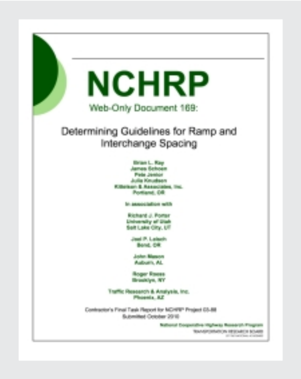

Determining Guidelines for Ramp and Interchange Spacing

DETAILS

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panel members customized and adapted their participation in the research to provide an improved product.

Abstract

This project considered the effects of geometry, traffic operations, safety, signing, and other factors to develop guidelines for understanding the considerations that influence minimum ramp and interchange spacing values. Phase I included conducting a literature search and other information gathering activities, developing a work plan to assess the impact of ramp spacing on traffic operations and safety, and developing a framework for the research guidelines. Phase II included creating microscopic simulation models of closely-spaced ramp combinations calibrated with field data, constructing a crash database and developing crash prediction models, developing a set of guidelines for ramp and interchange spacing, and recommending changes to major resource documents within the transportation profession.

Traffic operations research investigated the impact of ramp spacing on mainline freeway speed and was primarily focused on two ramp combinations: an entry ramp followed by and exit ramp and an entry ramp followed by another entry ramp. Entry-exit combinations were studied with and without auxiliary lanes. These combinations were selected by the research team and project panel as having the greatest amount of vehicle interaction and thus would be most sensitive to the distance between the ramps. To supplement the findings of the simulation models, the research team reviewed datasets from several previous NCHRP projects.

Safety research analyzed a dataset constructed specifically for this project and contained detailed information on ramp and interchange geometry. The team developed crash prediction models for entry-exit and entry-entry ramp combinations. Models considered the total number, type, and severity of crashes. The team attempted to include exit-entry and exit-exit ramp combinations in the analysis but this could not be done for sample size reasons.

As a final product, the team wrote *NCHRP Report 687: Guidelines for Ramp and Interchange Spacing ("Guidelines")* to assist users as they consider new or modified ramps and interchanges. The *Guidelines* stress the importance of ramp spacing, as opposed to interchange spacing, when considering new or modified ramp and interchange concepts and established clear definitions of "ramp" and "interchange" spacing..

The *Guidelines* provide information on federal, state, and local policies related to ramp and interchange spacing, as well as the effects of geometry, traffic operations, signing, and safety. The *Guidelines* and intended to supplement existing resource documents such as the AASHTO Green Book, the *Highway Capacity Manual*, the *Manual of Uniform Traffic Control Devices*, and the *Highway Safety Manual*.

Chapter 1
Introduction

Chapter 1 INTRODUCTION

The purpose of NCHRP Project 3-88 was to investigate the impact of ramp and interchange spacing on traffic operations and safety and to develop a set of guidelines to help users consider ramp and interchange spacing needs when planning and assessing new or reconstructed freeway facilities.

The project team used simulation models, calibrated with field data, to assess the impact of ramp spacing on freeway speed. The project team studied two combinations of ramps: an entrance ramp followed by an exit ramp (with and without an auxiliary lane) and an entrance ramp followed by an entrance ramp.

The project team constructed a crash database to assess the impact of ramp spacing on crash frequency. The project safety models also addressed crash type and crash severity.

Research activates were primarily focused on ramps, not interchanges, because the wide variety of interchange forms and ramp designs in existence can greatly impact ramp spacing dimensions at any given interchange spacing dimension.

Research activities and the resulting guidelines were focused on ramp-freeway junctions and the effects of the spacing between ramps on the performance of the freeway. Ramp design and performance of ramp-terminal intersections were outside the scope of this project and was not directly addressed in research conducted as part of this project or within the *Guidelines*.

1.1 PURPOSE OF THIS FINAL REPORT

This Final Report documents the research effort including the literature review, research methodology, research findings, *Guidelines* development, recommended changes to the major resource documents, and recommendations for future research. The *Guidelines* themselves are being published separately from this Final Report. A key finding of the literature review that influenced subsequent project activities is that the origins of existing ramp and interchange spacing guidance, some of which date back to the early days of freeway building in America, are somewhat uncertain yet have been incorporated into numerous policy documents and have become standards in some cases. The project *Guidelines* avoid a one-size-fits-all approach and allow ramp and interchange spacing dimensions to be customized for a particular project condition.

1.2 SUMMARY OF PHASE I RESEARCH ACTIVITIES

The project team conducted extensive information gathering at the onset of the project. In addition to a literature search, the team conducted a focus group meeting with practitioners from across the country and the wealth of experience from the project's panel was accessed. Information gathering activities are fully discussed in Chapter 2 of this report.

The literature search was conducted by searching online databases such as the Transportation Research Information Service (TRIS), and the Institute of Transportation Engineers (ITE) Journal archive. Additionally, some team members had extensive libraries of relevant literature. The literature search included reviewing the current editions of the AASHTO *Policy on Geometric Design of Highways and Streets* (Green Book), (HCM), and *Manual of Uniform Traffic Control Devices* (MUTCD) as well as all past editions of the HCM and AASHTO Policy (Green Book, Blue Book, and Red Book). The project team identified and reviewed state-level documents and policies by searching state DOT websites. Many of the documents reviewed were several decades old and dated to a time when construction of new freeways in America was more common than it is today.

A focus group meeting, held with designers, planners, and operators of freeways, helped to identify concerns or needs in the current practice of ramp and interchange spacing. The issues raised by the participants ultimately helped the project team craft the *Guidelines* to be more useful to practitioners. The project team sought similar feedback from the Panel, who provided meaningful contributions to improve the early draft *Guidelines*.

The project team also developed the Phase II work plan, which consisted of an operations and a safety component, during Phase I. The project team presented the work plan to the Panel as part of Interim Report #1 and at the panel meeting held at TRB headquarters at the conclusion of the Phase I. The Panel reviewed and approved the work plan.

The project team also drafted an annotated outline of the *Guidelines* during Phase I and presented it to the Panel as part of Interim Report #1. This allowed the project team to receive valuable feedback on the *Guidelines* content before drafting a complete version of the document during Phase II

1.3 SUMMARY OF PHASE II RESEARCH ACTIVITIES

Phase II activities consisted of execution of the work plan, producing of the *Guidelines,* and the drafting of recommended changes to major resource documents. The work plan results, a draft of the *Guidelines,* draft recommendations of resource document changes were presented to the Panel as part of Interim Report #2. After receiving comments from the Panel, the project team produced the two final deliverables of NCHRP Project 3-88: the *Guidelines* document and this Final Research Report.

1.3.1 Traffic Operations Work Plan

The traffic operations work plan consisted of several elements:

- Analysing datasets from previous NCHRP projects to supplement the limited field data collected for this project

  - Project 3-37: Capacity of Ramp-Freeway Junctions
  - Project 3-75: Analysis of Freeway Weaving Sections
  - Project 3-92: Production of the 2010 Highway Capacity Manual
- Reviewing the HCM to identify any minimum ramp or interchange spacing values or other thresholds dictated by traffic operations considerations.
- Collecting field data and conducting simulation modelling

The project team's review of data from previous NCHRP projects revealed little about the impact of ramp spacing or interchange spacing on mainline freeway speed. It did, however, help to reaffirm the project team's assertion that ramp spacing has a greater effect on traffic operation and interchange spacing.

Reviewing the HCM produced planning-level guidance, although only for a fairly specific situation: identifying minimum spacing values needed to achieve a desired level of service between and entry ramp and an exit ramp on six-lane freeways.

Collecting field data and conducting simulation modeling formed the largest component of the traffic operations work plan. Collected data included lane-by-lane speed and volume data at an entry-exit (without auxiliary lane) ramp combination and an entry-entry ramp combination in Phoenix, Arizona. The data was collected using side-mounted digital wave radar and video cameras. Data collection site features included modern design elements, variations in traffic volume, vantage points for cameras, and the availability of supplemental data from Arizona Department of Transportation sensors. Data at each site was collected from 2 p.m. to 6 p.m. to capture off-peak and peak conditions.

The project team constructed a calibrated VISSIM mode of each data collection site. The team then varied traffic volume and the distance between the ramps to assess the impact of ramp spacing on mainline freeway operating speed. The project team modeled combinations of the following scenarios:

- Mainline freeway volumes of 1250, 1500, and 1750 vehicles per hour per lane (vphpl)
- Ramp volumes of 750, 1250, and 1750 vehicles per hour
- Short (700' for entry-entry and 1000' for entry-exit) and long (2500' for both ramp combinations) ramp spacing dimensions

The models provided speed estimates at five different locations: at the painted merging and diverging tips and at three locations in between.

Model results of the entry-entry ramp combination indicated that ramp spacing has an impact on mainline freeway speeds except at high (1750 vphpl) mainline volume. Model results of the entry-exit ramp combination indicated that ramp spacing has an impact on mainline freeway speeds except at moderate to high (1500+ vphpl) mainline volume.

For the entry-exit ramp combination, the project team conducted a second set of model runs with an auxiliary lane between the ramps. Model results indicated that the benefits (in terms of mainline freeway speed) of an auxiliary lane were greatest with shorter ramp spacing and higher mainline and exiting volume.

1.3.2 Safety Work Plan

The safety work plan focused on examining the impact of ramp spacing on crash frequency, type, and severity. This analysis was performed by examining 650 directional miles of freeway in Washington State using crash data from the Highway Safety Information Service (HSIS), interchange diagrams, and aerial photography. The project team concluded that that many previous studies of ramp spacing were limited by the accuracy and quality of the datasets. For this project, the project team placed an emphasis on including detailed geometric and volume data for all interchanges.

The project team initially sought to develop safety performance functions and accident modification factors for all ramp combinations, but ultimately developed them for only entry-exit ramps and entry-entry ramps. The sample size of exit-exit ramps was not sufficient for performing analysis. Exit-entrance ramps were generally part of the same interchange, and the project team concluded there was limited value in analyzing such ramps.

Analysis results for entry-exit ramp combinations found that ramp spacing has a negligible impact on crash frequency at spacing values greater than 2600 feet. Below this dimension, crash frequency increases with increasing sensitivity as ramp spacing decreases. Crash severity was also found to increase as ramp spacing decreased. Introducing an auxiliary lane between the ramps was found to reduce crashes by approximately 20 percent.

Analysis results for entry-entry ramps produced similar findings. Ramp spacing was found to have a negligible impact on crash frequency at spacing values greater than 2200 feet. As ramp spacing decreased from this value, increases in total and severe crashes occurred. For entry-entry analysis, the team supplemented Washington State data with California data to increase the sample size.

1.3.3 Guidelines

The *Guidelines*, published separately from this document, incorporate the findings of the information gathering activities in Phase I as well as work plan activities in Phase II. The *Guidelines* are intended to assist users as they consider new or modified ramps and interchanges. The following summarizes the general content of each *Guidelines* chapter:

- Chapter 1 defines ramp and interchange spacing

- Chapter 2 presents relevant federal, state, and local policies.
- Chapter 3 discusses elements of geometric design and freeway signing relevant to ramp and interchange spacing
- Chapter 4 discusses traffic operations and safety considerations for ramp and interchange spacing
- Chapter 5 presents ranges of recommended ramp and interchange spacing dimensions
- Chapter 6 presents five scenario-based case studies that apply the principles presented in the preceding chapters
- The Appendix presents tools and findings developed as part of the operations work plan

1.3.4 Resource Document Revisions

Based upon the findings of this project, the project team revisited relevant sections of the AASHTO Green Book, HCM, MUTCD, and HSM to determine if changes should be made. The project team concludes that no changes should be made the HCM or the MUTCD. The HSM does not contain quantitative information related to ramp and interchange spacing. However, the models and findings of NCHRP 3-88 will be directly relevant to future updates of the HSM. The safety performance functions and crash modification factors developed here could be combined with additional research to form the basis of a greatly expanded HSM chapter on the subject.

The project team recommends changes to the interchange spacing and ramp spacing guidance in Chapter 10 of the 2004 AASHTO Green Book. For interchange spacing, the team recommends including a table developed as part of NCHRP 3-88. The table provides ranges of interchange spacing dimensions that are "likely not geometrically feasible", "potentially geometrically feasible", "likely geometrically feasible" for different interchange forms. For ramp spacing, the team recommends replacing Exhibit 10-68 with a ranges of ramp spacing dimensions that are "likely not geometrically feasible", "potentially geometrically feasible", "likely geometrically feasible" for each ramp combination.

Chapter 2
Information Gathering

Chapter 2 INFORMATION GATHERING

The project team collected information to identify the origins of the current design standards and practice for ramp and interchange spacing and to determine how various spacing and interchange configurations can impact a facility's safety and operations. The primary information gathering activities that the project team completed include:

- Conducting and summarizing domestic and international research on ramp and interchange spacing, operations, and safety;
- Reviewing and summarizing human factors considerations, such as sign sequencing and message units; a review of sample information from five state agency freeway signing handbooks; and a summary of the underlying philosophy for providing guidance information and driver information processing;
- Summarizing design vehicle evolution, such as documenting changes in passenger car performance characteristics (i.e., acceleration, braking, transmission type, etc.) and design vehicles (i.e., weight-to-horsepower ratios and various tractor-trailer combinations);
- Identifying and summarizing the various terms and design elements associated with ramp and interchange spacing described in various planning, operations, and design documents used in common practice today;
- Conducting a focus group meeting consisting of planners, designers, and operators of freeways and interchanges and other interested parties to assist in identifying concerns or needs in the current practice of ramp and interchange spacing;
- Requesting input from the NCHRP 3-88 panel to collaborate and generate ideas for the work plan and guidelines development; and,
- Assessing existing datasets from recent and ongoing NCHRP projects on highway capacity and operations.

