multiple lane closures (the more traditional construction approach). All simulation findings pointed to the general success of the total closure approach to rehabilitation projects.

DECISION MAKING

The authors have recommended a checklist of items that should be considered when closure strategies are selected for highway reconstruction projects. The checklist could be used as a basis for preparing a checklist of items that are most relevant to a specific project.

REFERENCES

Amemiya, T. (1985). Advanced Econometrics, Harvard University Press, Cambridge, Massachusetts.

Asphalt Construction Handbook. (1992). Barber-Greene, DeKalb, IL.

Ben-Akiva, M. and S. Lerman (1987). Discrete Choice Analysis. MIT Press, Cambridge, MA.

Berkson, J. (1944). Application of the logistic function to Bioassay, Journal of America Statistics Association, 39, 357-365.

Daganzo, C., F. Bouthelier and Y. Sheffi (1977). Multinomial probit and qualitative choice: A computationally efficient algorithm, Transportation Science 11:338-358.

Domencich, T.A. and D. McFadden (1975). Urban Travel Demand: A behavioral analysis, North-Holland Publishing Company.

Ellis, R.D. and S.J. Amos (1996a). Development of work zone lighting standards for nighttime highway work. *Transportation Research Record 1529*, TRB, National Research Council, Washington, D.C., pp. 35-42.

Ellis, R.D. and A. Kumar (1993). "The influence of nighttime construction on cost and productivity." *Transportation Research Record 1389*, Transportation Research Board, national Academy Press, Washington, DC

Garrison, D. and F. Mannering (1990). Assessing the traffic impacts of freeway incidents and driver information, *ITE Journal*, Vol. 60, No. 8, 19-23.

Garrison, D., B. Sebranke, and F. Mannering (1989). Seattle-area incident impact analysis: microcomputer traffic simulation results, Volume III, WA-RD 204.4, 131pp.

Greene, W.H. (1993). Econometric analysis, 2nd Ed, Macmillan Publishing.

Greene, W.H. (1995). LIMDEP 7.0 User's Manual, Econometric Software Inc.

Hall, J.W. and V.M. Lorenz (1989). Characteristics of construction zone accidents. *Transportation Research Record 1230*, TRB, National Research Council, Washington, D.C., 1989, pp. 20-27.

Hausman, J and D.A. Wise (1978). A conditional probit model for qualitative choice: Discrete decisions recognizing interdependence and heterogeneous preference, Econometrica 46, 403-426.

Hausman, J. and D. McFadden (1984). Specification tests for the multinomial logit model, Econometrica 52, 1219-1240.

Herbsman, Z.J. (1994). "A+B bidding method—hidden success story for highway construction." *J. of Constr. Engrg. and Mgt.*, ASCE, 121(4), 430-437.

Hinze, J.W. and D. Carlisle (1990). An Evaluation of the important variables in nighttime construction. Transportation Northwest (TRANSNOW), University of Washington, Seattle.

Horowitz, J. (1981). Identification and diagnosis of specification errors in the multinomial logit model, Transportation Research 15B, No. 5, 345-360.

Horowitz, J. (1985). Travel and location behavior: State of the art and research opportunities, Transportation Research 19A, No. 5/6, 441-453.

Hot Mix Asphalt Fundamentals, Compaction America, Inc., Kewanee, IL.

Huft, D.L. (1992). "Analysis and recommendations concerning profilograph measurements on F0081(50)107 Kingsbury County." *Transportation Research Record 1348*, Transportation Research Board, 29-34.

Hughes, C.S. (1996). *NCHRP Synthesis of Highway Practice 232: Variability in Highway Pavement Construction*. TRB, National Research Council, Washington, D.C., 38 pp.

Lerman, S. and C. Manski (1981). On the use of simulated frequencies to approximate choice probabilities, in: C. F. Manski and Daniel McFadden eds., Structural analysis of discrete data with econometric applications, MIT Press, Cambridge, MA.

Linden, R.N., Mahoney, J.P., and Jackson, N.C. (1989). "Effect of Compaction on Asphalt Performance." *Transportation Research Record 1217*, TRB, National Research Council, Washington, D.C.

Luce, R. and P. Suppes (1965). Preference, utility and subjective probability,. In handbook of mathematical psychology, vol. 3, R. Luce, R. Bush and E. Galanter eds., Wiley, New York.

Mannering, F. and D. Hensher (1987). Discrete/continuous econometric models and their application to transport analysis. Transport Reviews 7(3), 227-244.

Mannering, F., S. Abu-Eisheh and A. Arnadottir (1990). Dynamic traffic equilibrium with discrete/continuous econometric models. Transportation Science, Vol. 24, No. 2, 105-116.

Markey, S.J., Mahoney, J.P., and Gietz, R.H. (1994). "An initial evaluation of the WSDOT quality assurance specification for asphalt concrete". Report No. WA-RD 326.1 to the Washington State Department of Transportation, April.

McFadden, D. (1981). Econometric models of probabilistic choice, in: C. F. Manski and Daniel McFadden eds., Structural analysis of discrete data with econometric applications, MIT Press, Cambridge, MA.

McFadden, D., W. Tye and K. Train (1977). An application of diagnostic tests for the irrelevant alternatives property of multinomial logit model, Transportation Research Board 637, 39-46.

Pal, R. and K.C. Sinha (1996a). Evaluation of crossover and partial lane closure strategies for interstate work zones in Indiana. *Transportation Research Record 1529*, TRB, National Research Council, Washington, D.C., pp. 10-18.

Pal, R. and K.C. Sinha (1996b). Analysis of crash rates at interstate work zones in Indiana. *Transportation Research Record 1529*, TRB, National Research Council, Washington, D.C., pp. 43-53.

Paulsen, R.J., D.W. Harwood, and J.C. Glennon (1978). Status of traffic safety in highway construction zones. *Transportation Research Record 693*, TRB, National Research Council, Washington, D.C.

Pigman, J.G., and K. R. Agent (1990). Highway crashes in construction and maintenance work zones. *Transportation Research Record 1270*, TRB, National Research Council, Washington, D.C., pp. 12-21.

Price, D.S. (1986). *Nighttime Paving.* Washington D.C., Colorado Department of Transportation for Federal Highway Administration.

Read, S.A. (1996). Construction related temperature differential damage in asphalt concrete pavements. Masters thesis submitted to the University of Washington Department of Civil Engineering.

Scofield, L.A., Kalvela, S.A., and Anderson, M.R. (1992). "Evaluation of California profilograph." *Transportation Research Record 1348*, Transportation Research Board, 1-7.

Small, K. and C. Hsiao (1982). Multinomial logit specification tests, International Economic Review, Vol. 26, No. 3, 619-627.

SR405 Mainline Overlay Report: C4756 Tukwila to Factoria SC&DI Stage 1 (1997). Final draft, WSDOT, August.

Thurston, L. (1927). A law of comparative judgement, Psychological Review 34, 273-286.

Train, K. (1986). Qualitative Choice Analysis: Theory, Econometrics, and an Application to Automobile Demand. MIT Press, Cambridge, MA.

Trowbridge, Amity, Doohee Nam, Fred Mannering and Jodi Carson (1996). The potential for freight productivity improvements along urban corridors, WA-RD 415.1.

Wang, J., W.E. Hughes, F.M. Council, and J.F. Paniati (1996). Investigation of highway work zone crashes: what we know and what we don't know. *Transportation Research Record 1529*, TRB, National Research Council, Washington, D.C., pp. 54-62.

Zavoina, R and W. McElvey (1975). A statistical model for the analysis of ordial level dependent variables, Journal of mathematical sociology, Summer, 103-120.

APPENDIX A
METHODOLOGY

APPENDIX A
METHODOLOGY

METHODOLOGICAL APPROACH: TRAFFIC OPERATIONAL IMPACTS

To measure the impact of complete weekends closures, several traffic assignment software packages were considered. The traffic assignment package chosen is a standard user equilibrium assignment package that had been previously applied to the Seattle network with considerable success (Garrison and Mannering 1990). The assignment package, XXE, is a deterministic, macroscopic assignment program that is based on the user-equilibrium theory. This theory is that all travelers will choose routes that minimize their travel times and user equilibrium will exist when no traveler can unilaterally improve his/her travel time by changing routes. The package predicts traffic flows on individual highway links for a highway network by using an origin-destination matrix, the physical characteristics of the highway network, and highway link performance functions (functions that relate travel time to traffic volume). A more detailed explanation of the mathematical formulae, assumptions, and constraints of the methodology of XXE can be found in Garrison, Sebranke, and Mannering (1989).

Use of the XXE program required three input files: (1) a network file, NW.DAT, (2) a vehicle origin-destination file, OD.DAT, and (3) a control file, CN.DAT. The data for these files needed to assess the I-405 closures discussed above are described in the following sections.

Input Files

NW.DAT

NW.DAT contained all the data pertaining to the link performance characteristics. It was structured in two parts. Each line in the first part of NW.DAT contained the highway link origin, the highway link destination, the length of the link, the capacity of the link, the speed limit of the link, and a short description of the link. A more detailed

explanation can be found in “Generation and Assessment of Incident Management Strategies Volume III” (Garrison et al. 1989). The general format of this input file is given in Table A-1. The data in this file had to be sorted by ascending order, from the "from" nodes to the "to" nodes.

Table A-1. The Format of the NW.DAT Input File

Columns	Format	Description
1-4	I4	“From” node or A-node of link
5-8	I4	“To” node or B-node of link
9-13	F5.2	Link length, miles
14-18	F5.0	Capacity at LOS E
19-21	F3.0	Free flow speed on link, mph
22-41	5A4	Link description

OD.DAT

The OD.DAT file contained all the information needed from the origin-destination matrix. Each line of this file listed the origin, the destination, and the number of vehicles that traveled from the origin to destination in the period of interest. The format of this file is given in Table A-2. Similarly to the NW.DAT file, the OD.DAT file had to be sorted in ascending order—first by origin zone and then by destination zone.

Table A-2. The Format of the OD.DAT Input File

Columns	Format	Description
1 - 4	I4	Origin zone
5 - 7	I3	Destination zone
8 - 12	F5.0	Trips from origin to destination

CN.DAT

The CN.DAT file described the files NW.DAT and OD.DAT. It also described the main program values for convergence (convergence criteria for the user equilibrium Frank-Wolfe algorithm), the maximum number of iterations if Frank-Wolfe algorithm convergence was not achieved, and the type of printout desired. The format this data file is presented in Table A-3.

Table A-3. The Format of the CN.DAT Input File

Columns	Format	Description
1 -5	I5	Total number of links
6 -10	I5	Number of zones
11 -15	I5	Total number of nodes
16 - 20	I5	Number of transportation links
21 - 25	I5	Number of records on OD.DAT
26 - 30	I5	Number of first network node
31 - 38	F8.5	Convergence criterion
39 - 41	I3	Maximum number of iterations
42 - 44	I3	Print centroid connectors (1 = yes, 2 = no)

Network Description

The application of the user equilibrium model to the Seattle-area highway network required that highway links and nodes be specified and that the origin-destination characteristics of both SOV and HOV travel be determined. The manner in which this was done is described below.

Links and Nodes

The network defined for this analysis consisted of 1002 directional links, 277 nodes, and 30 origin and destination zones. Of the 1002 directional links, 503 were transportation links; the remaining 499 links were access links between the transportation

network and the zone centroid. It was impractical to include all the streets and intersections in the model; instead, the freeways, highways, and major arterials were used to represent the network. All other streets were assumed not to contribute significantly to the volumes of interzonal traffic and, more importantly, were assumed to have minimal impact on the travel times and overall traffic congestion resulting from the implementation of the proposed options.