The following sections provide a summary of findings from these activities.

2.1 LITERATURE REVIEW

2.1.1 General Literature

In the early days of the Interstate Highway system, a number of studies offered general guidelines for interchange and ramp spacing values. *Interchange* spacing values were often expressed in terms of the centerline distance between crossroads. *Ramp* spacing studies were often focused on urban cores where conventional interchange forms were often not used.

In 1957, Owens of the Automotive Safety Foundation stated that "one mile between interchanges is a desirable minimum with one-half mile an absolute minimum" (1). For purposes of estimating the cost of the Interstate Highway System, a guide by the Bureau of Public Roads (BPR) identified general considerations for interchange spacing:

> "It is important that interchanges be located so as to properly discharge and receive traffic from other Interstate and Federal-aid system routes or major arterial highways or streets. It is equally important that they not be spaced so closely as either to unnecessarily increase the cost of the System or interfere with the free flow and safety of traffic on the Interstate System" (2).

In practice, the BPR report noted that interchange spacing of 1 to 2 miles "appear to be the evolving pattern" in areas just outside of the central business district, with an increase to "about 2 to 4 miles in suburban outlying areas" (2). In downtown areas, the study assumed spacing would be as close as physically possible.

In 1959, Jack Leisch offered interchange and ramp spacing guidance, beginning with the importance of the issue:

> "Widely spaced interchanges do not provide the needed service or develop the potential use of the facility. Too many interchanges, on the other hand, result in friction, inefficiency, and loss of speed and capacity (3)."

To determine the "right" spacing of interchanges on urban freeways, Leisch considered city size, area type, street pattern, geometric features, and operational characteristics and presented some general considerations:

- Large commercial and industrial areas require more interchanges than less developed areas.
- Cities with an irregular street pattern also tend to require more interchanges than cities with a grid.
- The distance between a direction interchange and a "regular" interchange should be greater than the distance between two regular interchanges.

Leisch acknowledged signing needs as a "definite consideration" in the spacing of interchanges but did not incorporate them directly into his spacing guidelines.

Leisch considered the "maneuver and weaving length" between an entrance ramp and exit ramp to be the basis of "absolute minimum spacing." By assuming ramp lengths, the spacing values were presented as a measure of crossroad centerline to crossroad centerline. Exhibit 2-1 shows that the absolute minimum spacing was 1,800 feet, the normal minimum spacing was 2,600 feet, and the preferable minimum spacing was 4,200 feet.

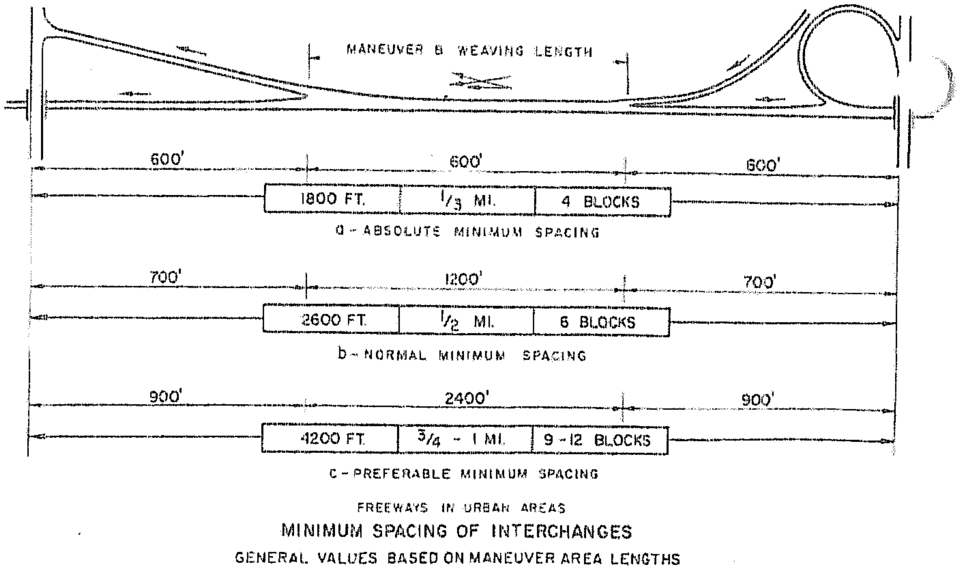
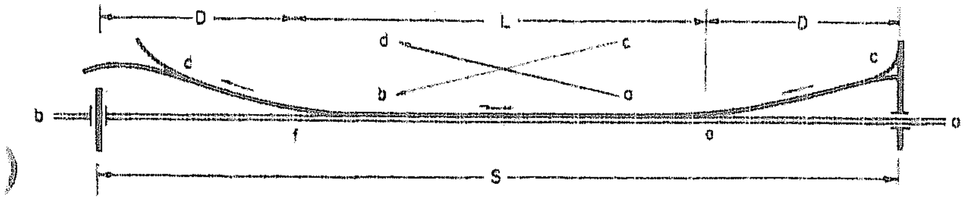


Exhibit 2-1 General Interchange Spacing Recommendations by J.E. Leisch, 1959 (3)

To account for the effects of volume on weaving operation, Leisch presented a table, shown in Exhibit 2-2, which was more appropriate for use in ramp and interchange design if the level of required information was available. The "low limit," or minimum spacing, maintained a 35 mile per hour (mph) free flow speed on the freeway.



LIMITS OF SPACING	$(W_1 + W_2)$ weaving volume vph	D length allowed for each ramp feet	L* length of weaving section feet	S interchange spacing feet
LOW LIMIT (minimum)	1000 1500 2000 2500	650 850 1000 1100	500 900 1400 2000	1800 2600 3400 4200
HIGH LIMIT (desirable)	1000 1500 2000 2500	850 1000 1000 1000	2300 4000 6000 8000	4200 6000 8000 10,000

*From AASHO Policy on Arterial Highways in Urban Areas, 1957:
Minimum based on relations for 35 mph average running speed, p. 492;
Desirable based on distances at which traffic maneuvers pass out of realm of weaving, p. 493.

FREEWAYS IN URBAN AREAS
LIMITS OF INTERCHANGE SPACING
BASED ON WEAVING MANEUVERS

Exhibit 2-2 Specific Interchange Spacing Recommendations by J. E. Leisch, 1959 (3)

Leisch noted some areas, such as central business districts, had such great traffic demand that more ramps than the number allowed by spacing guidelines, shown in Exhibits 2-1 and 2-2, might be needed. Leisch presented several strategies of dealing with this, shown below in Exhibit 2-3.

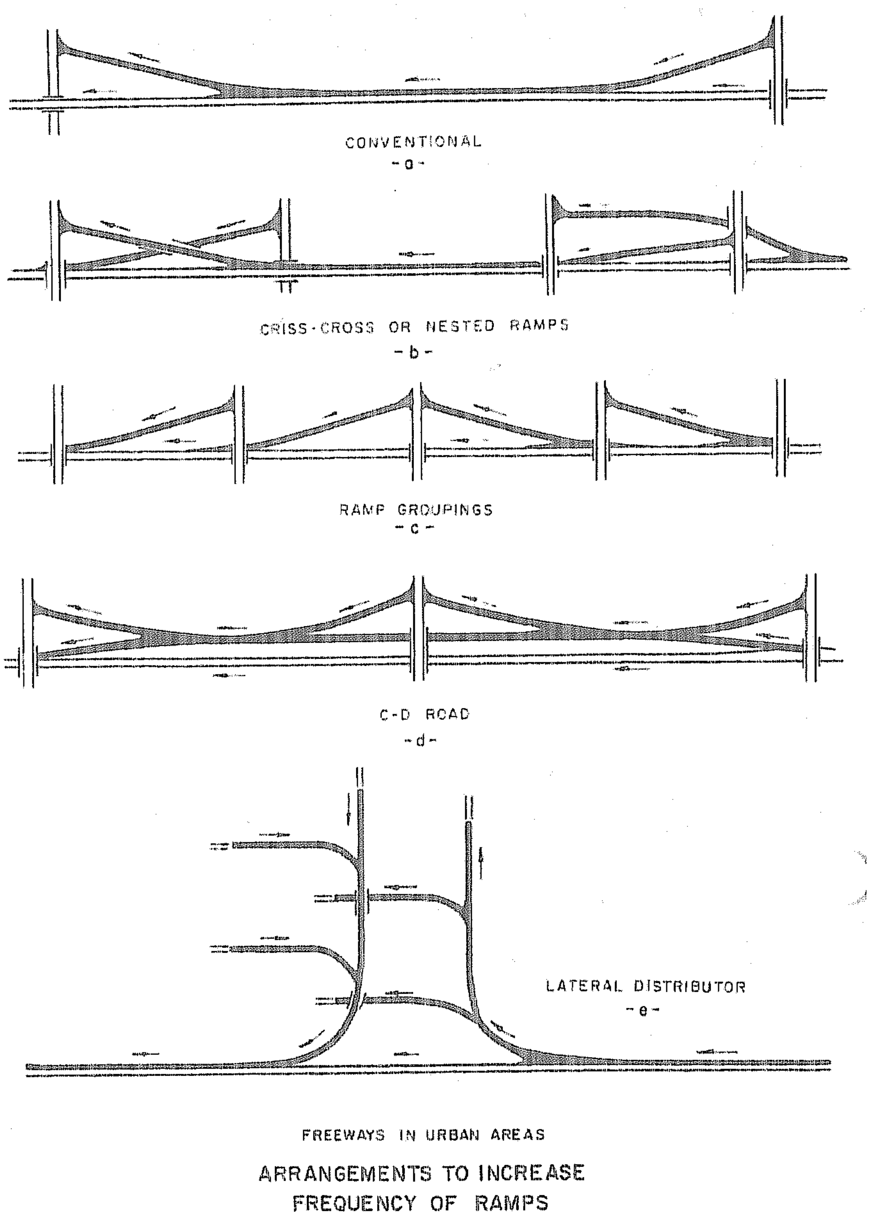


Exhibit 2-3 Methods of Increasing the Number of Ramps by J.E. Leisch, 1959 (3)

Leisch also approximated the increase in the number of ramps that could be achieved with the configurations above. He noted the use of criss-cross ramps, now often referred to as braided ramps, could permit 1.2 times as many ramps per mile as a conventional design would. Ramp groupings, or collector-distributor roads (C-D roads), could permit 1.3 times as many ramps per mile. Lateral distributors might permit twice as many ramps per mile as conventional design. In addition to non-conventional ramp configurations, Leisch suggested building parallel or feeder freeway facilities traffic where volumes would be high enough to justify doing so.

Over the years, guidelines from these early studies and others have been incorporated into various versions of policy by the American Association of State Highway and Transportation Officials (AASHTO) and the American Association of State Highway Officials (AASHO), AASHTO's previous name. In addition, some states have their own spacing policies, such as many states use have a 1 mile minimum crossroad-to-crossroad interchange spacing guideline for urban areas and a 2 or 3 mile minimum spacing guideline for rural areas. Since 1984, editions of AASHTO's *A Policy on Geometric Design of Highways and Streets,* commonly referred to as the AASHTO Green Book, have stated that "a general rule of thumb for minimum interchange spacing is 1.5 km [1 mi] in urban areas and 3.0 km [2 mi] in rural areas" (4-8).

2.1.1.1 COMPONENTS OF INTERCHANGE SPACING

The Institute of Transportation Engineers' (ITE) *Freeway and Interchange Geometric Design Handbook* (ITE Freeway Handbook) declares that the 1 mile urban spacing minimum is arbitrary to a certain extent (9). The ITE Freeway Handbook presents a rational for the interchange spacing values based upon the geometric requirements of different interchange components, as shown in Exhibit 2-4. The crossroad-to-crossroad spacing value resulting from this approach is approximately 1 mile, which is the commonly used minimum interchange spacing guideline for urban areas.

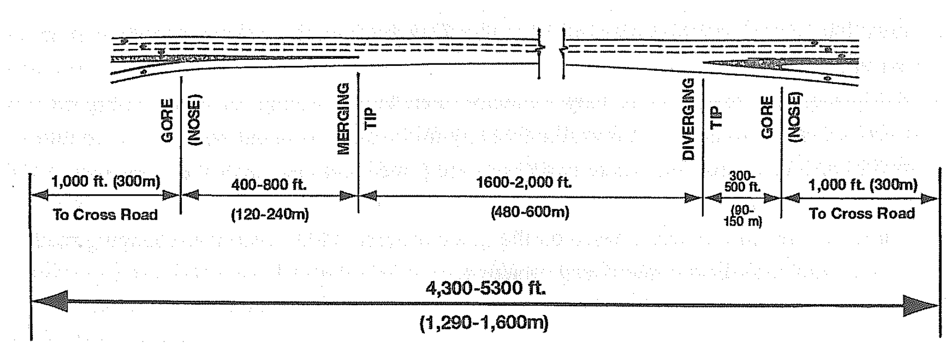


Exhibit 2-4 Interchange Spacing – Urban Areas, ITE Freeway Handbook (9)

The ITE Freeway Handbook notes that it takes approximately 1,000 feet to reach the gore of the entrance ramp from the crossroad. This length accommodates grade changes, acceleration, and queues from ramp meters, if they exist. The distance from the entrance gore to the merging tip varies based on entrance type (taper or parallel) and the curve of the ramp, but it is generally between 400 and 800 feet. The minimum distance between the merge tip and diverge tip (painted gores) is 1,600 feet if both interchanges are service interchanges and 2,000 feet if one interchange is a system interchange; AASHTO Policy is cited as the basis of this measurement.