The highway links included in the analysis described the primary commuting routes and common diversion routes within the Seattle area. Routes included were I-5, I-90, I-405, SR 99, SR 104, SR 167, SR 202, SR 509, SR 518, SR 520, SR 522, SR 599, SR 900, SR 908, and a number of arterials.

Origin and Destination Data

Because weekend origin-destination (O-D) data were not available, a systematic, iterative approach was adopted in which estimated (by the XXE traffic model) weekend O-D matrices for single occupancy vehicles (SOV) and high occupancy vehicles (HOV) were compared to actual observed weekend peak-hour traffic flows in August 1996. If estimated traffic flows deviated from observed traffic flows, the O-D matrix was revised and the process was repeated until model-estimated and observed traffic flows were virtually identical.

As an initial point, Origin and Destination matrices for single occupant and high occupant vehicles were obtained from the previous study ("The Potential for Freight Productivity Improvements along Urban Corridors," Trowbridge et al. 1996). Morning peak hour O-D matrices was available for the year of 1990. The weekend O-D matrix was first approximated by reducing the single-occupancy vehicle's O-D trip matrix by 20 percent and the high-occupancy vehicle's O-D trip matrix by 25 percent on the basis of traffic characteristics observed during the weekends of August 1996. The assumption of 20/25 percent was a good starting point and matched actual traffic-count data reasonably well.

Note that this iterative procedure did not produce a unique solution. That is, in theory, many different O-D matrices could produce the same observed weekend flows. However, our approach of using the single-occupant O-D matrix along with a separate high-occupancy O-D matrix gave us some confidence that our constructed O-D matrices were close to the actual O-D matrices.

Model Calibration

After the appropriate data for the network (highway-link information) had been, existing traffic flows were simulated. The simulation required two O-D matrices—one for SOVs and one for HOVs. The traffic indicated in these two matrices was assigned sequentially (a simultaneous assignment was not mathematically possible within the XXE model and may not have been realistic because of the lane choices made by HOVs while en route). The simulation-running sequence of first SOVs and then HOVs seemed logical. SOVs do not have a choice to use the HOV lanes, so it seemed natural to assign them first. HOVs can decide to take HOV lanes in response to congestion observed in the general purpose lanes and can thus respond to SOV traffic flows. Therefore, they were assigned second.

Next, the model was calibrated. The objective of calibration was to replicate the actual traffic flows on the network. The process of calibrating the model involved three steps. First, the access-link lengths (i.e., links that allow trips from the centroids of traffic zones to the physical highway network) were adjusted. Zonal-centroid to highway-network access points were added, and the access-link capacity was adjusted. (These access links are not physical highway links, and thus their length and capacity were intended to represent the difficulty that travelers in the traffic zone encounter, in terms of distance and congestion, when they access or exit the physical highway network.)

Second, the network was refined. This process included adding and deleting links and nodes and adjusting capacities, lengths, and the speeds of various links to closely approximate actual vehicle counts. Third, the origin-destination matrices were adjusted

through a procedure similar to that described above for the creation of the weekend O-D matrix.

The actual calibration process could not begin until the XXE model had been run error free. This step involved a painstaking search through the data files, NW.DAT and CN.DAT, to determine whether any links had been omitted or had been improperly coded. In terms of coding, data on no-turning restrictions were collected and, to prohibit vehicles from traveling on turning-restricted links, separate links and nodes were defined for each direction of travel. This problem proved to be quite significant near the Seattle central business district.

Once a successful run had been accomplished, the links of the modeled network were refined to provide a more accurate description of existing conditions. To account for merging, weaving, and geometric effects, the capacity determination procedures outlined in the HCM (Highway Capacity Manual 1994) were used to determine link capacity, a critical input element.

The network was considered to be calibrated when most traffic volumes were within 20 percent of the measured counts obtained from the Traffic Systems Management Center (TSMC) traffic database.

Emission Factors

The EPA MOBILE5A model was used to calculate the emission factors for carbon monoxide, oxides of nitrogen, and volatile organic compounds. These values were then used to create the emission factor input files (CO.DAT, NOX.DAT, VOC.DAT) to incorporate into the XXE model. The input parameters for MOBILE5A were obtained from the Puget Sound Air Pollution Control Agency.

These emissions are calculated by the following procedure:

$$\frac{((\text{VMT}*(\text{grams pollutant})/\text{VMT}))}{\text{Time Period}} = \text{grams pollutants/sec}$$

Note that emission factors vary considerably with the speed of the vehicles. Thus, XXE was revised to calculate the mobile emissions of each link by applying the correct emission factor associated with the calculated average speed of each link. However, for speeds lower than 5 mph or greater than 65 mph, emissions were calculated by applying a constant emission factor interpolated from the CO.DAT, NOX.DAT, and VOC.DAT files.

USER SURVEY ANALYSIS METHODOLOGY

Discrete Choice Models

Discrete choice problems have been of interest to researchers for many years in a variety of disciplines, including the transportation field. The probabilistic choice model based on a utility approach originally appeared in mathematical psychology (see Thurston 1972, Luce and Suppes 1965) and also has been used in biometrics applications (Berkson 1944). The applications of discrete choice models to transportation have been oriented toward mode choice and other travel related choices such as trip destination, trip frequency, car ownership, residential location, and housing (Domencich and McFadden 1975, Amemiya 1985, Horowitz 1985, Train 1986, Mannering 1987, Ben-Akiva and Lerman 1987, Mannering *et al.* 1990). Discrete choice models assume that an individual's choices among the available alternatives can be described with a utility function and that the individual selects the alternatives with the greatest utility. The utility is a sum of (1) a deterministic component that accounts for systematic effects of observed variables that influence a choice and (2) a random component that accounts for the effects of unobserved variables. The individual is always assumed to select the utility-maximizing choices, implying that the utility of the chosen alternative will exceed the utilities of all of the other feasible alternatives.

Multinomial Logit/Probit Model

Suppose an individual, i, has n alternative choices. The systematic utility, ν_{ij}, is a function of the observed attributes of alternative j and of the observed socioeconomic

characteristics of i. Unobserved characteristics, such as tastes and unmeasured attributes of alternatives are captured in the error term (a random component) ε_{ij}. So, the utility (U_{ij}) of choice j to an individual (i) can be expressed as follows:

$$U_{ij} = \nu_{ij} + \varepsilon_{ij} \qquad \text{(A-1)}$$

Assuming that random components (ε_{ij}) are independently and identically distributed (IID) with Gumbel type I distribution, a multinomial logit model can be derived. The multinomial logit model is defined by

$$P_{ij} = \left[\sum_{k=0}^{m_i} \exp(x'_{ik}\beta) \right]^{-1} \exp(x'_{ik}\beta),$$

$$i = 1,2,.....,n \text{ and } j = 0,1,.....m_i \qquad \text{(A-2)}$$

and the loglikelihood function for the multinomial logit model is given by

$$\log L(\beta_1,.....\beta_k) = \sum_{i=1}^{n} \sum_{j=1}^{C} Y_{ij} \left[\bar{\beta}' x_{ij} - \log\left(\sum_{i=1}^{C} e^{\beta' x_{ij}} \right) \right] \qquad \text{(A-3)}$$

The most widely discussed aspect of the multinomial logit model is independence from irrelevant alternative property (IIA), which means that the ratio of choice probabilities of any two alternatives is entirely unaffected by the systematic utilities of any other alternative. McFadden, Tye, and Train (1977); Horowitz (1981); Hausman and McFadden (1984); and Small and Hsiao (1985) developed tests to detect violations of the IIA properties. The procedure of Hausman and McFadden's specification test is, first, to estimate the model with all choices. The alternative specification is the model with a smaller set of choices. Thus, the model is estimated with this restricted set of alternatives and the same model specification. The set of observations is reduced to those in which one of the smaller sets of choices was made. The test statistic is asymptotically χ^2 distributed with k degrees of freedom, where k is the number of elements in the subvector

of coefficients that is identifiable from the restricted choice set model (Ben-Akiva and Lerman 1987, Greene 1995).

$$((\hat{\beta}_{c-} - \hat{\beta}_{c})'\left(\hat{\beta}_{c} - \hat{\beta}_{c}\right)^{-1}\left(\hat{\beta}_{c-} - \hat{\beta}_{c}\right) \qquad \text{(A-4)}$$

Another popular approach is the multinomial probit model, which can handle arbitrary correlations expressed in the form of a general variance-covariance matrix. In this model, a random component (ε_{ij}) has a normal distribution. The loglikelihood function for a binary probit model is given by

$$\log L(\beta_1,.....\beta_k) = \sum_{i=1}^{n} Y_i \log \Phi(-\beta' x_i) + \sum_{i=1}^{n}(1-Y_i) \log(1-\Phi(\beta' x_i)) \qquad \text{(A-5)}$$

$$\text{where, } \Phi(t) = \frac{1}{\sqrt{2\pi}} \int_{-x}^{t} e^{-t^2/2} du$$

The probit model is difficult to use because the integrals that occur have to be analyzed numerically. Several procedures have been developed, such as direct numerical methods (Hausman and Wise 1978), the simulated frequency method (Lerman and Manski 1981), and iterative approximation procedures (Daganzo *et al.* 1977). In contrast, the multinomial logit model is mathematically significant and simpler. More detailed presentations of the assumptions and derivations of discrete choice models can be found in Domencich and McFadden (1975), McFadden (1981), Ben-Akiva and Lerman (1987), and others.

Ordered Logit/Probit Model

The ordered model is appropriate in applications such as opinion surveys, in which the respondent expresses a preference with an ordinal ranking. Although the outcome is discrete, the multinomial logit or probit models would fail to account for the ordinal nature of the dependent variable (Zavoina and McElvey 1975). If the situation being modeled is unordered, an ordered model can create serious biases in the estimation

of the probabilities. On the other hand, if the type of event under study is ordered, an unordered model loses efficiency rather than consistency (Amemiya 1985).

The ordered model defined by

$$P(y = j|\mathbf{x},\theta) = p(S_j) \tag{A-6}$$

for some probability measure (p) depending on $\mathbf{x}$ and θ, and a finite sequence of successive interval $\{S_j\}$, depending on $\mathbf{x}$ and θ. In most cases, the ordered model takes a simpler form for some distribution functions.

$$P(y = j|\mathbf{x},\mu,\beta) = F(\mu_j - \mathbf{x}\beta') - F(\mu_{j+1} - \mathbf{x}\beta') \tag{A-7}$$

$$j = 0,1,.....,m, \qquad \mu_0 = -\times, \qquad \mu_j \leq u_{j+1}, \qquad \mu_{m+1} = \times$$

If $F = \Phi$ (i.e., a standard normal distribution), equation A-7 defines the ordered probit model, and if $F = \Lambda$ (i.e., a standard logistic distribution), it defines the ordered logit model. The model depicted in equation A-7 is motivated by consideration of an unobserved continuous random variable (y*), which determines the outcome of y by the rule $y = j$ if and only if $\mu_j < y^* < \mu_{j+1}$ with $j = 0, 1,....., m$. With a normal distribution, the probabilities can be shown as follows:

$$P(y = 0) = \Phi(-\beta'\mathbf{x}), \tag{A-8}$$

$$P(y = 1) = \Phi(\mu_1 - \beta'\mathbf{x}) - \Phi(-\beta'\mathbf{x}),$$

$$P(y= 2) = \Phi(\mu_2 - \beta'\mathbf{x}) - \Phi(\mu_1 - \beta'\mathbf{x}),$$

$$\vdots$$

$$P(y = j) = 1 - \Phi(\mu_{j-1} - \beta'\mathbf{x}).$$

The computations of marginal effects are particularly meaningful for the ordered model, in which the effect of variable $\mathbf{x}$ on the intermediate categories is ambiguous. The marginal effect of regressors on the probabilities is not equal to the coefficients. This

point has been overlooked in some of the literature. Most papers simply report coefficients and t-statistics with some commentary about significant effects, but they rarely suggest upon what or in what direction those effects are exerted (Greene 1993). For example, suppose there are three categories (i.e., 0, 1, 2), and marginal effects of changes in the categories are

$$\begin{aligned} \frac{\partial P(y=0)}{\partial \mathbf{x}} &= -\phi(\beta'\mathbf{x})\beta, \\ \frac{\partial P(y=1)}{\partial \mathbf{x}} &= (\phi(-\beta'\mathbf{x}) - \Phi(\mu - \beta'\mathbf{x}))\beta, \\ \frac{\partial P(y=2)}{\partial \mathbf{x}} &= \phi(\mu - \beta'\mathbf{x})\beta \end{aligned} \tag{A-9}$$

In Figure A-l, the probability distributions of y and y* are shown in the solid curves. Assuming that a particular β was positive would shift some probability to the right or to the left, but what would happen to the middle category is ambiguous. In general, relative to the signs of the coefficients, only the sign of changes in *PO; = 0)* and *P(y = j) are* clear. In this example, *P(y = 0)* has the opposite sign of β, and *P(y =2)* must have the same sign as β. Thus, the coefficients in the model should be interpreted with caution.