Similar to AASHTO, the ITE Freeway Handbook acknowledges that required weaving distances, as outlined in the 2000 *Highway Capacity Manual* (HCM), may be longer than 1,600 to 2,000 feet. If this is the case, the ITE Freeway Handbook notes the HCM weaving distances should be used as the basis of minimum ramp spacing. Between the diverging tip and the exit gore, a distance of 300 to 500 feet is needed depending on exit design (taper or parallel). Finally, another 1,000 feet between the exit gore and the centerline of the next crossroad is needed to accommodate the exit ramp. These distances sum to a length of 4,300 to 5,300 feet or approximately 1 mile.

The ITE Freeway Handbook cautions that 1 mile spacing in urban areas "is a reasonable minimum guide [but] should not be policy" (9). Geometric considerations, such as ramp profile requirements or the presence of turning roadways, and operational considerations, such as weaving, multilane ramps requiring lane drops, or queue storage, are noted by the ITE Freeway Handbook as factors that may require the dimensions in Exhibit 2-1 to increase. This would result in centerline-to-centerline spacing values of more than 1 mile. In cases where interchange spacing of *less* than 1 mile may be needed, the ITE Freeway Handbook states that C-D roads, ramp braids, and frontage roads with split interchanges should be employed.

In rural areas, the ITE Freeway Handbook states that a "5-mile minimum spacing is generally appropriate…to prevent every local or secondary road from interchanging with the freeway" (9). Once again, the ITE Freeway Handbook states that this distance is only a guide and can change for specific situations. For close rural spacing, the ITE Freeway Handbook suggests use of the same unconventional interchange forms noted in the section on close urban spacing.

2.1.1.2 INTERCHANGE COMPONENT LENGTHS

A number of studies have examined one or more of the spacing values shown in Exhibit 2-4. This literature review is not intended to be an exhaustive summary of all research that has been conducted on ramp length, merging and diverging areas, or weaving. Instead, it is intended to provide an overview of common factors that have historically influenced interchange and ramp spacing values. Understanding the functionality of ramp components may assist in considering entrance and exit ramp geometric design event points that could form the basis for defining interchange and ramp spacing dimensions.

In the 1960s, Fukutome and Moskowitz found that vehicles entering a freeway under low volume conditions on both the ramp and mainline use as much or even more merging distance than under high volume conditions (10). The study implied that even if a ramp is designed for high speed and is located in an area where volumes will always be low, it should still be designed with a long merging section. For diverging sections, Fukutome and Moskowitz noted past research, which found that many drivers did not use a deceleration lane when one was provided prior to the exit gore and behaved as if the ramp were of a taper design (11). Fukutome and Moskowitz felt this justified allowing more flexibility in the length of a diverge section than in a merge section, as drivers seemed more willing to shorten a diverge compared to a merge.

Weaving has long been recognized as a consideration when determining the spacing of ramps and was acknowledged in AASHO's 1954 *Policy on Geometric Design of Rural Highways* (commonly referred to as the Blue Book) and the 1950 HCM (12, 13). Currently, the 2004 AASHTO Green Book provides Exhibit 10-68, which specifies minimum ramp spacing for several different combinations of ramp types (8). In addition to using AASHTO's Exhbit 10-68, the 2004 Green Book also recommends conducting HCM weaving calculations and using the longer of the two distances to determine ramp spacing in a specific situation. In the 2000 HCM, minimum weaving lengths were primarily a function of weave type, volume, and free-flow speed (14). NCHRP 3-75, conducted by Polytechnic University, revisited the weaving analysis procedures of the HCM, and the results were incorporated into the 2010 HCM. A later section of this report provides more information on the history of the ramp spacing and weaving in AASHTO Policies and the HCM.

2.1.1.3 IMPACTS OF SPACING ON FREEWAY AND ROAD NETWORK OPERATIONS

Close spacing of ramps and interchanges can also have an effect on freeway operations as a whole, not just operations in isolated weaving areas. Additionally, ramp and interchange spacing impacts traffic conditions apart from freeways on arterials and other components of the road network.

In 1958, Morawski studied lane distribution on a section of the New York Thruway with three lanes in each direction (1). The distribution of vehicles in the three lanes at a point one mile beyond an entrance ramp was similar to lane distribution at points 2, 3, and 10 miles beyond the entrance ramp. Morawski concluded that the "influence area" of an on-ramp extends less than 1 mile beyond the end of the ramp and noted that his findings were similar to a study done on the New Jersey turnpike. Martin et al's 1973 study noted that it could be possible to reduce the amount of lane imbalance and turbulence that occurs in the first place by creating two low volume ramps instead of one high volume ramp (15). Martin et al noted this would work best if two off-ramps or two on-ramps could be placed consecutively to avoid any weaving problems.

Three studies conducted in the 1960s examined the impact of ramp and interchange spacing on freeway operations. Studies in Atlanta and Detroit were conducted with field observations, and a third study was conducted with a travel demand model calibrated with data from Chicago. The Atlanta and Chicago studies included analysis of the impacts of interchange spacing on arterial operations and the road network as a whole. A summary of each is provided below.

2.1.1.3.1 Atlanta study (16)

In 1963, Covault and Roberts studied the Atlanta freeway that is now part of I-75/85 and known as the downtown connector. Their study area began in downtown Atlanta at Williams Street and ran north to where the freeway divides into what is now I-75 and I-85. This segment of freeway is approximately two miles long and had four on-ramps, three-off ramps, and the diverge of the two freeways at the northern end. The freeway had three lanes in each direction, and only the northbound direction of the freeway was studied. This study varied the spacing of on-ramps by closing ramps during the p.m. peak hour, when traffic would be heaviest on this segment. The highest volume on the freeway occurred when all ramps were open, and the closure of any of the ramps resulted in "smoother" and more desirable flow on the freeway. However, closing any of the ramps resulted in higher traffic volumes on surrounding arterials. The study identified one benefit to the arterial network when a ramp was closed: the elimination of a conflict point at the ramp terminal intersection.

The authors suggested closing the 14th Street ramp during the p.m. peak period. This ramp was closest to where the freeway divides and where weaving was most intense. During the study, closing this ramp resulted in a significantly lower travel time on the freeway than any other scenario but also in a higher overall system travel time than any other scenario.

2.1.1.3.2 Detroit study (17)

Forbes, Mullin, and Simpson studied three sections of the Lodge Freeway in Detroit in 1965. The sections did not have common endpoints and there were unstudied areas between the study sections. Each section was analyzed in both directions, resulting in six segments of study. Generally, the segments ended at a full interchange and had a partial interchange within them. Ramp spacing within the six study segments varied from 1,200 to 3,350 feet. It is unclear what the endpoints of these measurements were.

Two successive on-ramps were found to interfere with traffic flow more than two successive off-ramps or an on-ramp and an off-ramp spaced at nearly the same distance apart. Two of the six segments had two on-ramps, and one of these segments experienced the lowest average velocity and highest number of stops for mainline vehicles. The authors found that operations were improved on some segments due to ramp congestion that effectively metered the flow of entering vehicles. In fact, the segment with the closest spacing of consecutive on-ramps performed better than a segment where the on-ramps were spaced further apart due to this phenomenon. Weaving, even with high volumes, did not necessarily result in a high number of vehicle stoppages or low average speeds.

The findings of this study that are relevant to NCHRP 3-88 include the operational conditions posed by closely spaced on-ramps and the benefits of metered on-ramp flow. The authors did not provide any minimum or desirable spacing values based upon the results of their study

2.1.1.3.3 Chicago study (2)

In 1967, Satterly and Berry constructed an 8-mile by 8-mile model consisting of 430 links and 2,500 nodes, including entry nodes. Freeways were spaced 4 miles apart, resulting in one system interchange in the middle of the network and others along the edge. Arterials were spaced ¼ mile apart, with one of every four arterials (1 mile spacing) being major. Freeway spacing was determined based on other research identified by the authors, and arterial spacing was based on the existing road networks of Chicago and Detroit.

Travel data collected from two 8-mile by 8-mile squares of Chicago in 1956 were used as the input of the model. One of the squares had a density of 21,000 people per mile, and the other had a density of 8,300 people per mile. The authors chose Chicago in part because it has a grid road system similar to the one that was modeled.

The authors examined both interchange spacing and grade separation spacing. Grade separations are where arterials cross a freeway without an interchange; the alternative to this or an interchange is terminating the arterial on either side of the freeway. Interchange spacings of ½, 1, 2, and 4 miles and grade separation spacings of ¼, ½, 1, and 2 miles were studied.

The metric used to determine optimal spacing was "annual transportation cost." This cost included right-of-way purchases (where the model determined widening would be necessary), construction cost, and user costs, such as vehicle operation, accidents, and time. Costs were established for accidents and travel time based on other studies. The authors considered including land use impacts, community benefits and property values, maintenance costs, and comfort and convenience costs to users in the model but did not due to a lack of information about these factors. The minimum time path was used for route assignment.

The authors found in their preliminary model runs that 4-mile interchange spacing was not feasible in the high density model because arterial volumes became extremely high. Even with 2-mile interchange spacing, the major (1 mile apart) arterials needed 8 lanes in the high density model. With both density scenarios, increasing interchange spacing from one-half to 1 mile increased total vehicle miles traveled (VMT) in the system. Increasing spacing from 1 to 2 miles decreased VMT, and increasing spacing from 2 miles to 4 miles increased VMT. The lowest VMT was observed with 2 mile interchange spacing. This spacing encouraged drivers to choose more direct arterials when travelling instead of the freeways. Volumes on arterials with an interchange increased with 2-mile interchange spacing compared to 1 mile or one-half-mile spacing.

The analysis of annual transportation cost found that in the high density area, optimum spacing of interchanges was 1 mile and optimum spacing of grade separations was one-half mile. For the low density area, optimum spacing of interchanges was 2 miles and optimum spacing of grade separations was one-half or 1 mile.

However, the annual transportation cost differences between the scenarios were so small – generally 2 to 4 percent – that the authors recommend it not be used to determine interchange spacing. Instead, they suggested the following criteria: "(a) the characteristics of traffic operations on the system, (b) the amount of land required for the transportation facilities which must be removed from the taxable base of the community, (c) the reorganization of land use patterns due to the spacing of interchanges, and (d) convenience to the people of the community" (2).

2.1.1.4 GENERAL LITERATURE SUMMARY

In the early days of the Interstate Era, a number of studies examined the spacing of ramps and interchanges, primarily on urban freeways. These studies generally defined spacing as the distance between the centerlines of successive crossroads that have interchanges, although some studies that were focused on weaving defined spacing as the distance between the ends of ramps. Exit signing requirements were not noted by the majority of studies identified here and do not appear to have played a prominent role in spacing guideline development.

Studies that examined the road network as a whole noted a tradeoff between freeway operations and arterial operations. Maximizing the number of ramps and interchanges results in poor freeway operation but removes the greatest amount of traffic from surrounding arterials. Likewise, reducing the number of ramps and interchanges and spacing them further apart results in better freeway operation but may create congestion on arterials.

Both Owings and Leisch independently recommended a "desirable" or "preferred" 1 mile minimum centerline to centerline spacing. Satterly and Berry found 1 mile spacing to be optimal in a high density area. Morowski's study suggests 1 mile spacing is acceptable. These studies may have played a role in determining the 1 mile crossroad-to-crossroad urban interchange spacing guideline used by many states and found in the AASHTO Green Book since 1984. Rural interchange spacing and rural case studies are not as prominent in the literature. Ramp terminal spacing studies have primarily considered weaving operations, either qualitatively or through analytical procedures that were developed at the time. Today, the methodology of the 2000 HCM is the most common means of analyzing weaving sections, and revisions to this methodology may be incorporated in the 2010 HCM.

2.1.2 Primary Resource Documents

The AASHTO Green Book and the HCM are two commonly used resources for freeway and interchange planning and design. The AASHTO Green Book recommends minimum interchange spacing dimensions, and the HCM quantifies the impact of interchange spacing on traffic operations. In addition, The Freeway and Interchange Geometric Design Handbook (ITE Freeway Handbook) published by the Institute of Transportation Engineers (ITE) and TRB's Access Management Manual provide planning and design guidance related to interchange and ramp spacing. Summaries of these documents are discussed in the following section.

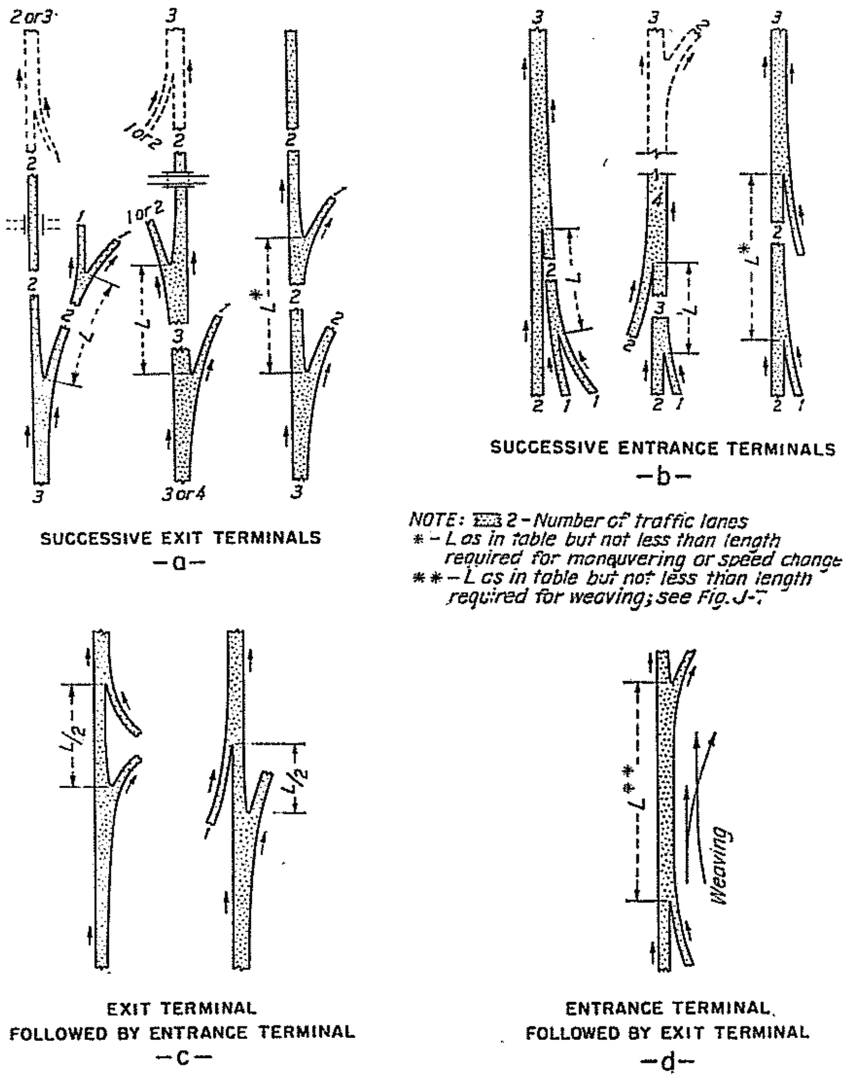
2.1.2.1 AASHTO POLICIES

The 2004 AASHTO Green Book provides recommended minimum ramp and interchange spacing dimensions. Historically, the American Association of State Highway Officials (AASHO), the previous name of AASHTO, first addressed ramp spacing considerations in a 1944 Policy. Subsequent publications including A Policy on Geometric Design of Rural Highways (commonly referred to as the Blue Book) and A Policy on Geometric Design of Urban Highways and Arterial Streets (commonly referred to as the Red Book), both of which were the precursors to the 1984 Green Book, have addressed ramp and interchange spacing dimensions. AASHTO also publishes A Policy on Design Standards Interstate System, a document specifically for design of the Interstate Highways.

2.1.2.1.1 Ramp Spacing

The first AASHO publication to address ramp sequence was *A Policy on Grade Separations for Intersecting Highways* in 1944 (18). No dimensions were given; however, the document presented examples of an entrance followed by an exit and an exit followed by an entrance ramp combinations. The use of an auxiliary lane for an entrance followed by an exit was suggested for the first time in this document.

The 1954 Blue Book was the first AASHO publication to recommend that weaving analyses be conducted to determine the spacing distance between an entrance ramp and an exit ramp (12). The analysis could be done with the 1950 HCM. AASHO's 1957 Red Book provided diagrams of various ramp combinations and presented guidelines for minimum and desirable spacing between them (19). This diagram is shown below in Exhibit 2-5. The distances were measured "between successive approach noses or merging ends." Minimum distances were based upon combined response and maneuver times of 5 to 6 seconds, and desirable distances were based on a combined response and maneuver time of 7 seconds. Response time consisted of the time necessary for a driver to "observe, comprehend, and respond to a sign or to some other guide", and maneuver time consisted of the time necessary for a driver to shift one lane.



DISTANCE BETWEEN SUCCESSIVE RAMP TERMINALS

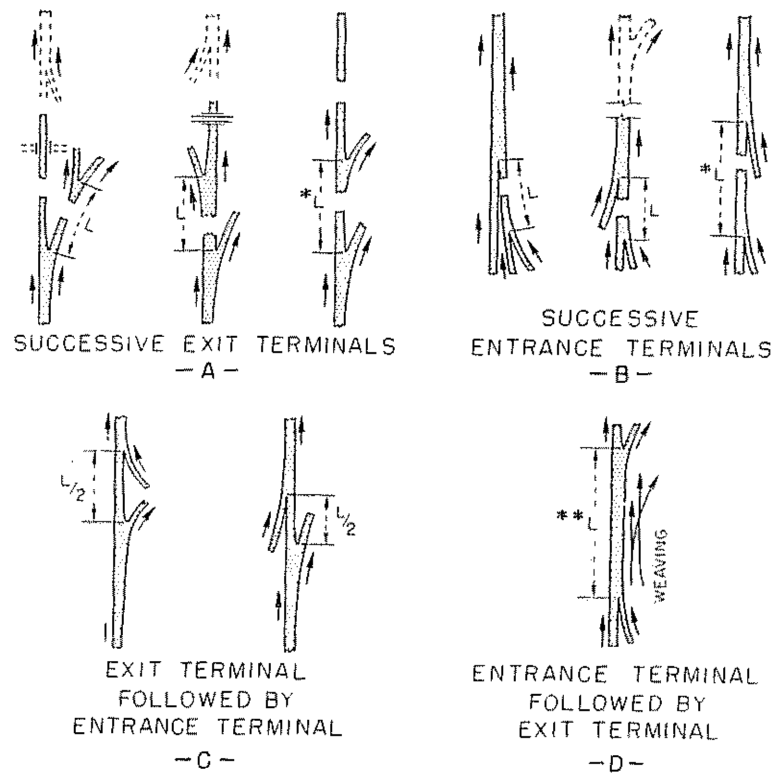
Design speed, mph.	30 or less	40 to 50	60 or more
Av. running speed, mph.	20 to 25	35 to 40	45 to 50
Distance L - feet			
Minimum	175	300	400
Desirable	300	450	600

ARRANGEMENTS FOR SUCCESSIVE RAMP TERMINALS

Figure J-5

Exhibit 2-5 Ramp Terminal Spacing Guidelines, AASHO Red Book (1957) (19)

The 1965 Blue Book provided diagrams similar to those in the 1957 Red Book, but with longer minimum and desirable distances between ramp terminals. This diagram is shown in Exhibit 2-6 (20). The distances were based on a decision and maneuver time as they had been in the 1954 Blue Book, the time was changed from 5 to 8 seconds to 5 to 10 seconds and 80 mile per hour design speed category was added to the table. The document also noted that, for consecutive exits, the minimum spacing for adequate signing is 1,000 feet on a full freeway and 600 feet between an exit on a full freeway and an exit on a C-D road. The minimum spacing dimensions in Exhibit 2-6 do not appear to account for this signing requirement.



* L as in table but not less than length required for maneuvering or speed change as shown in Table VII - 10

** L as in table but not less than length required for weaving; see fig. IX-16 or IX-17

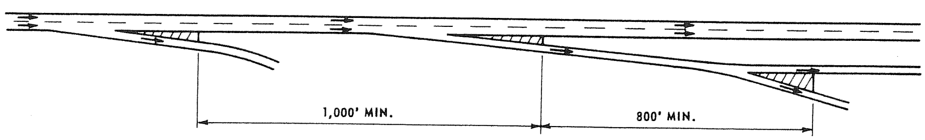
DISTANCE BETWEEN SUCCESSIVE RAMP TERMINALS

Design speed, mph	30 or less	40 to 50	60 or 70	80
Av. running speed, mph	23 to 28	36 to 44	52 to 58	64
Distance L - Feet				
Minimum	200	400	500	900
Desirable	400	700	900	1200

ARRANGEMENTS FOR SUCCESSIVE RAMP TERMINALS
FIGURE IX - 11

Exhibit 2-6 Ramp Terminal Spacing Guidelines, AASHO Blue Book (1965) (20)

The 1973 Red Book recommended a minimum of 1,000 feet between successive exits on a full freeway and 800 feet between an exit on a full freeway and an exit on a collector-distributor road, as shown in Exhibit 2-7 (21). This full freeway spacing dimension exceeded the spacing dimension for the same exit arrangement in the 1965 Blue Book, and this full freeway to collector-distributor spacing dimension exceeded the spacing dimensions in the 1965 Blue Book for all but an 80 mph design speed. The 1973 Red Book ramp spacing guidelines also met or exceeded the minimum requirements based on signing that where presented in the 1965 Blue Book. The 1973 Red Book also included tables of minimum acceleration and deceleration lane lengths. The maximum acceleration lane length listed was 1,590 feet, while the maximum deceleration lane length was only 615 feet.

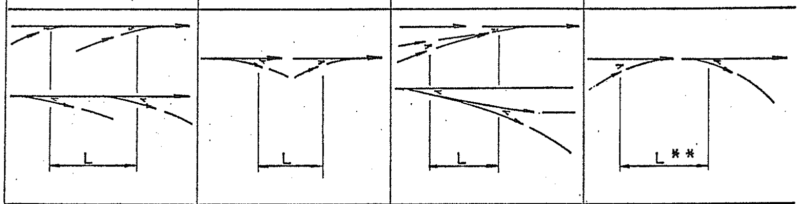


SUCCESSIVE EXIT TERMINALS
Figure J-30

Exhibit 2-7 Minimum Spacing Between Successive Exit Terminals, AASHO Red Book (1973) (21)

In 1975, Jack E. Leisch presented a paper to the Region 2 AASHTO Operating Committee on Design in Mobile, Alabama, that contained a table with "Recommended Minimum Ramp Terminal Spacing" for various combinations of ramps (22). The table included "desirable minimum," "adequate minimum," and "absolute minimum" spacing values, and is shown below in Exhibit 2-8. The "absolute minimum" values in Leisch's table were included in Figure X-67 of the 1984 Green Book and have been carried forward into all succeeding Green Books. Metric equivalents for Leisch's US Customary units appeared in the 1994 edition. Currently, these values appear in Exhibit 10-68 of the 2004 AASHTO Green Book, which is depicted below in Exhibit 2-9. The table contains a footnote that states the distances between the ramp terminals are to "provide sufficient weaving length and adequate space for signing."

RECOMMENDED MINIMUM · RAMP TERMINAL SPACING *



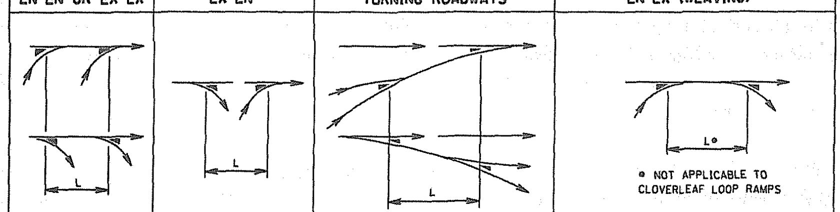
MINIMUM VALUES	EN–EN OR EX–EX: FULL FREEWAY	EN–EN OR EX–EX: C-D ROAD OR FWY. DIST.	EX–EN: FULL FREEWAY	EX–EN: C-D ROAD OR FWY. DIST.	TURNING ROADWAYS: SYSTEM INTERCHANGE	TURNING ROADWAYS: SERVICE INTERCHANGE	EN–EX (WEAVING): SYSTEM TO SERVICE INTERCHANGE: FULL FWY	EN–EX (WEAVING): SYSTEM TO SERVICE INTERCHANGE: C-D ROAD OR FWY DIST.	EN–EX (WEAVING): SERVICE TO SERVICE INTERCHANGE: FULL FWY	EN–EX (WEAVING): SERVICE TO SERVICE INTERCHANGE: C-D ROAD OR FWY DIST
DESIRABLE	1500	1200	750	600	1200	1000	3000	2000	2000	1500
ADEQUATE	1200	1000	600	500	1000	800	2500	1800	1800	1200
ABSOLUTE	1000	800	500	400	800	600	2000	1500	1500	1000

FIGURE 27

* BASED UPON OPERATIONAL EXPERIENCE AND NEED FOR FLEXIBILITY

**ALSO TO BE CHECKED IN ACCORDANCE WITH PROCEDURE OUTLINED IN THE HIGHWAY CAPACITY MANUAL, 1965 (LARGER OF THE VALUES TO BE USED)

Exhibit 2-8 Minimum Ramp Terminal Spacing, J. E. Leisch, 1975 (22)



EN-EN OR EX-EX: FULL FREEWAY	EN-EN OR EX-EX: CDR OR FDR	EX-EN: FULL FREEWAY	EX-EN: CDR OR FDR	TURNING ROADWAYS: SYSTEM INTER-CHANGE	TURNING ROADWAYS: SERVICE INTER-CHANGE	EN-EX (WEAVING): SYSTEM TO SERVICE INTERCHANGE: FULL FWY.	EN-EX (WEAVING): SYSTEM TO SERVICE INTERCHANGE: CDR OR FDR	EN-EX (WEAVING): SERVICE TO SERVICE INTERCHANGE: FULL FWY.	EN-EX (WEAVING): SERVICE TO SERVICE INTERCHANGE: CDR OR FDR
MINIMUM LENGTHS MEASURED BETWEEN SUCCESSIVE RAMP TERMINALS									
300 m [1000 ft]	240 m [800 ft]	150 m [500 ft]	120 m [400 ft]	240 m [800 ft]	180 m [600 ft]	600 m [2000 ft]	480 m [1600 ft]	480 m [1600 ft]	300 m [1000 ft]

NOTES: FDR - FREEWAY DISTRIBUTOR ROAD; CDR - COLLECTOR DISTRIBUTOR ROAD; EN - ENTRANCE; EX - EXIT

THE RECOMMENDATIONS ARE BASED ON OPERATIONAL EXPERIENCE AND NEED FOR FLEXIBILITY AND ADEQUATE SIGNING. THEY SHOULD BE CHECKED IN ACCORDANCE WITH THE PROCEDURE OUTLINED IN THE HIGHWAY CAPACITY MANUAL (4) AND THE LARGER OF THE VALUES IS SUGGESTED FOR USE. ALSO, A PROCEDURE FOR MEASURING THE LENGTH OF THE WEAVING SECTION IS GIVEN IN CHAPTER 24 OF THE 2000 HIGHWAY CAPACITY MANUAL (4).
THE "L" DISTANCES NOTED IN THE FIGURES ABOVE ARE BETWEEN LIKE POINTS, NOT NECESSARILY "PHYSICAL" GORES.
A MINIMUM DISTANCE OF 90 m [270 ft] IS RECOMMENDED BETWEEN THE END OF THE TAPER FOR THE FIRST ON RAMP AND THE THEROETICAL GORE FOR THE SUCCEDING ON RAMP FOR THE EN-EN (SIMILIAR FOR EX-EN).