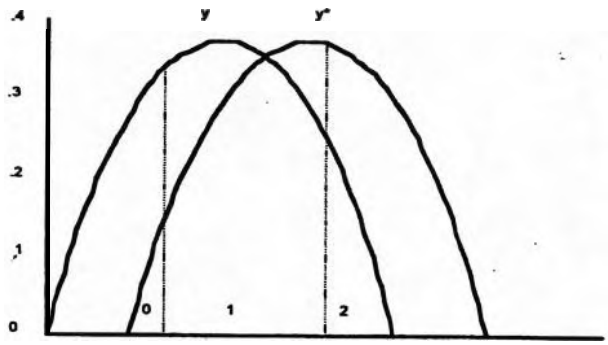


Figure A-l. Effects of change in x on Predicted Probabilities

APPENDIX B

PROBIT AND BINARY LOGIT MODEL ESTIMATION RESULTS

APPENDIX B
PROBIT AND BINARY LOGIT MODEL ESTIMATION RESULTS

Detailed descriptions of the probit and binary logit model estimation results are contained in Chapter 6, Survey Results: Public Feedback.

Table B-1. Ordered Probit Model Estimation Results for Opinions That the Weekend Closures of I-405 Had a Major Impact on Travel Plans

Variable*	Estimated Coefficients	Marginal Effects (y = 0)	(y = 1)	(y = 2)	(y =3)	(y = 4)
Constant	0.499 (5.64)	-0.1881	0.0156	0.0737	0.0624	0.0364
Age dummy (1 if less than 30, 0 otherwise)	0.255 (1.63)	-0.0961	0.0080	0.0377	0.0319	0.0186
Income dummy (1 if less than $30,000, 0 otherwise)	-0.383 (-1.11)	0.1442	-0.0119	-0.0565	-0.0478	-0.0279
Education dummy (1 if post graduate, 0 otherwise)	-0.427 (-2.93)	0.1607	-0.0133	-0.0630	-0.0533	-0.0311
Geographic location dummy (1 if living in Seattle, 0 otherwise)	-0.191 (-1.05)	0.0719	-0.0060	-0.0282	-0.0239	-0.0139
Geographic location dummy (1 if living in Bellevue, 0 otherwise)	-0.415 (-2.79)	0.1563	-0.0129	-0.0613	-0.0519	-0.0302
Threshold μ_1	0.881 (12.79)					
Threshold μ_2	1.528 (16.40)					
Threshold μ_3	2.187 (17.00)					
Restricted Log-likelihood	-520.49					
Log-likelihood at convergence	-509.59					
Number of Observations	378					

* Dependent variable is "The weekend closures of I-405 had a major impact on my travel plans", 0:disagree strongly, 1:disagree, 2:neutral, 3:agree, 4:agree strongly.

** t-statistics in parenthesis

Table B-2. Ordered Probit Model Estimation Results for Opinions That the State and the Media Did a Good Job of Making the Public Aware of the I-405 Closures

Variable*	Estimated Coefficients	Marginal Effects (y = 0)	(y = 1)	(y = 2)	(y =3)	(y = 4)
Constant	2.349 (10.97)	-0.0561	-0.0623	-0.3357	-0.4827	0.9369
Age dummy (1 if 30~54, 0 otherwise)	-0.274 (-2.07)	0.0066	0.0073	0.0392	0.0564	-0.1095
Number of working people in household	0.152 (2.19)	-0.0036	-0.0040	-0.0218	-0.0313	0.0608
Geographic location dummy (1 if living in Bellevue, 0 otherwise)	0.201 (1.23)	-0.0048	-0.0053	-0.0287	-0.0413	0.0801
Geographic location dummy (1 if living in Seattle, 0 otherwise)	-0.389 (-1.88)	0.0093	0.0103	0.0555	0.0799	-0.1550
Geographic location dummy (1 if living in Kirkland, 0 otherwise)	-0.291 (-1.10)	0.0070	0.0077	0.0417	0.0599	-0.1162
Threshold μ_1	0.339 (2.13)					
Threshold μ_2	1.170 (5.74)					
Threshold μ_3	2.400 (11.11)					
Restricted Log-likelihood	-381.88					
Log-likelihood at convergence	-390.47					
Number of Observations	372					

* Dependent variable is "The state and the media did a good job of making the public aware of the I-405 closure", 0:disagree strongly, 1:disagree, 2:neutral, 3:agree, 4:agree strongly.

** t-statistics in parenthesis

Table B-3. Ordered Probit Model Estimation Results for Opinions That Closing Highways Completely For a Weekend Is Better Than Closing a Few Lanes During the Day for Several Days

Variable*	Estimated Coefficients	Marginal Effects (y = 0)	(y = 1)	(y = 2)	(y =3)	(y = 4)
Constant	1.702 (8.32)	-0.1101	-0.0959	-0.1115	-0.3255	0.6430
Age dummy (1 if 30~54, 0 otherwise)	-0.186 (-1.30)	0.0120	0.0105	0.0122	0.0356	-0.0704
Income dummy (1 if over 50,000, 0 otherwise)	0.174 (1.27)	-0.0112	-0.0098	-0.0114	-0.0332	0.0656
Education dummy (1 if post graduate degree, 0 otherwise)	0.307 (1.70)	-0.0199	-0.0173	-0.0201	-0.0588	0.1162
Number of working people in household	0.132 (1.82)	-0.0085	-0.0074	-0.0086	-0.0252	0.0498
Geographic location dummy (1 if living in Kirkland, 0 otherwise)	-0.389 (-1.68)	0.0251	0.0219	0.0255	-0.0744	0.1469
Geographic location dummy (1 if living in Mercer, 0 otherwise)	-0.633 (-1.75)	0.0409	0.0357	0.0414	0.1210	-0.2390
Threshold μ_1	0.363 (3.60)					
Threshold μ_2	0.675 (5.76)					
Threshold μ_3	1.578 (11.49)					
Restricted Log-likelihood	-378.37					
Log-likelihood at convergence	-370.81					
Number of Observations	372					

* Dependent variable is "Closing highways completely for a weekend is better than closing a few lanes during the day for several days", 0:disagree strongly, 1:disagree, 2:neutral, 3:agree, 4:agree strongly.

** t-statistics in parenthesis

Table B-4. Ordered Probit Model Estimation Results for Opinions That the Weekend Closure of I-405 Had a Significant, Negative Impact on Area Business

Variable*	Estimated Coefficients	Marginal Effects (y = 0)	(y = 1)	(y = 2)	(y =3)	(y = 4)
Constant	1.163 (7.58)	-0.3024	-0.1601	0.3224	0.0966	0.0435
Age dummy (1 if 30~54, 0 otherwise)	0.216 (1.69)	-0.0561	-0.0297	0.0598	0.0179	0.0081
Education dummy (1 if high school diploma, 0 otherwise)	-0.177 (-1.33)	0.0460	0.0244	-0.0491	-0.0147	-0.0066
Number of household people	-0.099 (-2.23)	0.0259	0.0137	-0.0276	-0.0083	-0.0037
Geographic location dummy (1 if living in Redmond, 0 otherwise)	-0.298 (-1.02)	0.0776	0.0411	-0.0828	-0.0248	-0.0112
Geographic location dummy (1 if living in Bellevue, 0 otherwise)	-0.273 (-1.95)	0.0711	0.0376	-0.0758	-0.0227	-0.0102
Threshold μ_1	0.850 (11.68)					
Threshold μ_2	2.472 (20.57)					
Threshold μ_3	3.100 (17.25)					
Restricted Log-likelihood	-460.61					
Log-likelihood at convergence	-454.06					
Number of Observations	372					

* Dependent variable is "The weekend closure of I-405 had a significant, negative impact on area businesses", 0:disagree strongly, 1:disagree, 2:neutral, 3:agree, 4:agree strongly.

** t-statistics in parenthesis

Table B-5. Multinomial Logit Model Estimation Results of Impacts on Travel Plans by the Weekend Closure of I-405

Variable*	Estimated Coefficients**	Marginal Effects***
Constant	-1.023 (-2.03)	-0.2543
Age dummy (1 if less than 30, 0 otherwise)	0.920 (2.41)	0.2287
Age dummy (1 if equal or over 55, 0 otherwise)	-1.076 (-3.06)	-0.2677
Household Income	0.251 (3.05)	0.0624
Education dummy (1 if college degree, 0 otherwise)	-0.431 (-1.59)	-0.1073
Number of children under age 6	-0.762 (-3.12)	-0.1895
Geographic location dummy (1 if living in Seattle, 0 otherwise)	-0.732 (-1.84)	-0.1821
Geographic location dummy (1 if living in Bellevue, 0 otherwise)	0.428 (1.19)	0.1064
Geographic location dummy (1 if living in Renton, 0 otherwise)	0.704 (1.40)	0.1752
Geographic location dummy (1 if living in Kent, 0 otherwise)	1.497 (2.15)	0.3723
Restricted Log-likelihood	-201.84	
Log-likelihood at convergence	-177.58	
Number of Observations	292	

* Dependent variable is "Did the weekend closure of I-405 affect your travel plans in any way" (1-yes, 0-no).

** t-statistics in parenthesis

*** Partial derivatives of probabilities with respect to the vector of characteristics, are computed at the means of the Xs and all observations are used.

Table B-6. Multinomial Logit Model Estimation Results of Routes Taken Because of the Weekend Closure of I-405

Variable*	Estimated Coefficients**	Marginal Effects***
Constant	0.816 (0.90)	0.1638
Age	-0.036 (-2.41)	-0.0072
Household Income	0.201 (1.79)	0.0405
Education dummy (1 if college degree, 0 otherwise)	-0.943 (-2.64)	-0.1893
Number of children under age 6	-0.832 (-2.91)	-0.1671
Number of operable vehicles	0.294 (1.64)	0.0591
Geographic location dummy (1 if living in Seattle, 0 otherwise)	-0.678 (-1.48)	-0.1362
Geographic location dummy (1 if living in Bellevue, 0 otherwise)	1.797 (2.95)	0.3609
Geographic location dummy (1 if living in Renton, 0 otherwise)	1.209 (1.77)	0.2427
Geographic location dummy (1 if living in Kent, 0 otherwise)	0.877 (1.24)	0.1761
Geographic location dummy (1 if living in Kirkland, 0 otherwise)	0.811 (1.21)	0.1629
Restricted Log-likelihood	-136.46	
Log-likelihood at convergence	-116.10	
Number of Observations	219	

* Dependent variable is "Did you use a route that you would not normally have taken because of the weekend closure of I-405" (1-yes, 0-no).