Exhibit 10-68. Recommended Minimum Ramp Terminal Spacing

Exhibit 2-9 Current AASHTO Policy on Minimum Ramp Terminal Spacing, AASHTO Green Book, 2004 (8)

AASHTO's Exhibit 10-68 notes that dimensions presented should be checked according to the procedures presented in the 2000 HCM. The exhibit also states that larger dimensions of the HCM and values of Exhibit 10-68 should be used as the basis of design.

2.1.2.1.2 Interchange Spacing

Interchange spacing guidance first appeared in the 1984 Green Book. The text has remained virtually the same in all Green Books since, including the 2004 Green Book, which states:

> "Minimum spacing of arterial interchanges (distance between intersecting streets with ramps) is determined by weaving volumes, ability to sign, signal progression, and lengths of speed-change lanes. A general rule of thumb for minimum interchange spacing is 1.5km (1 mi) in urban areas and 3.0km (2 mi) in rural areas." (8)

The statement implies that one mile spacing is for adjacent interchanges where there are ramps between the two (entrance from the upstream interchange followed by an exit to the downstream interchange).

2.1.2.1.3 Spacing on the Interstate Highway System

AASHTO's A Policy on Design Standards Interstate System (AASHTO Interstate Standards) presents standards specifically for the Interstate Highway System (23). The most recent version was published in 2005, and defines its role as follows:

> "All interstate highways shall meet the following minimum standards for segments constructed on new right-of-way and segments undergoing complete reconstruction along existing right-of-way. (23)"

Freeways built or added to the Interstate Highway System prior to 2005 are grandfathered in under the expectation that they meet standards that were in effect at the time of their construction and/or inclusion into the Interstate Highway System (23).

For interchanges, the AASHTO Interstate Standards note that spacing "has a significant effect on the operation of interstate highways" and "in areas of concentrated development, proper spacing may be difficult to obtain because of demand for frequent access (23)." The following spacing dimensions are offered:

> "As a rule, minimum spacing should be 1.5 km (1 mi) in urban areas and 5 km (3 mi) in rural areas, based on crossroad to crossroad spacing. In urban areas, spacing of less than 1.5 km (1 mi) may be developed by grade-separated ramps or by collector-distributor roads. (23)"

Similar to the AASHTO Green Book, separate spacing dimensions are provided for urban and rural areas, and the minimum urban spacing dimension is 1 mile. However, the AASHTO Interstate Standards call for 3-mile interchange spacing in rural areas, while the Green Book calls for only 2-mile interchange spacing in rural areas. The two documents are not in conflict with one another, because not all interchanges are on the Interstate Highway System.

2.1.2.1.4 AASHTO Summary

AASHTO policies on ramp and interchange spacing in the 2004 Green Book have not changed significantly since the first Green Book was published in 1984. In 1984, ramp spacing values for entrance-entrance, exit-exit, and entrance-exit ramp combinations were increased in comparison to the 1965 Blue Book, while ramp spacing values for exit-entrance and turning roadway ramp combinations remained similar in the 1965 Blue Book. Prior to 1965, ramp spacing dimensions were not quantified in AASHTO Policy. Interchange spacing values did not appear in AASHTO policies prior to 1984, when the current guideline of 1-mile spacing in urban areas and 2-mile spacing in rural areas was introduced. In addition to the Green Book, AASHTO also publishes a policy specifically for the interstate highway system which contains minimum interchange spacing dimensions.

2.1.2.2 HIGHWAY CAPACITY MANUAL

The Highway Research Board, now known as the Transportation Research Board (TRB), published the first edition of the HCM in 1950. This first edition addressed uninterrupted flow facilities, weaving sections, and ramps. Subsequent editions of the HCM in 1965, 1985, 1994, 1997, 2000, and 2010 have provided updated analysis procedures. Ramp and interchange spacing in the most recent edition of HCM is addressed in three chapters: analysis of basic freeway segments, weaving, and freeway merge and diverge segments.

2.1.2.2.1 Basic Freeway Segments

The 1965 edition of the HCM was the first to include the concept of level-of-service (LOS) (24). For freeways and other expressways, LOS was defined in terms of operating speed and volume. No method of calculating these numbers was provided, but they could be measured in the field. The 1985 HCM was the first to base basic freeway LOS explicitly on density, a measure of passenger cars per mile, per lane (25). Density was computed from flow rate and free-flow speed. If free-flow speed was not measured in the field, it could be estimated by assuming a base free-flow speed and making adjustments for a number of different factors. The 1994, 1997, 2000, and 2010 HCMs have used this same framework to calculate free-flow speed (26, 27, 14). In the 1997 and 2000 HCMs, interchange density was one of the factors in the calculation of free-flow speed (27).

In the 1997 and 2000 HCMs, interchange density was calculated over a 6-mile segment of freeway: 3 miles upstream and 3 miles downstream of the location being studied (14). An interchange was defined as having at least one on-ramp, so interchanges only having off-ramps are not included in the determination of interchange density. The base interchange density in the HCM was 0.50 interchanges per mile. With this density, no adjustment to base free-flow speed is made. With a density of two interchanges per mile, base free-flow speed was reduced by 7.5 miles per hour. Base free-flow speed adjustments were not specified for densities of more than 2.0 interchanges per mile.

In the 2010 HCM, total ramp density replaced interchange density in the equation used to calculate free-flow speed. Total ramp density is defined as the number of ramps per mile of a 6-mile segment of freeway: 3 miles upstream and 3 miles downstream of the location being studied (28). There is no assumed base density of ramps, so a reduction in FFS is always applied unless there are none over a six mile segment.

2.1.2.2.2 Weaving

The 1950 HCM defined weaving as "the act performed by a vehicle in moving obliquely from one lane to another, thus crossing the path of other vehicles moving in the same direction" (13). Observations summarized in the 1950 HCM, primarily from the freeway network near the Pentagon, identified that capacity of a weaving section decreased as weaving volume increased (13).

The 1965 HCM defined weaving as "the crossing of traffic streams moving in the same general direction, accomplished by successive merging and diverging"(24). The primary weaving model of the 1965 HCM was based upon weaving volume and weaving length. The curves accounted for weaving operational impacts with segments up to 8,000 feet in length. No other edition of the HCM has provided a weaving analysis procedure for a segment this long. Weaving length was measured "from a point at the merging end where the distance between the projected edges is 2 ft to a point at the diverge end where the distance between the edges is 12 ft" (13). This definition has been used, with modifications in wording but not dimensions, in all editions of the HCM since 1965.

The 1985 HCM defined weaving as "the crossing of two or more traffic streams travelling in the same general direction along a significant length of highway without the aid of traffic control devices (25). The 1985 HCM also noted that "Weaving areas are formed when a merge area is closely followed by a diverge area, or when an on-ramp is closely followed by an off-ramp and the two are joined by an auxiliary lane" (25). With minor modifications, both of these statements have been used in all editions of the HCM through 2000.

"Close" spacing was defined in the 1985 through 2000 HCMs as 2,500 feet or less between the ramps or the merging and diverging movements. This distance, shown in Exhibit 2-10, is measured "from a point at the merge gore where the right edge of the freeway shoulder lane and the left edge of the merging lane(s) are 2 ft apart to a point at the diverge gore where the two edges are 12 ft apart" (14). This definition was based on the geometry of loop ramps (28).

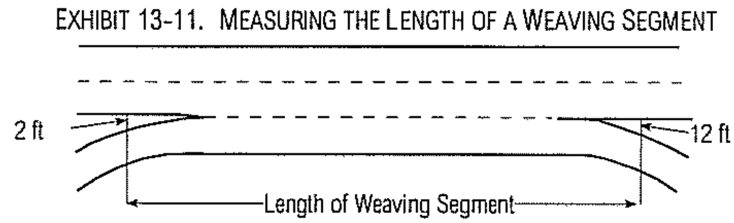


Exhibit 2-10 Definition of Weaving Segment Length, 1985 through 2000 HCMs (25, 26, 27, 14)

The weaving model of the 1985 HCM was based upon several research projects conducted in the early 1980s (25). LOS was based upon speed of weaving and non-weaving vehicles in the weaving segment, and length of the weaving segment is one of the inputs into the equation used to calculate speed. With recalibration, this basic model was used in the 1994, 1997, and 2000 editions of the HCM. In the 1997 edition, the determination of LOS was changed to be based upon density instead of speed, with speed being used in the calculation of density (27).

Currently, the 2010 HCM defines weaving as "the crossing of two or more traffic streams traveling in the same direction along a significant length of highway without the aid of traffic control devices (except for guide signs)" (28). The 2010 HCM contains a new analysis procedure not based on the 1985 HCM, and a new definition of weaving segment length shown below in Exhibit 2-11 that is not based upon loop ramp design. Segments are no longer limited to 2500 feet in length.

In Exhibit 2-11, the weaving segment length is defined as L_S (the "short length" except in cases where barrier stripes do not exist. In those cases, L_B (the "base length") is used to define weaving segment length.

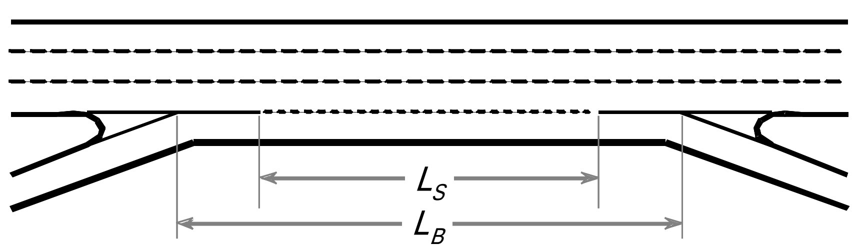


Exhibit 2-11 Definition of Weaving Segment Length, 2010 HCMs. (28)

Weaving segment LOS is a function of density. Speed is an input used to calculate density, and weaving segment length is an input used to calculate speed.

2.1.2.2.3 Freeway Merge and Diverge Segments

The 1965 HCM was the first edition to analyze operations at ramp junctions on freeways. LOS was based upon volume and number of lanes. Dimensions of the ramp and location of nearby ramps (except in weaving situations) were not factored into the analysis (24). The 1985 HCM was the first edition to consider the influence of nearby ramps on ramp junction LOS. Ramps within 6,000 feet of a study ramp could influence LOS, depending upon volume, number of lanes, and ramp type. In the 1994 HCM, the "influence area" of a ramp was reduced to 1,500 feet downstream from a physical merge point and 1,500 feet upstream of a physical diverge point (26). The influence area was also limited to the two right lanes of the freeway. The 1997, 2000, and 2010 HCMs have continued to use the dimension of the 1994 HCM to define a ramp's influence area (27, 8, 28). These dimensions are shown in Exhibit 2-12.

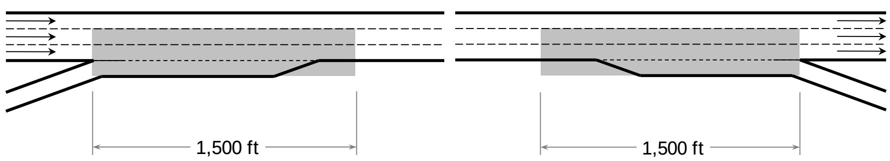
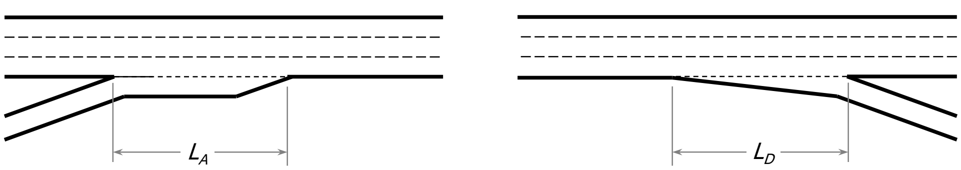


Exhibit 2-12 Definition of Merge and Diverge Influence Areas, HCM (2010) (28)

The LOS of merging and diverging areas in the 2010 HCM is based on density, and the length of the acceleration lane or deceleration lane is used in the density calculation. The length of the acceleration or deceleration lane is measured from "the intersection of the edge of the travel way to the freeway and the ramp (Point A) and the downstream intersection of the freeway and ramp edges of the travel way (Point B)" (14). These dimensions are shown in Exhibit 2-13.



(a) Parallel Acceleration Lane (b) Tapered Deceleration Lane

Exhibit 2-13 Acceleration and Deceleration Lane Length, HCM (2010) (28)

2.1.2.2.4 HCM Summary

The methodologies of the 2010 HCM contain several procedures that are relevant to ramp and interchange spacing. The analysis of basic freeway segments identifies a reduction in free-flow speed as total ramp density increases Weaving is found to occur at locations where an off-ramp or major diverge area closely follows an on-ramp (with auxiliary lane) or a major merge area. The definition of "close" has changed over the years through the different editions of the HCM. Finally, the 2010 HCM states that turbulence areas extend 1,500 feet upstream of diverge areas and 1,500 feet downstream from merge areas.