** t-statistics in parenthesis

*** Partial derivatives of probabilities with respect to the vector of characteristics, are computed at the means of the Xs and all observations are used.

Table B-7. Binary Logit Model Estimation Results of Departure Time Change Because of the Weekend Closure of I-405

Variable*	Estimated Coefficients**	Marginal Effects***
Constant	0.735 (1.92)	0.1778
Marital status (1 if married, 0 otherwise)	-0.402 (-1.25)	-0.0973
Age dummy (1 if equal or over 55, 0 otherwise)	-0.849 (-2.14)	-0.2053
Income dummy (1 if less than 20,000, 0 otherwise)	-0.977 (-1.09)	-0.2363
Income dummy (1 if over 50,000, 0 otherwise)	-0.523 (-1.79)	-0.1264
Number of children aged 6 to 16	0.348 (2.07)	0.0841
Number of operable vehicles	-0.169 (-1.09)	-0.0409
Geographic location dummy (1 if living in Seattle, 0 otherwise)	-0.918 (-2.05)	-0.2221
Restricted Log-likelihood	-173.44	
Log-likelihood at convergence	-160.96	
Number of Observations	255	

* Dependent variable is "Did you change the departure time of any of your trips because of the weekend closure of I-405? " (1-yes, 0-no).

** t-statistics in parenthesis

*** Partial derivatives of probabilities with respect to the vector of characteristics, are computed at the means of the Xs and all observations are used.

Table B-8. Binary Logit Model Estimation Results of Trip Cancellation

Variable*	Estimated Coefficients**	Marginal Effects***
Constant	-1.307 (-1.96)	-0.0847
Marital status (1 if single, 0 otherwise)	0.577 (1.00)	0.0374
Age dummy (1 if less than 30, 0 otherwise)	-1.298 (-1.60)	-0.0841
Education dummy (1 if high school diploma, 0 otherwise)	-0.666 (-1.00)	-0.0432
Number of operable vehicles	-0.483 (-1.67)	-0.0313
Geographic location dummy (1 if living in Renton, 0 otherwise)	1.079 (1.67)	0.0699
Restricted Log-likelihood	-75.02	
Log-likelihood at convergence	-69.58	
Number of Observations	256	

* Dependent variable is "Did you cancel a trip that you would normally have taken because of the weekend closures of I-405" (1-yes, 0-no).

** t-statistics in parenthesis

*** Partial derivatives of probabilities with respect to the vector of characteristics, are computed at the means of the Xs and all observations are used.

Table B-9. Multinomial Logit Model Estimation Results of Change of Shopping Places

Variable*	Estimated Coefficients**	Marginal Effects***
Constant	-2.078 (-2.27)	-0.0978
Gender dummy (1 if gender is male, 0 otherwise)	0.636 (1.18)	0.0299
Marital status (1 if single, 0 otherwise)	-0.908 (-1.25)	-0.0427
Age dummy (1 if less than 30, 0 otherwise)	1.183 (1.90)	0.0557
Education dummy (1 if college degree, 0 otherwise)	0.837 (1.58)	0.0394
Number of people in household	-0.694 (-1.93)	-0.0326
Number of children aged 6 to 16	0.684 (1.36)	0.0322
Geographic location dummy (1 if living in Seattle, 0 otherwise)	-1.301 (-1.17)	-0.0612
Geographic location dummy (1 if living in Bellevue, 0 otherwise)	0.804 (1.39)	0.0379
Restricted Log-likelihood	-67.92	
Log-likelihood at convergence	-60.44	
Number of Observations	259	

* Dependent variable is "Did you shop at different places because of a weekend closures of I-405" (1-yes, 0-no).

** t-statistics in parenthesis

*** Partial derivatives of probabilities with respect to the vector of characteristics, are computed at the means of the Xs and all observations are used.

Table B-10. Multinomial Logit Model Estimation Results of Awareness of the I-405 Closures Before They Happened on August 15-18 or August 22-25.

Variable*	Estimated Coefficients**	Marginal Effects***
Constant	1.634 (1.97)	0.0785
Age dummy (1 if 30~54, 0 otherwise)	-1.015 (-1.89)	-0.0488
Income dummy (1 if over 50,000, 0 otherwise)	-0.562 (-1.21)	-0.0270
Education	0.268 (1.39)	0.0129
Number of working people in household	0.745 (2.65)	0.0358
Geographic location dummy (1 if living in Bellevue, 0 otherwise)	0.920 (1.21)	0.0442
Restricted Log-likelihood	-91.43	
Log-likelihood at convergence	-84.03	
Number of Observations	369	

* Dependent variable is "Were you aware of the I-405 closures before they happened on August 15-18 or August 22-25" (1-yes, 0-no).

** t-statistics in parenthesis

*** Partial derivatives of probabilities with respect to the vector of characteristics, are computed at the means of the Xs and all observations are used.

APPENDIX C

SURVEY FORMS

APPENDIX C.1

Motorist Survey

Washington State Department of Transportation

University of Washington

Washington State Transportation Center

Dear Motorist:

The Washington State Department of Transportation and the Washington State Transportation Center at the University of Washington are working together to gain an understanding of your reaction to the recent weekend closures of I-405 (these closures were made to repave the roadway). The results of this survey will be used to assist the Washington State Department of Transportation in its scheduling of future highway construction projects. Your answers will be confidential (please remove your address label before returning your postage-paid survey). We appreciate your time in completing this survey.

Section A: Impact of the I-405 Closure on Your Travel

1. Were you in the Seattle Area during the weekends of either August 15-18 or August 22-25? ❑ Yes ❑ No

   ↳ If no, did you arrange your schedule to be out of the area because of the I-405 weekend closure?

   ❑ Yes ❑ No

   If you were not in the Seattle area during the closure go to question 8.

2. Did the weekend closure of I-405 affect your travel plans in any way? ❑ Yes ❑ No

   ↳ If no, **go to question 8**.

3. Did you use a trip route that you would not have normally taken because of the weekend closure of I-405? ❑ Yes ❑ No

   ↳ If yes, which of the following routes did you take instead of the closed section of I-405? (check all that apply)

   ❑ I-5 ❑ I-90 ❑ SR-520 ❑ SR-18 ❑ SR-167 ❑ SR-169 ❑ SR-900 ❑ Other

4. Did you change the departure time of any of your trips because of the weekend closure of I-405? ❑ Yes ❑ No

5. Did you cancel a trip that you would have normally taken because of the weekend closure of I-405? ❑ Yes ❑ No

   ↳ If yes, which of the following trip-types did you cancel? (check all that apply)

   _____shopping trip _____recreational trip _____other
   _____business trip _____visiting friends

6. Did you spend less money shopping because of a weekend closure of I-405? ❑ Yes ❑ No

7. Did you shop at different places because of a weekend closure of I-405? ❑ Yes ❑ No

Section B: Your Awareness and Opinions on the I-405 Closure

8. Were you aware of the I-405 closures before they happened on August 15-18 or August 22-25? ❑ Yes ❑ No

   ↳ If no, **go to question 10**

9. How did you acquire advanced knowledge of the I-405 closures? (check all that apply)

   _____road signs _____television _____other
   _____radio _____word of mouth _____ Newspaper

10. How do you usually acquire information about traffic conditions when driving in the Puget Sound region? (check all that apply)

    _____road message signs _____television _____other
    _____radio _____word of mouth _____do not normally seek
    ____ newspaper ____ internet inform about traffic conditions

(Please Continue on Next Page)

Section B: Continued

11. Please indicate the extent to which you agree or disagree with the following statements

	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly
The weekend closures of I-405 had a major impact on my travel plans.	_____	_____	_____	_____	_____
The State and the media did a good job of making the public aware of the I-405 closures.	_____	_____	_____	_____	_____
Closing highways completely for a weekend is better than closing a few lanes during the day for several days.	_____	_____	_____	_____	_____
The weekend closure of I-405 had a significant, negative impact on area businesses.	_____	_____	_____	_____	_____

Section C: About Yourself

12. Are you? _____male _____female

13. Are you? _____married ____single _____separated _____divorced _____other

14. What is your age? _____

15. What is your approximate annual household income?

____no income ___$10,000-$19,999 _____$30,000-$39,999____$50,000-$74,999

____Over $100,000 ___under $10,000 ___$20,000-$29,999 __$40,000-$49,999 __$75,000-$100,000

16. What is your highest level of education?

❏ some high school ❏ technical college degree (A.A.) ❏ post graduate degree

❏ high school diploma ❏ college degree

17. Including yourself, how many people live in your household? _____

18. How many children in your household are under age 6? _____

19. How many children in your household are aged 6 to 16? _____

20. How many people living in your household work outside the home? _____

21. How many licensed and operable motor vehicles do you have? _____

22. What City do you live in?_____

Comments:

_____

(Thank you)

APPENDIX C.2
State Highway Agency Survey

SURVEY OF HIGHWAY RECONSTRUCTION PRACTICES IN MAJOR METROPOLITAN AREAS

Please answer the following assuming ACP overlay of multi-lane expressways:

1) How many major highway reconstruction projects (≥ 25,000 tons of paving) have been completed in your state during the last three years? _____

2) How many major highway reconstruction projects are slated to begin in your state over the next three years? _____

3) Please rank the reconstruction methods below with 1 being the most frequently employed in your state for highway reconstruction. Indicates methods that are not used by placing a zero in the blank.

_____ single lane closures daytime

_____ single lane closures nighttime

_____ single lane closures around the clock (≥ 24 hrs)

_____ multiple lane closures daytime

_____ multiple lane closures nighttime

_____ multiple lane closures around the clock

_____ full lane closures (one direction) daytime

_____ full lane closures nighttime

_____ full lane closures around the clock

_____ other: describe _____

4) How have you found construction operations or quality to be affected positively or adversely by the closure method employed most frequently (#1 above) versus other specific methods? Mark all that apply.

Difference with respect to:

Compaction: ❑ Lower average density ❑ Greater variability in density

❑ Higher average density ❑ Less variability in density

❑ No noted difference

Gradation: ❑ Greater variability ❑ Less variability ❑ No noted difference

Longitudinal Joints: ❑ Better overall quality ❑ Less overall quality ❑ No noted difference

Smoothness or Rideability: ❑ Better ride ❑ Worse ride

❑ Not measured soon enough after construction

Work Zone Safety: ❑ Higher motorist accident rate ❑ Lower motorist accident rate
❑ Higher worker accident rate ❑ Lower worker accident rate
❑ No noted difference

"Cyclic Segregation", Truck Fans, etc: ❑ Higher rate of occurrence
❑ Lower rate of occurrence
❑ No noted difference
❑ Not a problem due to _____

Cost: ❑ Higher pay factors associated with _____
❑ Lower pay factors associated with _____
❑ No noted difference

Hourly Production Rates: ❑ Higher average rates ❑ Lower average rates
❑ Greater variability ❑ No noted difference
❑ Less variability

Public Reaction/Impact: ❑ Motorists adjust well with little complaint
❑ Businesses prefer
❑ Mostly negative feedback received
❑ Mostly positive feedback received
❑ Higher traffic incident rate on alternate routes

5) Is your SHA considering specific alternative approaches, with respect to lane closure, time of day, etc., to deal more effectively with current highway reconstruction constraints? If so, please describe. _____

_____
_____
_____
_____
_____
_____
_____
_____
_____

Thank you for your contribution to this study!

APPENDIX D
COMMENTS FROM MOTORISTS

ID Number	COMMENTS
2	Great way to go!
4	I405 always has work done on it. Improvements have been happening for the last 15 years. State union employees never work, they all stand around and watch someone else. “They” are too many chiefs and no indians.
17	It proves that road repairs can be done in an expeditious manner, instead of extended periods of time.
18	Close I-5 by Tukwila on any weekend to resurface the added lane.
20	I wish this would be the way all road construction would be done. A short inconvenience, such as a weekend, is much better than months or weeks of inconvenience. I have traveled I405 since construction-great job!
21	When it comes to traffic repairs in this area, quick is most painless. While I don’t use I405 often, I would prefer the same weekend closure approach on 520 which I drive daily.
22	The closure went smoother than I expected.
26	I work in Woodinville and travel I405 daily and to me the closure was great way to get the work done.
29	Weekend closure is the best idea that has happened in years.
30	Do this more!!
31	I rarely go to the Eastside so the closure wouldn’t have affected me even had I been in town.
32	If it saves money and the end product (i.e., quality of the paving) is better I’m all for closing down for the weekend.
35	For the weekend closure, I strongly recommend the quality of road surface is far better than several pavements, safer for transportation crew. I like this idea. Eventually, I think less patches will be required in downstream maintenance.
37	Yes, it was necessary for our normal 405 travel to be rerouted, but with the advanced warning from the media, we were able to plan accordingly. I think the weekend closure was a good idea and saved many headaches, accidents, delays during the week.
38	I like the idea of official concern by technically responsible planners.
45	Closing the freeway for the weekend was a great idea and saved a lot of commuting frustration on following weekdays.
47	Closed highway is best method.
51	I would have gone an alternative route when 405 closed, much better a short inconvenience than dragging out road repairs.
52	Bit of a problem coming home from a concert. Not a big problem! My son uses that route to work-was better for him.
57	I think it should be done as quickly as possible. Time is of essence.
58	Please do more road work like this. I felt it had no negative impacts.
61	Finish the I5 Tukwila S-curve project that has had terrible surface for 2 years close it for 3 weeks if needed, but get it done.
62	I drove I405 yesterday southbound, looks and feels like they did a good job.

63	Closure on weekends are best! Wish it would happen in southbound. Also after 10:30 p.m. is good.
65	Delivery service-which I do on weekend- was greatly effected.
66	I feel it worked out well closing 405 on the weekend. It would have been very difficult to close during the week or 4 or 2 lanes at a time-more negative impact.
69	Your overhead electronic signs are worthless. Drivers slow to read them and create traffic slow downs unnecessarily.
70	Great job-look at highway 18-start at Everett and at Ft.lewis, with exits to new port hills, Renton, Kent, exits.
73	After commuting to Kent for 2 years of construction, I fully approve of weekend closure.
76	I think that the work should be done during the evening hours to early morning (10:00 p.m. -5:00 am).
77	I feel that too many commuters were inconvenienced by the lane closures. In the future, I believe that weekend closure are much more effective. Remember that our tax dollars are paying for these road improvements and the constructions crew need to work.
80	I commute everyday to the eastside but usually in the a.m. I go I5 and I90 to get to work, evening 7:00-8:00 p.m. usually I405 south from I90. During the day time it is bad on our freeways but what can you do when we advertise this is the best city to live
81	Seattle needs a third bridge over Lake Washington.
84	Please do road work all after Puget Sound as quickly as can be scheduled. That is, don't drag out work over a whole year.
87	I think DOT did a great job. I had plenty of warning and planned accordingly. I have relatives in Auburn and just went to visit the weekend before the closures.
88	Any improvement of roads is worth any number of delays or closures.
89	Although the closure was a chunk out of the middle of my commute, I much preferred being inconvenienced for 2 weekends than months on end. The new surface is very nice to drive on. It makes my car (30 yr. old VW bug) feel like driving a luxury car.
91	Weekend closure is a good idea to save big $$ and get it all done in one fell swoop!
93	Closures are a good idea - Keep it up!
98	I don’t travel (usually) that far south I405 Factor. Hwy. 169 to do business from Woodinville. I usually go to Bellevue or Seattle.
99	Hope you won’t do this again.
100	If I had needed to go out, it would not be a big deal to use another route for the weekend or any other time.
102	The paving job on I405 north and south was the best and most professional I’ve seen anywhere in the world. My compliments to everyone involved. Keep up the good work. Thank you very much!
104	I personally would rather the weekend closure if the tax payers realize savings and the continual on again off again closure of one or two lanes, that affect my commute and off hour travel info.
105	I think it went really well.
106	I felt sorry for all the out of town people trying to get through without detour signs.
108	Great Idea-allows people to plan ahead.

116	With the amount of traffic on I405, I would get rid of the carpool lane, it doesn't seem to help out the traffic situation, and the amount of traffic on a 2 lane doesn't work.
119	I believe that weekend road closure is the best way to ease traffic problems during the weekdays. Thank you for asking my opinion.
120	I found I was inconvenienced much less by having I405 closed all weekend than during the week everyday. This system was much more efficient
121	I object to the use of road message signs for non-emergency messages. They distract drivers and increase risk of accidents.
124	What I dislike the most are surprises, for example coming upon lane closures (and resulting slow traffic) without warning. I was aware of the I405 closures ahead of time and was able to easily use alternate routes.
127	I feel this was a good decision to get a big job done quicker and cost effective. I would support this method over long delays on other highway projects.
130	HOV lanes should be eliminated. They are underutilized.
133	2 people lane in Bellevue, work in Tukwila-the single lane closures during weekdays, even on evenings, have been a real headache, we appreciate your creative approach to the situation.
141	Had I got caught-up in the I405 mess, I would have been extremely pissed off because of lack of notification.
142	Excellent and efficient job done on the I405, keep up the good work.
152	As a owner of a major regional retail business that draws 30-50% of its business from the eastside, closures had a major negative impact on our sales.
156	I personally think by closing the construction site completely for a weekend is very time and cost effective for such a large scale project. I would like to see more of that happening.
161	Very good. Gave me enough time to prepare for the closing.
167	Excellent job! Well done! I travel to the airport and love the new stretches of freeway. We are very impressed with the length completed during the short closure. A little hardship is definitely worth the results.
168	I needed to be at Sea-Tac airport to pick up arriving passenger and drove I90 to I5 and the Mariners game let out at the same time and caused extreme delays on southbound I5 (I would have usually taken I405 route)
169	Would have preferred to have both sides of the freeway closed at the same time so only one weekend would have been impacted.
171	It seems remarkably short-sighted not to have added a lane during all the summer work that was being done! You repaved (and it needed it) but did very little to actually help the stress of the I405 commute.
174	I appreciate the states' innovative approach to handling I405. The I405 late morning to early afternoon lane closures are so unpredictable and aggravating (over the last months) that two little weekends of planning road trips in truly insignificant.
175	Most of my highway traveling is up the I5 corridor. A closure of that highway would have a far more significant impact on me.
184	I commute everyday to Issaquah using SR520 and I405 and I90. I experienced no difficulty. The commute was also on Saturday and Sunday.
185	I thought this was a great idea!! I heartily approve.

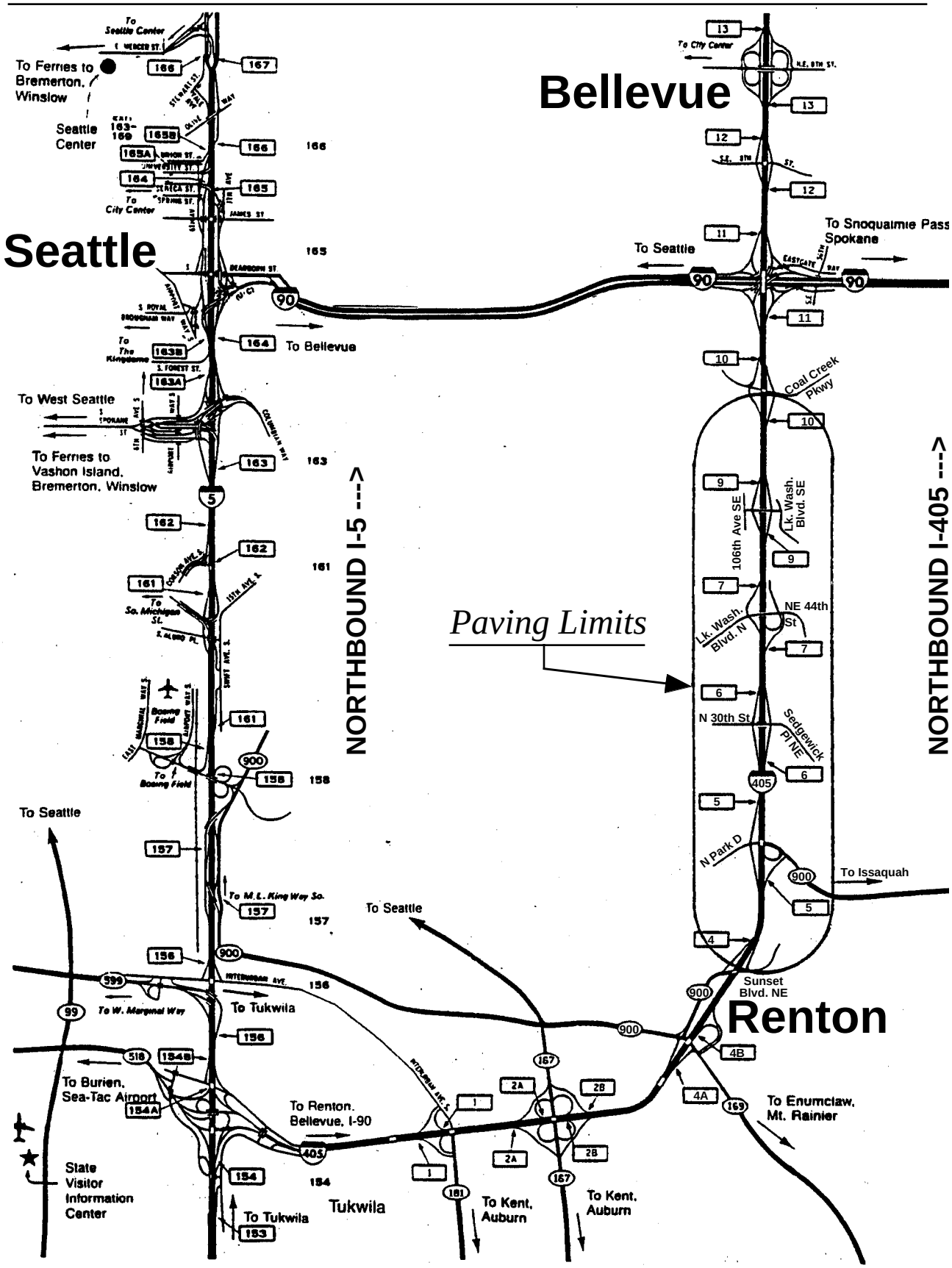
187	Don't "toll" the proposed narrow bridge.
195	The closure was a great idea. Having a large area paved all at once saves money that we pay and a lot of hassle for further congestion.
196	Some section of road, without reasonable bypass, should not be closed.
198	I am disappointed in the end result of I405. Traffic is no better now than before the work accomplished. Same configuration. Why keep transit lanes restricted during the entire day? Why not hours of restriction 6-9 a.m. and 4-7 p.m. I know you are against
199	I support the closure fully. A summer of I405 congestion during road work was hell. I applaud the closure as innovative and a relief.
201	For 5 years, there is ongoing work on this highway(SR167). Since this massive work began, the traffic conditions are most often worse than before. The effect is that of pouring concrete down a drain-I would like to see those funds used for enhancing light.
205	Why don't they schedule night time work on these major roads that need accessibility during the day? It seems that the State transportation could do a better job with the resources available. Use temporarily high light!
212	Great job on low impact process at I405.
215	We live just above I405 in Newport Hills. Although we were somewhat affected by construction noise we strongly agree with the weekend approach to get the job done and over in the space of two weekends.
218	Closing highway is better for safety than closing one lane at a time. However, you continue to close I405 one lane at a time.
220	As long as I have sufficient lead time, I plan activities, route, etc., accordingly.
228	The close it and finish it concept is far superior to partial closure. Made a drive on 8-1-97 north on I405 during partial closures in that was a nightmare of people cutting in and around at all opportunities. Traffic moved well during the total closure.
233	If I were in the area during that time instead of on vacation, the closure would have had adverse impacts on my normal transportation plans.
237	This closure did not affect me much- closing I405 north of Coal Creek parkway probably would cause me to leave town for the weekend.
238	Coordinating construction hours during the evening(10p.m. later) also contributes to fewer traffic problems during prime time traffic hours.
239	Excellent idea rather than tie up the roads for several weeks.
243	We think the closure of I405 was an excellent idea and should be done again.
248	#11-3 is "agree" if it was worded "...closing a few lanes during the day for several months" versus completely for a weekend. The traffic congestion on Coal Creek parkway wasn't as bad as expected.
250	Continue road repairs using complete road closure method-more efficient-saves tax dollars and on the whole is less disruptive.
251	Keep lanes open during weekdays, and if needed, close road for entire weekend and be done with it!
252	Financially it makes sense. Impacts on travel is less. Why are we not doing this more often?
256	Have moved from Renton to Gig Harbor and no longer use I405 regularly?
258	Smartest thing the WSDOT has ever done. Do all road projects like this.