To minimize the impacts of ramps and interchanges on freeway operations, these analysis procedures suggest the following designs:

- Total ramp density should remain low.
- On-ramps and off-ramps with an auxiliary lane or major merge and diverge areas should be separated far enough apart to avoid poor weaving section operation.
- On-ramps and off-ramps should be separated by more than 3,000 feet so that turbulence areas do not overlap.

2.1.2.3 OTHER NATIONAL-LEVEL DOCUMENTS

In addition to the AASHTO Green Book and the HCM, two other national level-documents have been developed to address ramp and interchange spacing dimensions. These include: *Freeway and Interchange Geometric Design Handbook* (ITE Freeway Handbook), published by the ITE in 2005 and the *Access Management Manual* published by TRB in 2003 (9, 29).

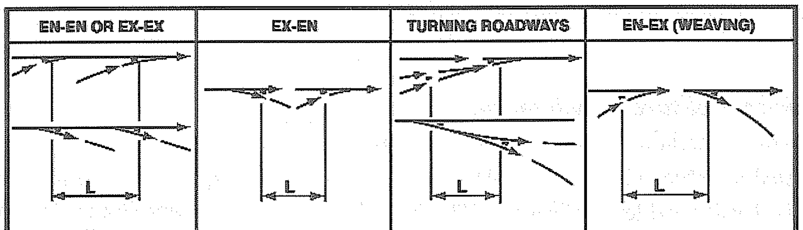
2.1.2.3.1 Freeway and Interchange Geometric Design Handbook (9)

The ITE Freeway Handbook's guidelines for ramp and interchange spacing dimensions are largely based on AASHTO policy and publications by Jack E. Leisch. The ITE Freeway Handbook states that most state departments of transportation (DOTs) have minimum interchange spacing guidelines of 1 mile in urban areas and 5 miles in rural areas, but the guidelines are "arbitrary to a certain extent." The ITE Freeway Handbook develops its own rational for urban interchange spacing, discussed in detail in another section of the literature review. Considering the geometric requirements of various interchange components, the ITE Freeway Handbook also arrives at a 1-mile minimum dimension for crossroad-to-crossroad interchange spacing in urban areas. However, this resource cautions that in many cases urban interchanges will need to be spaced further apart than this to due to factors such as ramp profile requirements, interchange form, weaving length, and queue storage requirements on ramps. To create interchange spacings of less than 1 mile, the ITE Freeway Handbook suggests using C-D roads, ramp braids, or frontage roads.

For ramp spacing, the ITE Freeway Handbook acknowledges both Exhibit 10-68 of the 2004 AASHTO Green Book (shown in Exhibit 2-9 of this report) and weaving analysis. Both should be considered, and the greater of the two distances should be used in design. The ITE Freeway Handbook suggests using the 2000 HCM or the Leisch method to conduct weaving analysis and provides updated charts for conducting the Leisch method.

The ITE Freeway Handbook also presents a different version of the AASHTO Green Book's Exhibit 10-68, developed by Jack E. Leisch. As seen in Exhibit 2-14, this version offers "desirable" and "adequate" ramp spacing dimensions in addition to "absolute" minimums. This version is similar to the table Jack E. Leisch presented in 1975 that is shown in Exhibit 2-8, but some of the distances in the "En-Ex (Weaving)" category of ramp groupings have been shortened in the version appearing in the ITE Freeway Handbook.

RATING	CRITERIA
GOOD	Spacing is "Desirable" or better according to criteria in below table
FAIR	Spacing is greater than "absolute minimum" but less than "Desirable"
POOR	Spacing is less than "absolute minimum"



MINIMUM VALUES	EN-EN OR EX-EX: FULL FREEWAY	EN-EN OR EX-EX: C-D ROAD OR FWY. DIST.	EX-EN: FULL FREEWAY	EX-EN: C-D ROAD OR FWY. DIST.	TURNING ROADWAYS: SYSTEM INTERCHANGE	TURNING ROADWAYS: SERVICE INTERCHANGE	EN-EX (WEAVING): SYSTEM TO SERVICE INTERCHANGE: FULL FWY	EN-EX (WEAVING): SYSTEM TO SERVICE INTERCHANGE: C-D ROAD OR FWY DIST.	EN-EX (WEAVING): SERVICE TO SERVICE INTERCHANGE: FULL FWY	EN-EX (WEAVING): SERVICE TO SERVICE INTERCHANGE: C-D ROAD OR FWY DIST.
DESIRABLE	1500	1200	750	600	1200	1000	3000	2000	2000	1500
ADEQUATE	1200	1000	600	500	1000	800	2500	1000	1000	1200
ABSOLUTE	1000	800	500	400	800	600	2000	1000	1000	1000

* Based on Operational Experience and Need for Flexibility
NOTE: FOR METRIC EQUIVALENTS DIVIDE ABOVE VALUES BY 3.3

Source: Jack E. Leisch and Associates.

Exhibit 2-14 Minimum Ramp Terminal Spacing Guidelines, ITE Freeway Handbook (2005) (9)

2.1.2.3.2 Access Management Manual (29)

The 2003 Access Management Manual states that "the minimum spacing between interchanges needed to allow unfamiliar drivers to make a safe lane change depends upon several factors: speed, through volume, on-ramp volume, off-ramp volume, driver performance, and signing" (29). Thus, mainline freeway safety seems to be the primary consideration in the manual's spacing guidelines, with an acknowledgement to the many factors that affect it. In suburban or "developing urban" areas, the manual recommends a 3-mile spacing of interchanges so that good route signing and decision distance can be provided on the freeway and surrounding land can develop in a "traditional manner." In rural areas, 6-mile interchange spacing is recommended to provide reasonable connection to rural highways. If the area suburbanizes, additional interchanges can be added to create 3-mile spacing.

2.1.2.4 PRIMARY DOCUMENT SUMMARY

Minimum interchange spacing guidelines from four national-level documents are presented below in Exhibit 2-15.

	Urban	Rural	Dimension Definition
A Policy on Geometric Design of Highways and Streets (2004)	1 mi	2 mi	Crossroad-to-crossroad
A Policy on Design Standards Interstate System (2005)*	1 mi	3 mi	Crossroad-to-crossroad
Freeway and Interchange Geometric Design Handbook (2006)	1 mi	2 mi acceptable, 5 mi preferred	Crossroad-to-crossroad
Access Management Manual (2003)	3 mi	6 mi	Not stated

* Applies to Interstate Highway System only

Exhibit 2-15 Interchange Spacing in National-Level Documents

Since 1984, the AASHTO Green Book has recommended that interchanges be spaced a minimum of 1 mile in urban areas and 2 miles in rural areas, with the distance measured crossroad-to-crossroad. It is unclear how these dimensions were chosen. AASHTO Interstate Standards, the Access Management Manual, and the Freeway Design Handbook also provide guidance on interchange spacing with distances being measured crossroad-to-crossroad. Additionally, the 2000 HCM has identified a reduction in basic freeway segment speeds when interchange density exceeds 0.5 interchanges per mile (i.e., 2-mile interchange spacing).

Information on minimum ramp spacing dimensions is provided by the 2000 HCM and the 2004 AASHTO Green Book. Per 2000 HCM methodology, weaving can occur with distances up to 2,500 feet, and the turbulence area caused by a ramp is 1,500 feet in length. The 2004 Green Book provides a table of minimum ramp terminal spacing dimensions for different combinations of ramp types. This table, with the same dimensions, first appeared in the 1984 Green Book.

2.1.3 State Spacing Guidance

The project team reviewed highway design and traffic engineering documents from a sample of states to consider a range of state-level policies and guidelines related to ramp and interchange spacing. A summary of interchange spacing is presented in Exhibit 2-16. None of the sampled state documents included in the review were found to have minimum interchange spacing guidelines below the 2004 AASHTO Green Book criteria of 1 mile in urban areas and 2 miles in rural areas. Some states adhere exactly to the

AASHTO values, and others call for greater spacing. Summaries and highlights from the sampled state documents are provided below.

	Urban Service Interchanges	Urban System Interchanges	Suburban or Transforming	Rural
California	1 mi	2 mi	-	2 mi
Florida*	1-3 mi	-	-	3-25 mi
Florida**	1 or 2 mi	-	3 mi	6 mi
Illinois	1 mi	-	2 mi	3 mi
New Jersey	1 mi	-	-	2 mi
Oregon	3 mi	-	-	6 mi
Pennsylvania	1 mi	-	-	2 mi

* Florida Manual of Uniform Minimum Standards for Design, Construction, and Maintenance for Streets and Highways
** Florida Technical Resource Document 1 and Plans Preparation Manual

Exhibit 2-16 State DOT Guidelines for Minimum Interchange Spacing

2.1.3.1 CALIFORNIA

California's Highway Design Manual (HDM) states that "minimum interchange spacing shall be one mile in urban areas, two miles in rural areas, and two miles between freeway-to-freeway interchanges and local street interchanges" (30). The HDM suggests that auxiliary lanes, grade separated ramps, collector distributor roads, and ramp metering are strategies that could improve operations at closely spaced interchanges. "Close spacing" is not defined in the HDM.

For successive on-ramps, the HDM states that the minimum distance between the ramps should be "about 1,000 feet" so that the standard on-ramp acceleration taper can be used. If the upstream ramp adds an auxiliary lane, the HDM states it should merge with the auxiliary lane in a standard 50:1 convergence. The HDM does not identify the exact points between which spacing should be measured.

For successive off-ramps, the HDM states that the minimum distance between the ramps should be 1,000 feet on a full freeway and 600 feet on a collector-distributor road. These distances are dictated by guide signing considerations.

For an on-ramp followed by an off-ramp, the HDM uses weaving considerations as the basis for spacing. According to the HDM, weaving sections should be designed for LOS C or D in urban areas or LOS B or C in rural areas. The HDM states LOS should be determined using the Leisch Method or the 1965 HCM, because other methods, including those in the 1994 HCM, may not always produce accurate results. The document states that a minimum weaving length of 1,600 feet should be provided on a main freeway in any area unless costs or environmental impacts would be severe.

In addition to the HDM, California issues Design Information Bulletins (DIB). DIB 77 states that "the minimum spacing between interchanges shall be 1.5 km (4,900 feet) in urban areas and 3.0 km (9,800 feet) in rural areas. The minimum spacing shall be 3.0 km between 'freeway-to-freeway' and 'local' interchanges" (31). These distances approximate the US Customary dimensions of the HDM.

2.1.3.2 FLORIDA

Florida has at least three documents that address interchange spacing. The Manual of Uniform Minimum Standards for Design, Construction, and Maintenance for Streets and Highway, commonly referred to as the Florida Green Book, calls for a minimum interchange spacing of 1 to 3 miles in urban areas and 3 to 25 miles in rural areas on all limited access highways (32). No guidance is provided for selecting a single value within these ranges.

However, two other FDOT documents show different minimum spacing values. The Technical Resource Document 1 – Department Engineering Standards cites standards from Rule Chapter 14-97 of the Florida Administrative Code, and the Plans Preparation Manual cites Florida DOT Access Management Guidelines Rule 14-97 (33, 34). Both of these documents call for a 1-mile minimum spacing in a central business district (CBD) and CBD fringe areas, a 2-mile minimum spacing in other parts of existing urbanized areas, a 3-mile minimum spacing in "transitioning" urban areas, and a 6-mile minimum spacing in rural areas. Spacing is measured from centerline-to-centerline of the crossroads.

2.1.3.3 ILLINOIS

The Illinois Bureau of Design and Environment Manual indicates that spacing interchanges further apart improves freeway operations, level of service, and safety (35). Desirable spacing between interchanges is noted as being at least 2 miles in urban areas, 4 miles in suburban areas, and 7.5 miles in rural areas. This provides an entering driver adequate distance to adjust to the freeway environment, allows for weaving maneuvers, and provides for an adequate sign sequencing distance. However, the manual also acknowledges that existing streets and highways, traffic operations, and social considerations may require the distances between adjacent interchanges to vary. The manual concludes that minimum distances should not be less than 1 mile in urban areas, 2 miles in suburban areas, and 3 miles in rural areas. Urban spacings of less than 1 mile may be developed, according to the manual, by using collector distributor roads.

2.1.3.4 NEW JERSEY

The New Jersey Roadway Design Manual (RDM) indicates that close interchanges interfere with traffic flow and safety because of insufficient distance for weaving (36). The RDM states minimum crossroad-to-crossroad spacing should be 1 mile in urban areas and 2 miles in rural areas. Spacing of less than 1 mile may be developed in urban areas with collector-distributor roads. For ramps, the RDM contains a diagram that provides the minimum physical nose to physical nose spacing guidelines for freeways, C-D roads, and arterials. The RDM identifies the diagram as an adaptation of material from the 2001 AASHTO Green Book. The spacing values do meet or exceed those specified in Exhibit 10-68 of the 2001 Green Book, but the diagram is similar in appearance to Figure IX-11 of the 1965 Blue Book. For cloverleaf interchanges, which are not included in Exhibit 2-16, the RDM calls for a maximum separation between the loop ramp terminals of 800 to 1,000 feet. The RDM diagram is shown below in Exhibit 2-17.