259	I think the DOT had done an excellent job to go ahead with this arrangement without consulting the general public's opinion, from time to time we need leadership like this to get the job done promptly. Everytime since, I traveled on I405.
260	Is this approach used on other than freeway? If not, it may be worth considering.
261	What can you do about the traffic tie-ups on I5 through Everett? I hope the I405 mess through Bothell gets completed soon. I much prefer a short total closure than the long range traffic problems like the 2 listed above.
264	Stayed w/in Seattle city limits and avoided I5 during I405 closure-kept to arterials and side streets.
266	We need more patrols in the construction area to protect the workers. Good job keep up the good work.
269	Interesting to have an impact survey perhaps it should be done more until adequate data base is established.
272	Much prefer closing a highway and getting the job done. Partial lane reduction in several weeks while a job is done creates a much larger negative impacts.
276	I think it was a good idea, it may not work as well on I5 but the advance warning and availability of other routes makes it a better choice than driving through unexpected(unprepared for) traffic delays caused by construction.
282	I travel I405 nearly everyday and I thoroughly appreciate the work done and the way it was done- I would rather make alternate plans for 2 days than be stuck in traffic for months! Thank you!
287	My business takes me north on I405 from I90. Had this been closed, I would have been affected and feel differently.
289	Before the county or cities allow multi-zoned buildings(apartments etc.) to be built why not improve the roads for adequate travel.
300	#15 this is question is offensive to me. It is none of your business what my income is- Also has nothing to do with this the subject.
301	It appears to me that closing for a weekend is more productive to the contractor and less problem to motorist.
303	I wonder how many accidents have happened? I5 is very dangerous during these repairs taking place, its too bad it couldn't be done like I405!
307	Continue with this type of weekend closures when appropriate.
308	I commute from Graham to Bellevue 5 days a week. I think this idea could be used on the highway 167 to speed up the completion of the carpool lane. The traffic in the valley is horrendous.
309	Weekend closures are the way to do it!
311	As long as there is enough prior knowledge, road work; as you had done it; should not be much if any problem at all! Thanks for trying something new!!
312	Work's for contractor that closed I405.
314	Thanks for the survey.
315	I405 has been a pain road. It will be nice to have it completed.
319	It was a great idea to close the road for the work-while a bit of inconvenience, it was limited. Congratulations!

322	#11-3 “Closing highways completely for a weekend is better than closing a few lanes”. This depends on the possibility of alternative routes to major areas. In the case of I405, there were many alternative routes. Maps with the alternative routes could be
323	I think the transportation department did a wonderful job on I405.
329	This was a good way to go; Do it during the weekend and finish a section! Lane closures during the work week should be avoided.
330	If you wanted this back by the 15th, should have sent it out earlier mine arrived on the 12th!
331	Would have been nice to know more about what work would be accomplished during the closure. When will traffic sensors and cameras be activated.
332	I tried to avoid traveling to work in Renton but had to go in on the 24th for a few hours.
337	I think it is much better to shut down the freeway for a weekend other than a lane per day.
343	When I worked in the Middle East, they had similar road problem as here. Heavy trucks had to be off the road at peak commuter times. This reduced a lot of fatal accidents and kept traffic flowing more safety. I notice many heavy vehicle with no side impact
346	#11, I would rather be complaining about 4 days of “chaos” than several weeks. This is what I have been saying for years, should happen to reduce dollars and spending “chaos” to the public.
347	The traffic problems need to be addressed.
349	It’s a lot easier to take I5 for a weekend than to have lanes closed during the week.
350	I often visit family in Bellevue and Kirkland, but because of advanced information did not go up there. I think you are finally on a grand idea and have heard good from others.
353	I’d rather have major highways closed on the weekends and fixed than a few days during the week.
354	Great idea-much more cost effective to the average commuter. No time lost in commuting. Do it again!
357	Forgot freeway was closed. Took a trip to the airport, no delay southbound open. Took alternate route to return home. Minor inconvenience.
361	The weekend closures were the best idea yet! The new road is great and complete in a couple weekend. All road work should be done this way!
362	Please fill potholes, also-the steel plates are very dangerous near Bothell-you need to almost stop(like a speed bump) or risk front end damage or bending your wheels.
365	Cellular phone traffic line and WEB page are excellent sources of info. and help a lot in re-routing my commute when necessary.
370	I work in South Seattle and travel I405 daily-I liked the way they used the weekend for repairs!
371	Great job of informing public in advance.
372	Do it again on I5 in Everett!!
376	This is a loaded question. The major work up until that time was done at night. That is preferable to either choice above. It did not result in a mitigation of future impacts as you are still closing lanes down to do work that should have been done at that same time. To close the whole thing down to do the edges was plain silly unless you were going to repave overpasses(which are still in their original bad condition) or do all remaining work.

APPENDIX E
SR 405 MAINLINE OVERLAY REPORT

Washington State
Department of Transportation



METHODOLOGY

Historically, pavement overlays constructed in congested urban areas are constructed at night with a series of nighttime lane closures. This process tends to be inefficient and subjects the public to construction inconveniences and hazards over a long period of time. In an attempt to provide a superior end product with less overall impact to the traveling public, WSDOT is planning to construct the SR405 overlay during two separate weekend closures, thus shortening the paving duration by an entire construction season.

CONTRACT PLAN INFO AND CHANGES

ROADWAY SECTIONS

There have been numerous changes to the Contract roadway sections, ail of which have been previously distributed to the Contractor (See *Appendix A*). The only 'further change is that the overlay will be constructed to the toe of all of the existing precast concrete barrier on the job, with the exception of the widenings of the SB 44th onramp, the SB Park onramp, and the NB-30th onramp. The final lift under the barriers on the aforementionedramps will be paved prior to resetting the barrier in its final configuration. At all other locations on the job, the precast barrier will not be moved for the sole purpose of constructing the overlay underneath of it since there would not be enough time during. the weekend closure to remove and reset the barrier.

PIVOT POINTS

As shown on the Contract roadway sections, the existing roadway has a pivot point at the HOV lane stripe between the inside and middle lanes. This pivot point occurs on both the northbound and southbound roadways. Also, the roadway sections show that this pivot point location moves transversely into the middle lane by as much as four feet. There isnothing in the Contract that shows at which stations this variation in pivot point location occurs. After conducting a field survey of existing pivot point location, it was found that in most areas the pivot point lies within a couple of feet of the HOV lane stripe. Prior to preleveling, the channelization will be placed into its final configuration. The prelevel will be used to make minor lateral shifts in the pivot point so that it lies directly on the HOV lane stripe between the inside and middle lanes.

There are a couple of areas where the pivot point lies a considerable distance from the HOV lane stripe. There was initial concern that re-establishing the pivot point at the HOV stripe in these areas would leave a substantial lip between the two lanes, causing a traffic hazard'if the HOV lane and the middle lane were not preleveled in the same work shift. Since the weekend lane closure hours have been extended to accommodate the installation of the preleveling, it will not be a problem to pave both lanes during the same work shift, so it is no longer an issue.

Also, the Contractor is concerned that there is another break point location in addition to the pivot point. The median widening in these areas was constructed to the superelevations shown in the Contract Plans, which did not necessarily match the existing superelevations of the adjacent HOV lane. This has caused a break point to occur at the median widening joint, This is a concern in areas where the break point lies less than 10' away from the median barrier since the standard paving machine will not be abie to fit between the barrier and the break point. In order to overlay these areas, a different paving procedure would have to be used, possibly including extensive hand work.

Since hand work would put the overlay completion time in jeopardy, this break point will be eliminated in one of two ways. Primarily, the median widening will be'overlaid with the preleveling course at the same superelevation as the adjacent HOV lane. In areas where this would cause the paving to extend too high up onto the median barrier, the break point will be planed out instead.

SUPERELEVATIONS

The actual existing roadway superelevations differ from those shown in the Contract to varying degrees. Since the intent of the overlay is roadway preservation instead of roadway reconstruction, the superelevations shown in the Contract are to be ignored for overlay purposes. The new overlay will be installed by paving constant depth over the existing and widened roadways.

PREPARATORY WORK ACTIVITIES

CRACK SEALING AND PAVEMENT REPAIR

The Contract Special Provisions give general areas where crack sealing and pavement repair are likely to be needed. WSDOT has since conducted a detailed review of the overlay limits, and has produced a summary sheet showing the approximate location and extent of crack sealing and pavement repair areas (see Appendix B). A copy of the actual detailed field survey sheets has been made and given to the Contractor for their reference. The field survey sheets show approximate crack sealing and pavement repair quantities every 50 LF of every lane in both roadway directions. This is intended to provide the Contractor with a general scope and approximate location of the repairs that will be required, but is not intended to be all inclusive as pavement conditions could change over the months prior to actual overlay construction.

After the Contractor has had a.chance to review the provided information, WSDOT and the Contractor will discuss and come to an agreement on the necessary personnel and equipment to perform the work. When the Contractor wishes to perform the repairs, WSDOT will paint the actual repair areas in the field prior to the Contractor performing the work.

PLANING IN LIEU OF PAVEMENT REPAIR

After the first few days of repairing pavement, it was concluded that the majority of the areas showing major distress did not extend all the way through the pavement section. Instead, the distress has been caused by the delamination of the previous overlay, leaving the underlying pavement in good condition. Therefore, the majority of the pavement repair was conducted by removing the delaminated upper asphalt lift (0.35' depth) and replacing it with new ACP Class 'A'. This removal was accomplished with a small planer called a 'zipper' which was attached to a front-end loader. After removing the upper ACP, the underlying ACP was evaluated for distress. If distress was noticed, then the pavement was repaired to full depth.

PRELEVEL

The entire width of the traveled lanes will be preleveled with a minimum 0.08 depth of asphalt concrete pavement Class G, with additional depth used to fill the ruts in the wheel tracks. At the roadway edge stripes, the prelevel course will begin tapering down to zero depth over a width of 2 feet. Primarily, this shoulder and median tapering will be done to reduce the total height that the overlay will come up on the existing and the new traffic barriers. In addition, the prelevel course will be used to shift the pivot point slightly to match the location of the new HOV lane stripe.

Contract plan quantity for ACP Class G for prelevel is 18,518 Tons. A brief survey of actual field conditions and existing rut depth indicate that the quantity used will probably be closer to 15,000 Tons.

PLANING

'Planing will be accomplished at all locations shown on the Contract paving plans unless otherwise noted in the body of this report or as modified by previous Change Order.

BRIDGE REHABILITATION

BR405/23 (PARK AVE)

Bridge 405123 will not be included in the overlay limits, nor will it receive any prelevel, pavement repair, joint repair, or cracksealing. This is consistent with the Contract roadway sections and with the Contract paving plans.

BR405/25 (MAY CREEK)

The Contract roadway sections do not address the limits of this bridge deck. However, the Contract paving plans show that the project overlay is continuous over the existing deck with no indicated planing of the existing deck overlay. The existing bridge deck will not support the dead load of an additional 0.15' depth of ACP. Therefore, the existing deck'overlay will be planed down 0.08'. This planing depth will taper down to 0.00' over a distance of 50 LF beyond each of the end piers. The existing deck will then be overlaid with 0.12' of ACP Class A. The overlay will transition from a 0.12' depth up to a 0.15' depth starting at the end piers and ending at the grinding limits 50 LF away from the end piers where it will match into the 0.15' deep mainline overlay.

The overlay of the new widened bridge deck will match the final overlay depth (combination of existing ACP and new ACP) on the adjacent existing deck at the widening joint. The overlay will then transition to a consistent 0.19' depth at the toe of the western barrier. The waterproof membrane on the new widening will be deleted. All of these changes and clarifications concerning the BR405/25 deck overlay have been presented in a Change Order.

BR405/30 (COAL CREEK PARKWAY)

The Contract shows that the project overlay ends at the southern pier of this bridge via a planed butt joint, This butt joint shall be installed per plan. In addition, the top 0.08' of the existing ACP overlay on the bridge deck shall be planed off. Planing any deeper would put the waterproof membrane in jeopardy. Afterwards, .an 0.08' depth of Asphalt Concrete Pavement Cl. G shall be placed over the entire bridge deck. This will result in no net increase in overlay depth compared to existing, which will eliminate any need to raise the interior expansion joints. This. work does not have to be done during the main overlay weekends. This added work is addressed in a Change Order and is being performed in reaction to numerous citizen complaints regarding the rutted condition of the existing deck overlay.

TRAFFIC DATA LOOPS

Per Standard Specification 8-20.3(14)C, all mainline and ramp traffic data loops falling within the overlay limits shall be installed after roadway grinding and prior to construction of the final wearing course. Primarily, the Contractor has chosen to install the loops prior to installationof the preleveling course as well.

MATERIAL STOCKPILING AND PRE-APPROVAL

It was mutually agreed that the Contractor would provide dedicated aggregate stockpiles for the sole purpose of constructing the overlay. Once the Contractor has built the stockpiles, they will notify WSDOT, who will in turn test the stockpiles for specification compliance prior to the weekend closures. The Contractor should provide the stockpiles. for testing at least 3 weeks prior to the weekend closure so as to allow sufficient time for testing and correction of any discovered deficiencies.

ADVANCE PUBLIC NOTIFICATION

ADVANCE NOTIFICATION SIGNS (FIXED MESSAGE)

WSDOT has provided a design for the mainline and the ramp advance notification signs (See Appendix C). There will be 4 mainline signs (2 each direction), and 15 ramp signs (7 for the southbound closure and 8 for the northbound closure). The Contractor will fabricate the signs and install them at locations staked by the Engineer. Payment to the Contractor for these signs will be by force account as provided for under Change Order #8.

The advance notification signs will be installed 11 days prior to the corresponding weekend closure and will remain up throughout the closure period. The Contractor will attach blank placards to the face of each sign after the closure has actually begun, These placards will cover up the 'will be' portion of the "will be closed" message so that the sign will simply say "closed" with the appropriate dates and limits.

ADVANCE NOTIFICATION SIGNS (VMS/HAR)

The Construction Traffic Section of WSDOT NW Region has provided maps showing the locations of all of the permanent VMS and HAR signs that will be used for advance notification before and during the weekend closures (See *Appendix D*). Also shown on these maps are locations where portable VMS and HAR signs are to be placed. All portable units will be provided, placed, and maintained by WSDOT Maintenance. The VMS and HAR signs will be put into service 11 days in advance of the appropriate weekend closures.

PRESSRELEASES

WSDOT has provided the media with preliminary notification of the roadway closures at a press conference held at the NW Region office on April 17, 1997. The NW Region Construction Traffic Public Information Officer will provide additional press release and media notification information 11 days prior to the beginning of the weekend closures.

PUBLIC AGENCY NOTIFICATION LETTERS

Per Contract, the Contractor will send public agency notification letters to the agencies listed in the 'Traffic Control Special Provision, The agencies to be notified include Washington State Patrol, Metro and other affected transportation companies, local school districts, and local emergency agencies (fire, police, etc.). The letters are to be sent one month prior to beginning the weekend closures.

NOTIFICATION PROCEDURE IN CASE OF WEATHER CONTINGENCY

Per Contract, weather delays will be decided at 3 PM of the Thursday preceding the weekend closure. The decision will be made jointly by WSDOT and the Contractor. If a weather postponement is decided, then WSDOT Maintenance will go to each portable VMS and portable HAR sign and change the message to notify the public of the delay. The WSDOT Project Office will notify the TSMC center so that they can change the message on the permanent VMS and HAR signs. The Project Office will also notify the NW Region Construction Traffic Public Information Officer, who will in turn notify the media. The Contractor will install "weather delay" plaques on the fixed message advance notification signs.' All of the above actions will be performed prior to the end of Thursday's work shift. The Contractor will also be responsible for immediately reissuing the public agency notification letters with the new weather contingency dates,

OVERLAY ACTIVITIES

PLANNED DATES / WEATHER CONTINGENCY DATES

The weekends for constructing the overlay are as follows:

Close and Overlay Southbound Lanes	8:00 PM August 15 to 5:00 AM August 18
Close and Overlay Northbound Lanes	8:00 PM August 22 to 5:00 AM August 25
Weather Contingency for Southbound Lanes	8:00 PM September 12 to 5:00 AM September 15
Weather Contingency for Northbound Lanes	8:00 PM September 19 to 5:00 AM September 22

PAVING LIMITS AND QUANTITIES

The overlay will be constructed to the limits shown on the Contract paving plans. In addition, the ramp overlay limits will be extended to included the entire length of all of the ramps. Due to the increased ramp paving quantities, WSDOT will allow the ramps to be paved either prior to or after the mainline overlay weekends.

The approximate planned and added overlay quantities at this time are as follows. For a more detailed breakdown, refer to *Appendix E.*

Southbound (mainline)	16,990 Tons	Northbound (mainline)	17,776 Tons
Southbound (ramps-planned)	2,518 Tons	Northbound (ramps-planned)	2,611 Tons
Southbound (ramps-added)	1,424 Tons	Northbound (ramps-added)	1,626 Tons
Southbound (total)	20,932 Tons	Northbound (total)	22,013 Tons

EQUIPMENT AND WORK METHODS

The Contract requires that the Contractor provide a paving plan that includes a comprehensive list of operational and backup equipment as well as indicating how the work will be staged. The Contractor has provided this information to. WSDOT (see *Appendix F).* It is important to note that the Contractor has gained permission to set up their mobile rotary drum plant in Boeing parking lot #6, which is 114 mile from the Park Ave ramps. This plant will be the sole source of mix for the overlay. If the plant breaks down, mix will have to be trucked in from the Tukwila or Auburn plants until the portable plant is repaired.

INSPECTION

CONTRACTOR'S QUALITY ASSURANCE

The Contractor will have their own quality assurance testers on site to monitor compliance with the compaction specifications. The Contractor will provide WSDOT with a preferred coordination procedure between their testers and WSDOT testers.

WSDOT

WSDOT will provide materials testers to monitor compaction efforts per the Contract requirements. The Contractor has requested that rolling patterns be performed. The Contractor has submitted their paving plan and indicated their rolling train equipment. The equipment and work method is acceptable, so WSDOT has agreed to conduct the rolling pattern.

TRAFFIC CONTROL

ROADWAY CLOSURE

WSDOT Maintenance will provide all roadway closures and traffic control except that which is necessary to implement Contractor haul routes. WSP will monitor the mainline closure points to ensure public compliance. City of Renton off-duty police officers will assist with flagging through the signalized intersections at Park Ave & 8th as well as at Park Ave & Southbound SR405.

The southbound SR405 mainline closure will begin far enough in advance of SR90 that traffic will be down to one through lane for access to Coal Creek Parkway by the time traffic reaches the exit to SR90. The one through lane will be signed as local access only. At Coal Creek Parkway, the roadway will be totally closed, and all traffic will have to exit. The westbound SR90 ramp to southbound SR405 will remain open to traffic and be signed as local access only. Similarly, the eastbound SR90 ramp to southbound SR405 will remain open and be slgned as local access only.

The Northbound SR405 mainline closure will begin far enough in advance of SR167 that traffic will be down to one lane which will be shifted onto the collector-distributor ramp. From that point, traffic can either exit onto SR167 or proceed on to SR169. The traffic proceeding to SRI69 will be relegated to the right lane only, which will be signed as local access to SR169. AT SR169, all traffic will have to exit. The northbound SRI67 ramp to northbound SR405 will be closed to all traffic. The southbound SRI67 ramp to northbound SR405 will also be closed to all traffic.

SITE ACCESS

The Contractor will provide a plan or procedure (such as an ID tag or vehicle window sign) as to how authorized Contractor, WSDOT, and UW personnel are to be allowed access to the job site. WSDOT Maintenance will be present at each mainline and ramp closure point, and will not allow anyone access to the job site unless they comply with the approved plan or procedure. (see Appendix G)

HAUL ROUTES

Southbound Paving : Truck traffic will exit Boeing parking lot #6 headed west on 8th, then turn north on Garden. At Park Ave, trucks will turn east and get onto SR405 via the southbound on ramp. Trucks headed back to the plant will exit SR405 via the same ramp, with a uniformed officer controlling traffic at the. bottom of the ramp at Park Ave. The trucks will then proceed west on Park Ave, and turn east on 8th, ending 'back at Boeing parking lot #6. Paving from Park Ave to Sunset will use the southbdund off ramp for access instead of the southbound on ramp (See Appendix F).

Northbound Paving: The route is the same as that for Southbound Paving (see above) with the exception that the trucks will enter an leave SR405 via the northbound off ramp. Paving from Park Ave to Sunset will use the northbound on ramp for access instead of the northbound off ramp. (See Appendix F).

EMERGENCY ACCESS PLAN

Per Contract, the Contractor has provided an emergency vehicle access plan. This plan will ensure safe access to emergency vehicles requesting access to the job site (See *Appendix H*).

UW RESEARCH STUDY

The University of Washington will conduct a federally funded research study to determine the costs and benefits of construction under a total roadway closure as compared to the historical method of numerous nighttime closures. They will have research teams in the field during construction in order to accumulate information regarding traffic impacts, economic impacts, construction productivity, end product quality, and safety, all of which will be assembled into a final report. This report will help WSDOT determine if total roadway closures are more beneficial than frequent nighttime closures and will have a significant impact on how construction of this nature is handled in the future.