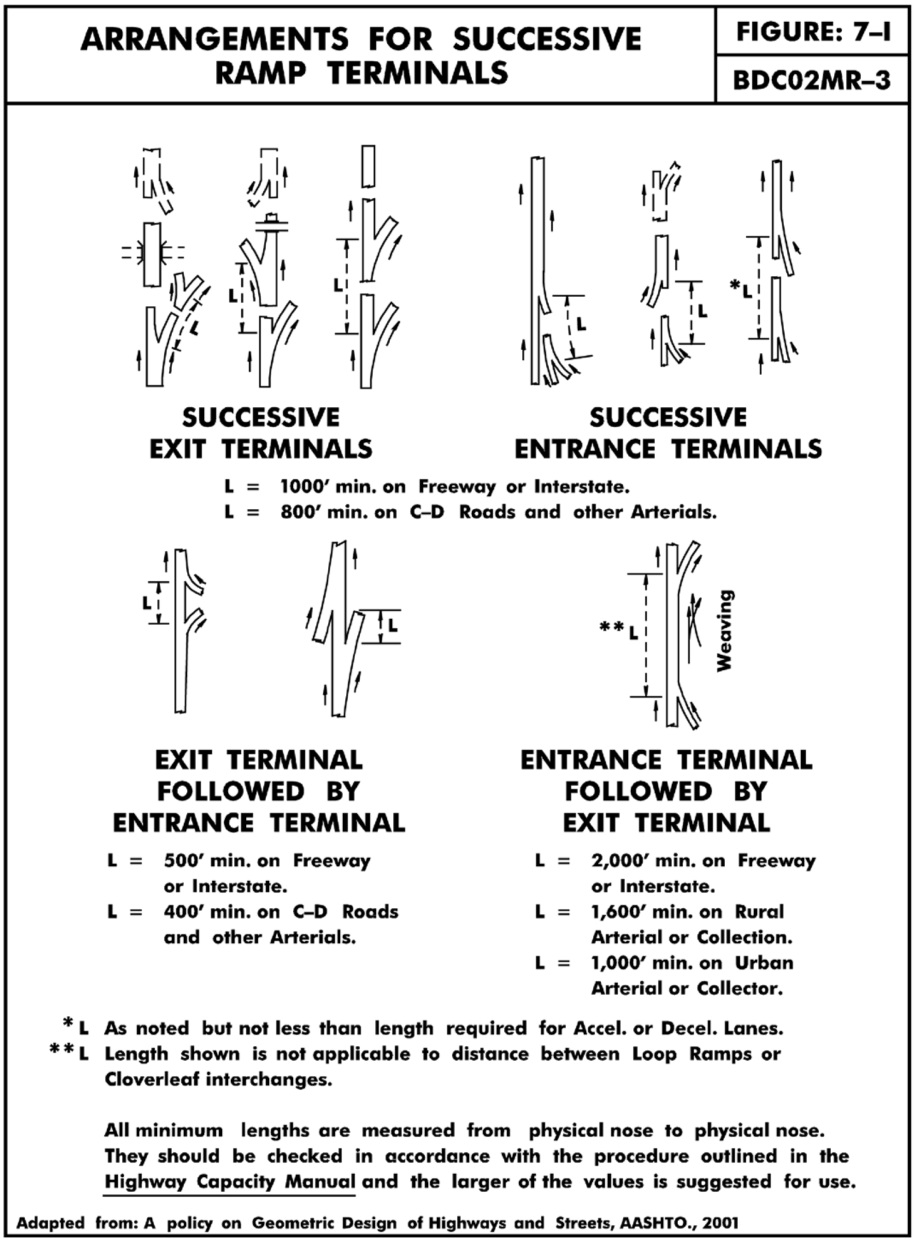
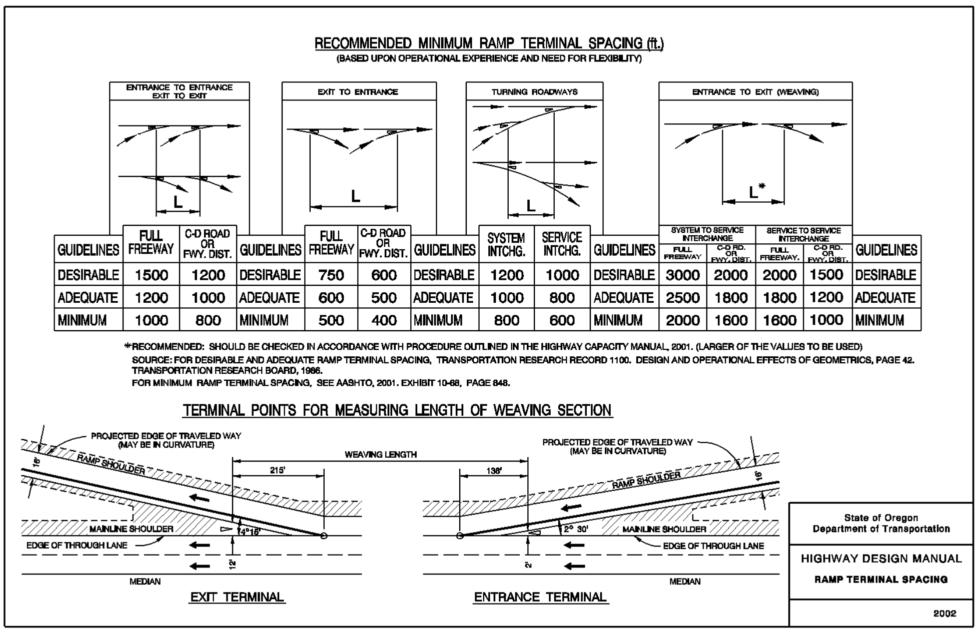


Exhibit 2-17 Ramp Spacing Guidelines, New Jersey *Roadway Design Manual* (2002) (35)

2.1.3.5 OREGON

Oregon's Highway Design Manual (HDM) addresses spacing in two separate sections (37). In Section 9.6 Interchange Design minimum interchange spacing is set at 3 miles in urban areas and 6 miles in rural areas. Distance is measured from crossroad-to-crossroad, and closer interchanges require a design exception. Oregon is unique among states sampled in that separate guidelines are provided for interchanges on non-freeways; the minimum spacing on such facilities is 1.9 miles in urban areas and 3 miles in rural areas. Section 9.6 also includes a figure similar to the one that has been in the AASHTO Green Book since 1984 showing minimum ramp terminal spacing for various combinations of entrance and exit ramps. The HDM's figure, shown below in Exhibit 2-18, also provides "desirable" and "adequate" spacing values.

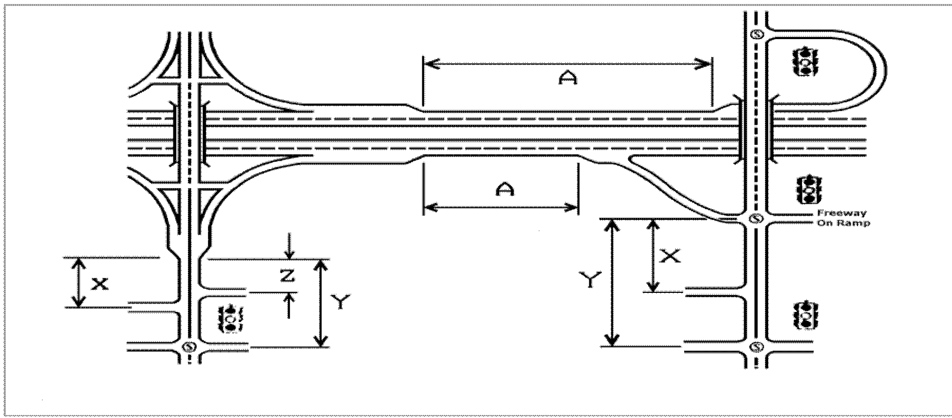


GUIDELINES	FULL FREEWAY	C-D ROAD OR FWY. DIST.	GUIDELINES	FULL FREEWAY	C-D ROAD OR FWY. DIST.	GUIDELINES	SYSTEM INTCHG.	SERVICE INTCHG.	GUIDELINES	SYSTEM TO SERVICE INTERCHANGE: FULL FREEWAY	SYSTEM TO SERVICE INTERCHANGE: C-D RD. OR FWY. DIST.	SERVICE TO SERVICE INTERCHANGE: FULL FREEWAY.	SERVICE TO SERVICE INTERCHANGE: C-D RD. OR FWY. DIST.	GUIDELINES
DESIRABLE	1500	1200	DESIRABLE	750	600	DESIRABLE	1200	1000	DESIRABLE	3000	2000	2000	1500	DESIRABLE
ADEQUATE	1200	1000	ADEQUATE	600	500	ADEQUATE	1000	800	ADEQUATE	2500	1800	1800	1200	ADEQUATE
MINIMUM	1000	800	MINIMUM	500	400	MINIMUM	800	600	MINIMUM	2000	1600	1600	1000	MINIMUM

*RECOMMENDED: SHOULD BE CHECKED IN ACCORDANCE WITH PROCEDURE OUTLINED IN THE HIGHWAY CAPACITY MANUAL, 2001. (LARGER OF THE VALUES TO BE USED)
SOURCE: FOR DESIRABLE AND ADEQUATE RAMP TERMINAL SPACING, TRANSPORTATION RESEARCH RECORD 1100. DESIGN AND OPERATIONAL EFFECTS OF GEOMETRICS, PAGE 42. TRANSPORTATION RESEARCH BOARD, 1986.
FOR MINIMUM RAMP TERMINAL SPACING, SEE AASHTO, 2001. EXHIBIT 10-68, PAGE 848.

Exhibit 2-18 Ramp Spacing Guidelines, Oregon *Highway Design Manual* (2003) (36)

Section 6.2 of the HDM, Interchange Spacing – Access Management, also lists minimum freeway interchange spacing values of 3 miles in urban areas and 6 miles in rural areas, measured from crossroad-to-crossroad. This section of the HDM also contains a figure showing minimum spacing standards between the end of an acceleration lane taper and the start of a deceleration lane taper. The standard is 1 mile in urban areas and 2 miles in rural areas. It is unlikely that these standards would dictate spacing between successive interchanges. The total length of ramps, acceleration lanes, and deceleration lanes would need to be 2 miles long in an urban area and 4 miles long in a rural area. Exhibit 2-19 shows the HDM's version of the minimum spacing standard figure for interchanges with two-lane crossroads. The HDM has another figure for interchanges with multilane crossroads, but distance "A" (the end of acceleration taper to start of deceleration taper measurement) is unchanged.



Category of Mainline	Type of Area	Spacing Dimension			
		A	X	Y	Z
FREEWAY	Fully Developed Urban	1 mi.	750 ft.	1320 ft.	750 ft.
	Urban	1 mi.	1320 ft.	1320 ft.	990 ft.
	Rural	2 mi.	1320 ft.	1320 ft.	1320 ft.

Exhibit 2-19 Minimum Spacing Standards Applicable to Freeway Interchanges with Two-lane Crossroads, Oregon *Highway Design Manual* (2003)

2.1.3.6 PENNSYLVANIA

Pennsylvania's Design Manual uses AASHTO's Policy on Design Standards Interstate System as the basis of its spacing guidelines of interchanges on all types of facilities, not just Interstate Highways (38). The Design Manual was last formally published in 2002, but the interchange spacing guidance was changed in 2007 to reflect AASHTO's 2005 Interstate Standards (39, 40). Currently, the Design Manual with Change #2 incorporated calls for 1-mile interchange spacing in urban areas and 3-mile spacing in rural areas. Spacing of less than 1 mile may be developed in urban areas with grade separated ramps or collector-distributor roads. Unlike the AASHTO Interstate Standards, the Design Manual does not define the points between which spacing is measured.

2.1.3.7 STATE GUIDELINE SUMMARY

The project team summarized interchange spacing guidance from six states and ramp spacing guidance from three states. Among the six states, minimum crossroad-to-crossroad interchange spacing varied from 1 to 3 miles in urban areas and from 2 to 25 miles in rural areas. The 25 mile spacing guidance comes from Florida's Green Book, which calls for a minimum rural interchange spacing range of 3 to 25 miles. No state sampled has interchange spacing values less than those in the 2004 AASHTO Green Book (i.e., 1 mile in urban areas and 2 miles in rural areas). California, New Jersey, and Oregon have additional guidance that specifically addresses spacing between ramps. Illinois and Pennsylvania indirectly address ramp spacing by stating that crossroad-to-crossroad interchange spacing of less than 1 mile may be developed by using C-D roads or "grade separated ramps" (Illinois only).

2.1.4 International Spacing Guidance

Literature reviewed for NCHRP 3-88 has shown that ramp and interchange spacing guidelines in the United States are based on research conducted domestically. To understand and document how interchange and ramp spacing considerations are applied abroad, the project team sampled spacing guidelines from a variety of foreign countries.

2.1.4.1 INTERNATIONAL FINDINGS

Two papers identified in the literature search provide an overview of ramp and interchange spacing dimensions and guidelines in outside the United States (41, 42). In some cases, the year of the other international guidelines is not provided; therefore, it is only known that they are at least as old as the documents in which they are cited. International minimum spacing values and considerations are summarized in Exhibit 2-20.

Country	Urban Areas	Rural Areas	Distance Definition	Year of Guidelines
United Kingdom	3.75*(mainline design speed in km/h) m		Nose-to-nose	1994 or earlier
Germany	2700 m preferred for system interchanges 2200 m preferred for access interchanges 1700 m preferred for low volume interchanges 600 m absolute minimum		Nose-to-nose	1976
France	1000 – 1500 m	-	Nose-to-nose	Not provided
Australia	1500 – 2000 m	3000 – 8000 m	Crossroad-to-crossroad	1984
South Africa – Gauteng Province	3600 – 4200 m for system interchanges 2400 – 2800 m for service interchanges		Crossroad-to-crossroad	Earlier than 2000
South Africa – Nationwide	8000 m		Not specified	1984
Austria	Cities spacing, but not specifics, as a consideration when planning a freeway system		-	1991
Switzerland, Greece, Ireland, Norway – No mention of spacing				1993 or earlier

Exhibit 2-20 Minimum Spacing Guidelines in Foreign Countries (41, 42)

European guidelines sampled consider spacing based on the distance between ramp noses and thus choose to define ramp spacing. Australia and

South Africa define spacing in terms of crossroad-to-crossroad distance, similar to the AASHTO Policies in the United States, thus choosing to define interchange spacing. The United Kingdom's definition of a nose is shown in Exhibit 2-21. Adding the merge taper distance, weaving length, and diverge taper distance will result in the nose-to-nose ramp measurement. Note that this figure is based upon driving on the left side of the road.