APPENDIX F
MEDIA COVERAGE

48 TV News Stories in Six Days

Prepared 8/19/97 by Tempo IV/Seattle

Report Range: 8/11/97 - 8/18/97 Phone (206) 822-1821
Report Topics: WSDOT\D.O.T.\Dept. of Transp.\Department of Transportation Fax: (206) 889-1452

Program	Clip Type	Time in Length	Description
Monday, August 11, 1997			
SEATTLE			
4 KOMO			
5:00 PM Segment of NEWS	Anchor Read	00:37:48/ 11:11:28	I-405 to be closed this weekend for repaving
Wednesday, August 13, 1997			
SEATTLE			
4 KOMO			
5:30 PM Segment of NEWS	Multiple Format	01:34:45/ 00:02:58	I-405 to close over weekend with no detour Int: Sue Horsey, angry commuter… Int: Commuter… Int: Claudia Cornish, Dept. of Transportation
11:00 PM Segment of LATE NEWS	Multiple Format	01:11:30/ 00:01:08	I-5 closing 2 lanes for repaving/ I-405 closing due to repaving…Int: Official
5 KING			
5:00 PM Segment of NEWS	Voice Over	0:21:11/ 00:00:24	I-405 closed over weekend
7 KIRO			
5:00 PM Segment of NEWS	Multiple Format	00:21:40/ 00:01:22	Traffic on 405 will get worse with temporary closings
6:30 PM Segment of NEWS	Voice Over	01:45:52/ 00:00:28	Section of 405 will be closed
Thursday, August 14, 1997			
NORTHWEST REGION			
35 NWCN			
7:00 PM Segment of NEWS	Voice Over	01:38:38/ 00:00:24	I-405 southbound lanes to close for weekend
SEATTLE			
4 KOMO			
11:00 AM Segment of MIDDAY NEWS	Anchor Read	00:08:12/ 00:00:35	Closure on 405 near Renton
5:00 PM Segment of NEWS	Anchor Read	00:37:35/ 00:00:30	I-405 southbound lanes closed over weekend
11:00 PM Segment of LATE NEWS	Anchor Read	01:20:14/ 00:00:48	Work crews to repair Alaska Way Viaduct this weekend/I-405 to close southbound lanes this weekend

Program	Clip Type	Time in Length	Description
5 KING			
12:00 PM Segment of NOON NEWS	Multiple Format	00:03:35/ 00:01:24	405 will be closed during this weekend for construction..Int: Kim Henry, DOT
6:00 PM Segment of NEWS	Multiple Format	00:21:08/ 00:02:08	I-405 closed southbound this weekend Int: Kim Henry, Dept. of Transportation
TACOMA			
11 KSTW			
10:00 PM Segment of LATE NEWS	Multiple Format	00:21:14/ 00:01:01	I-405 closure…Int: Kim Henry, Project Engineer
Friday, August 15, 1997			
NORTHWEST REGION			
35 NWCN			
7:00 PM Segment of NEWS	Multiple Format	00:41:12/ 00:00:37	Traffic woes: I-405 to close for weekend Int: Bill Southern, Dept. of Transportation
SEATTLE			
4 KOMO			
11:00 AM Segment of MIDDAY NEWS	Multiple Format	00:04:47/ 00:01:44	405 will be closed tonight/Int: Sue Horsey, 405 commuter/ Int: Claudia Cornish, Dept of Transportation
11:00 AM Segment of MIDDAY NEWS	Voice Over	00:08:31/ 00:00:24	Sound Transit: new transit name
5:00 PM Segment of NEWS	Multiple Format	00:14:36/ 00:01:38	I-405 to be shut down for the weekend… Coal Creek Parkway to Maple Valley Highway southbound
6:30 PM Segment of NEWS	Voice Over	01:42:59/ 00:00:36	I-405 southbound to be closed for weekend
11:00 PM Segment of LATE NEWS	Multiple Format	01:02:40/ 00:03:60	I-405 southbound closed for the weekend Int: Bill Southern, State Transp. Dept… Int: John Anderson, State Patrol…Int: Gary Hitzel, Bellevue resident…Int: Marty Kaplan, Bellevue resident
5 KING			
12:00 PM Segment of NOON NEWS	Voice Over	00:12:02/ 00:00:36	405 will be closed this weekend
6:00 PM Segment of NEWS	Multiple Format	00:21:30/ 00:02:40	I-405 southbound to be closed this weekend From Coal Creek to Maple Valley Highway Int: Bill Southern, Dept. of Transp Int: Royal Robinson, commuter
6:30 PM Segment of NEWS	Voice Over	01:41:20/ 00:00:20	I-405 closed for weekend for resurfacing
11:00 PM Segment of LATE NEWS	Multiple Format	01:06:58/ 00:01:13	Southbound I-405 to be closed for weekend for re-paving
11:00 PM Segment of LATE NEWS	Multiple Format	01:12:08/ 00:02:52	Commuter alert I-405 to be closed for the weekend…Int: (R)…Int: (R)
7 KIRO			
5:00 PM Segment of NEWS	Multiple Format	00:21:25/ 00:01:20	I-405 southbound closure for the weekend for re-paving

Program	Clip Type	Time in Length	Description
11:00 PM Segment of LATE NEWS	Multiple Format	00:39:45/ 00:00:25	I-405 southbound closure this weekend for re-paving TACOMA
11 KSTW			
10:00 PM Segment of LATE NEWS	Multiple Format	00:04:16/ 00:04:06	I-405 southbound closure this weekend for re-paving…Live coverage…Int: Bill Southern, State Transportation Dept.
Saturday, August 16, 1997			
NORTHWEST REGION			
35 NWCN			
7:00 PM Segment of NEWS	Multiple Format	01:35:40/ 00:01:40	I-405 closed, traffic is better than expected KING 5 story
SEATTLE			
4 KOMO			
5:00 PM Segment of NEWS	Voice Over	00:03:27/ 00:00:33	I-405 southbound closure to repave this week-end
6:00 PM Segment of NEWS	Multiple Format	00:08:15/ 00:02:10	I-405 new Factoria weekend closure coverage Int: Bill Southern, Dept of Transportation
6:30 PM Segment of NEWS	Multiple Format	01:35:15/ 00:00:42	I-405 closure this weekend going southbound Int: Bill Southern, Dept. of Transportation
11:00 PM Segment of LATE NEWS	Voice Over	00:07:15/ 00:00:30	I-405 closed this weekend
5 KING			
5:00 PM Segment of NEWS	Multiple Format	00:06:37/ 00:02:13	I-405 weekend closure coverage…for repave-ment…Int: Bill Southern, Dept of Transporta-tion…Alternative routes
6:30 PM Segment of NEWS	Multiple Format	01:35:48/ 00:01:50	I-405 closure this weekend…Int: Sgt John Anderson, Police
11:00 PM Segment of LATE NEWS	Multiple Format	00:07:37/ 00:01:43	I-405 southbound closure…coverage…closed this weekend for repaving
7 KIRO			
5:00 PM Segment of NEWS	Multiple Format	00:08:35/ 00:01:25	I-405 closure for repaving this weekend south-bound…Int: Heather Saunders, motorist
6:30 PM Segment of NEWS	Multiple Format	01:03:30/ 00:02?06	I-405 southbound closure…Int: Kim Lettich, gas station employee… Int: (R)
11:00 PM Segment of LATE NEWS	Multiple Format	00:05:37/ 00:00:48	I-405 southbound closed for weekend for repaving...Int: Kim Lettich, Chevron employee
TACOMA			
11 KSTW			
10:00 PM Segment of LATE NEWS	Multiple Format	00:06:20/ 00:01:10	I-405 southbound closure this weekend…Int: Bill Southern, Dept of Transportation

Program	Clip Type	Time in Length	Description
Sunday, August 17, 1997			
NORTHWEST REGION			
35 NWCN			
7:00 PM	Anchor Read	01:38:50/ 00:00:18	I-405 to reopen
Segment of NEWS			
SEATTLE			
4 KOMO			
5:00 PM	Voice Over	00:08:12/ 0:00:31	I-405 paving project is running on schedule
Segment of NEWS			
11:00 PM	Voice Over	01:07:57/ 00:00:21	I-405 paving on schedule
Segment of LATE NEWS			
5 KING			
5:00 PM	Voice Over	00:12:58/ 00:00:42	I-405 to reopen southbound lanes
Segment of NEWS			
11:00 PM	Voice Over	00:10:02/ 00:00:36	I-405 to reopen after paving
Segment of LATE NEWS			
7 KIRO			
6:00 PM	Voice Over	00:16:51/ 00:00:16	Interstate 405 closed for road construction
Segment of NEWS			
6:30 PM	Voice Over	01:11:35/ 00:00:28	Closures on 405 for construction repairs
Segment of NEWS			
11:00 PM	Voice Over	01:14:08/ 00:00:35	405 closed for construction
TACOMA			
11 KSTW			
10:00 PM	Voice Over	00:11:28/ 00:00:40	I-405 shutdown causes traffic problems
Segment of LATE NEWS			
Monday, August 18, 1997			
NORTHWEST REGION			
35 NWCN			
7:00 AM	Voice Over	00:42:03/ 00:00:29	I-405 paving done on southbound lanes
Segment of NEWS			
TACOMA			
11 KSTW	Voice Over	00:15:44/ 00:00:29	Southbound lanes of I-405 reopened on time this morning
Segment of LATE NEWS			

Local Newspaper Coverage
August 13 to August 28, 1997

Editor's note: The following is a list of articles and editorials that local newspapers printed between August 13 and August 28, 1997. The original, paper version of this report contains copies of these articles (most, unfortunately, without dates), but for this on-line version the publications, headlines, and authors are listed for reference. Most can be found on-line at the appropriate publication Web site, and all can be found in public library reference files.

Thursday, August 14, 1997
The Herald
There's light at the end of our traffic congestion, but watch out for I-405, by Bob Wodnick

Eastside Journal
A closed I-405 to call for creative driving, by Jacqueline Reis

Wednesday, August 13, 1997
The Seattle Times
I-405 Closures may spell gridlock, by Peyton Whitely

Eastside Journal
How can you avoid weekend 405 mess?, by Mike Ullmann

Sunday, August 17, 1997
Eastside Journal
After 50 years of building, I-405 still a work in progress, by Chris Norred

Sunday, August 17, 1997
South County Journal
I-405: After 50 years, still a work in progress, by Chris Norred

Monday, August 18, 1997
Seattle Post-Intelligencer
Repaved stretch of 405 to reopen early today, by PI Staff

South County Journal
Drivers muddle through thoroughfare's closure, by Mike Ullmann and Linda Woo

Sunday, August 17, 1997
Eastside Journal
No gridlock: Drivers skirt 405 closure, by Mike Ullmann and Linda Woo

Eastside Journal
Readers split over I-405 closures, by Mike Ullmann

Eastside Journal
405's lost weekend comes out a success, by Herbert Atienza

Eastside Journal
Don't relax: I-405 work isn't over yet, by Mike Ullmann

Eastside Journal
Motorists find ways past I-405 northbound closure, by Linda Woo

The Seattle Times, Eastside edition
I-405: Will weather cooperate again?, by J. Martin McOmber

Eastside Journal
Weather today will determine I-405 closure, by Jacqueline Reis

Eastside Journal
Drivers find ways around northbound 405 closure, by Journal staff

South County Journal
Paving served motorists, taxpayers, Our View

Sunday, August 24, 1997
Eastside Journal
The water cooler: What do you think of the weekend closures of I-405?, by Ann Garretson

Thursday, September 28, 1997
Eastside Journal
Walking the thin yellow line, Our View

Eastside Journal
Unusual closure sparks two UW traffic studies, by Mike Ullmann