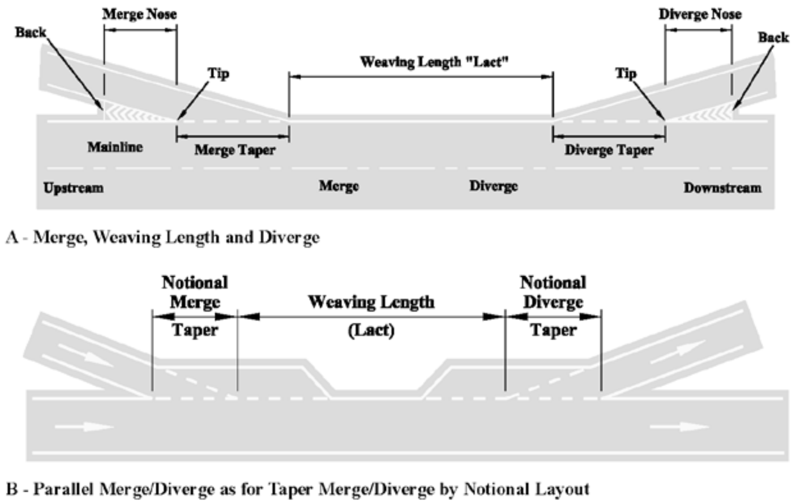


Exhibit 2-21 Definition of Ramp Components, United Kingdom *Design Manual for Roads and Bridges* (2006). Note left side driving. (43)

The United Kingdom is unique in that its spacing criteria vary based on design speed of the mainline facility. For design speed of 120 km/h, minimum nose-to-nose spacing would be 3.75*120 = 450 meters. For a design speed of 100 km/h, minimum spacing falls to 3.75*100 = 375 meters. Germany has longer minimum spacing values than other European countries, perhaps because German freeways do not have speed limits.

South African documents call for longer spacing dimensions than other countries. This was identified by a transportation agency in Gauteng, a province in South Africa, and was the basis of two studies (42, 44). The studies considered interchange spacing with respect to a number of factors and produced four policy statements that define how far apart interchanges should be:

- The distance between interchanges should ideally be based on distances required for adequate signage.
- The turbulence areas downstream from an off-ramp and upstream from an on-ramp should not overlap. Research in the United States incorporated into the HCM since 1994 has shown that turbulence extends approximately 450 meters (1,500 feet) upstream of off-ramps and downstream of on-ramps.
- In specific situations, weaving may require a longer spacing than dictated by either of the above.

- Spacing between roadways is too coarse of a measure to use as a basis for determining interchange spacing because of the differences among interchange forms. For example, ramp spacing with a Parclo-A followed by a Parclo-B interchange will be greater than ramp spacing with consecutive diamonds.

South Africa's sign manual calls for an advance exit direction sign, an exit direction sign, and a gore exit sign. Depending on the environment and type of interchange, there are recommended distances prior to the exit where these signs should be placed. However, if interchanges must be placed closer than is ideal for signing, weaving will then dictate absolute minimum spacing (42, 44).

The authors noted work by Cirillo in the United States who found that accident rates begin to increase sharply when nose-to-nose spacing falls below 2,500 meters. However, it was not apparent if this finding is incorporated into the guidelines. The South Africans also considered the impacts of spacing on speed, but data collected at two sites in South Africa found no correlation between interchange spacing and speed.

Considering all of these factors, the authors recommended new spacing guidelines based on the distance from the end of the merge taper to the start of the diverge taper, referred to in South Africa as the Yellow Line Break Point distance and shown in Exhibit 2-22. This would be a departure from South African guidelines at the time, which measured spacing from crossroad-to-crossroad. The Yellow Line Break Point distance is shorter than the nose-to-nose distance commonly used in Europe because the start of a diverge taper is further from the crossroad than the nose, as depicted in Exhibit 2-21. However, it is similar to European guidelines in that it is based upon ramps and not crossroads. Proposed Gauteng Province spacing guidelines are presented in Exhibit 2-23. It is unclear if Gauteng Province has adopted these guidelines at the present time.

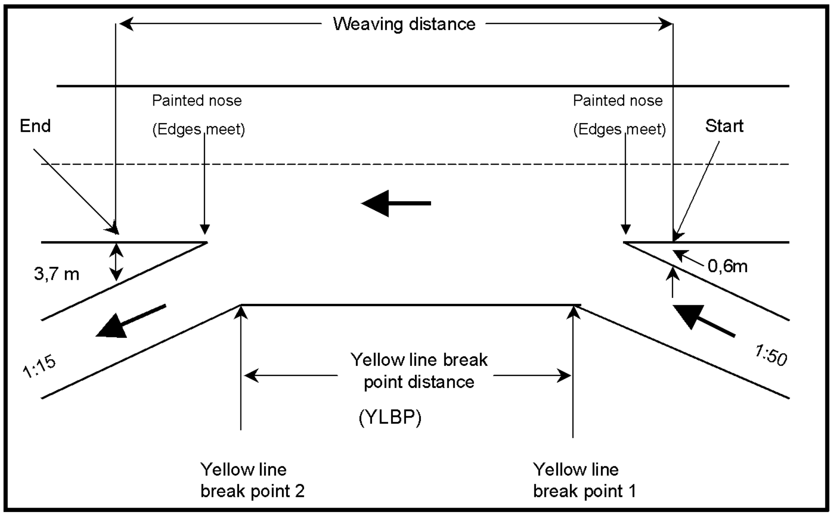


Exhibit 2-22 Definition of "Yellow Line Break Point Distance" Used in Gauteng Province, South Africa (2005). Note left side driving (44)

Configuration	Urban	Rural
Access to Access	1300 m	2200 m
Access to System	2100 m	3300 m
System to Access	1400 m	2200 m
Absolute Minimum	500 m	500 m

Distances are measured between the yellow line break point, as shown in Exhibit 2-20.

Exhibit 2-23 Proposed Minimum Spacing in Gauteng province, South Africa (2000) (42, 44)

2.1.4.2 INTERNATIONAL SUMMARY

The project team sampled international ramp and interchange spacing guidelines from three European countries, South Africa, and Australia. European guidelines define spacing as the distance between successive ramp noses, while South African and Australian guidelines measure spacing between successive crossroads. Australia's guidelines are similar to those used in the United States. South Africa's guidelines focus on the interchange type, service or system, instead of the area type, urban or rural.

Nose-to-nose ramp spacing guidelines from France and Germany call for spacing values greater than the "Entry-Exit (Weaving)" section of Exhibit 10-68 in the 2004 AASHTO Green Book. English guidelines call for spacing dimensions approximately 100 meters shorter than those in the 2004 Green Book for typical freeway design speeds. However, these countries may not measure ramp spacing from the same points.

2.1.5 Signing Considerations

Guide signs are used by drivers as a navigational aid while they travel. On freeways, guide signs identify upcoming exits in advance of and at the ramp itself. Ideally, signing should provide enough information for drivers to identify and locate exits but not so much information that drivers are overwhelmed with more information than they can comprehend. This presents challenges in adequately signing closely spaced interchanges because the amount of information provided in advance of an exit may exceed what drivers are able to comprehend, compared to distances typically provided at ramps with greater spacing distances.

The Manual of Uniform Traffic Control Devices (MUTCD) provides guidance on many aspects of freeway guide signs, including the number of signs that should be used and the spacing between them (45). Additionally, the ITE Freeway Design Handbook provides guidance on the number of message units, or pieces of information, which a driver can be expected to comprehend at a single sign assembly (9). Some states, such as Texas and California, offer additional guidance related to freeway signing.

2.1.5.1 SIGNING PRINCIPLES

Sign placement and spacing on interstates is dictated by the requirements of the driving task. The driving task consists of three subtasks: control, guidance, and navigation (46). Control consists of a driver's operation of a vehicle and includes steering, braking and accelerating. Guidance consists of staying in a lane and maintaining a safe speed and path; car following, passing, and reaction to traffic control devices are part of the guidance subtask. Navigation consists of reaching a destination by following a route. Routes can be well-known to drivers or can require maps or verbal assistance from a passenger (47, 48). Freeway driving requires all three subtasks to be performed simultaneously (48).

Control usually requires a low level of attention because it is a routine task that varies little from trip to trip. Guidance attention requirements vary greatly based on traffic and roadway conditions and a driver's prior experiences and knowledge. Navigation usually requires a low level of attention but in some environments can require a great deal of attention (47).

Sometimes the attention demands of all of the driving subtasks exceed what a driver is capable of handling. When this happens, the process of load shedding occurs. Drivers stop fully performing less important subtasks so attention can be dedicated to more important subtasks. Navigation is the first task to be sacrificed, followed by guidance. Drivers will allow themselves to miss an exit before allowing themselves to hit other vehicles or stop steering (47). Since navigation is the least important of the subtasks, aids such as signing should be made as clear and predictable as possible to minimize the amount of attention required to comprehend them.

In addition to being clear and predictable, signing must not be so extensive that it presents drivers with more information than they are able to process. Motorists should be presented with the maximum amount of useful visual information in a manner that is uniform but also prioritizes information that is most important (47). This concept is known as positive guidance. The MUTCD provides limits on the quantity of information (message units) that should be presented to drivers at once. Examples of message units include city names, route numbers, street names, cardinal directions, exit numbers, distances, and lane use arrows (47). According to the MUTCD, no more than two destination names or street names should appear on a single guide sign, and only one street name or destination name should appear on a guide sign when it is placed beside other guide signs (45). The MUTCD and the ITE Freeway Design Handbook recommend that no more than three guide signs should be placed at the same location (45, 9).

Texas's Freeway Signing Handbook cites a table by McNees and Messer allowing up to five guide signs at the same location but notes that the Texas MUTCD does not recommend this (47). Tables that specify limits on the number of message units that drivers can be expected to process at once are provided in Exhibits 2-24 and 2-25.

NUMBER OF SIGN PANELS IN SERIES AT ONE LOCATION		NUMBER OF MESSAGE UNITS*			
		MAX. PER SIGN		MAX. TOTAL ASSEMBLY	
NUMBER	APPLICATION	DESIRABLE	ABSOLUTE	DESIRABLE	ABSOLUTE
1 □	FREQUENTLY	5	6	5	6
2 □□	OCCASIONALLY	4	5	8	10
3 □□□	SPECIAL CASE	3	4	9	11
4 □□□□	NEVER	–	–	–	–

Exhibit 2-24 Message unit limits, ITE Freeway Handbook (2005) (9)

Number of Sign Panels	Units of Information per Structure	
	Desirable	Maximum
2	12	16
3	16	18
4	18	20
5	Undesirable Design	20

* Source: McNees, R.W. and C.J. Messer. Reading Time and Accuracy of Response to Simulated Urban Freeway Guide Signs. in *Transportation Research Record 844*, Transportation Research Board, Washington, D.C, 1982.

Exhibit 2-25 Message unit limits, reprinted in Texas *Freeway Signing Handbook (2008)* (47)

Driver expectancy also plays a large role in the driving task and attention demands become higher when unexpected events and situations occur. There are two types of expectancies: a priori and ad hoc. A priori expectancies are based on a lifetime of experience. Since most exits are on the right, a driver on an unfamiliar freeway will assume that exits will be on the right. Ad hoc expectancy is based on recent experiences within the driver's current situation. For example, a driver on a rural freeway who has just passed several diamond interchanges with ground mounted guide signs one mile in advance will not expect the next interchange to be a cloverleaf interchange (45). In general, advance warning information assists drivers in making appropriate exit maneuvers, especially in unusual situations (48).

Lunenfeld's paper (46) and the Texas Freeway Signing Handbook (47) identify attributes of good freeway signing, which are presented below in Exhibit 2-26.

Lunenfeld (1993) (46)	**Texas *Freeway Signing Handbook* (2008) (47)**
• Designed for drivers and target population • Responsive to task demands and driver attributes • Satisfies all information needs • Maintains interchange design and information system compatibility • Avoids surprises • Eliminates information-related error sources • Resolves conflicts when information sources compete • Uses spreading [distribute large amounts of information across multiple signs at multiple locations] • Uses repetition for interchange information treatments • Uses all available navigation aids and treatments	• Provides information to meet the needs of unfamiliar road users • Provides advance information to allow for adequate decision making time • Do not necessarily identify every possible choice • May direct users along a longer route if it simplifies signing • Gives driver maximum amount of useful visual information • Prioritizes information based on importance • Presents information uniformly • Information remains visible under most or all environmental conditions

Exhibit 2-26 Attributes of Good Freeway Signing Identified in Prior Studies

2.1.5.2 SIGN SPACING

2.1.5.2.1 FHWA's Manual of Uniform Traffic Control Devices (MUTCD) (45)

Considering the principles of good freeway signing, the MUTCD specifics distances for advance freeway signing by interchange type. For major and intermediate interchanges, the MUTCD states that advance guide signs should be placed 0.5 and 1 mile from the exit gore. If spacing permits, a third advance guide sign should be placed 2 miles in advance of the exit gore. Signs in advance of an exit allow a driver to begin making necessary lane adjustments in advance of the exit. Multiple signs provide drivers multiple opportunities to see and comprehend the navigational information. Multiple signs with the same information also aid drivers in retaining the signing information.

Examples of these sign placements specified in the 2009 MUTCD (Figure 2E-38 and 2E-35) are shown below in Exhibits 2-27 and 2-28.

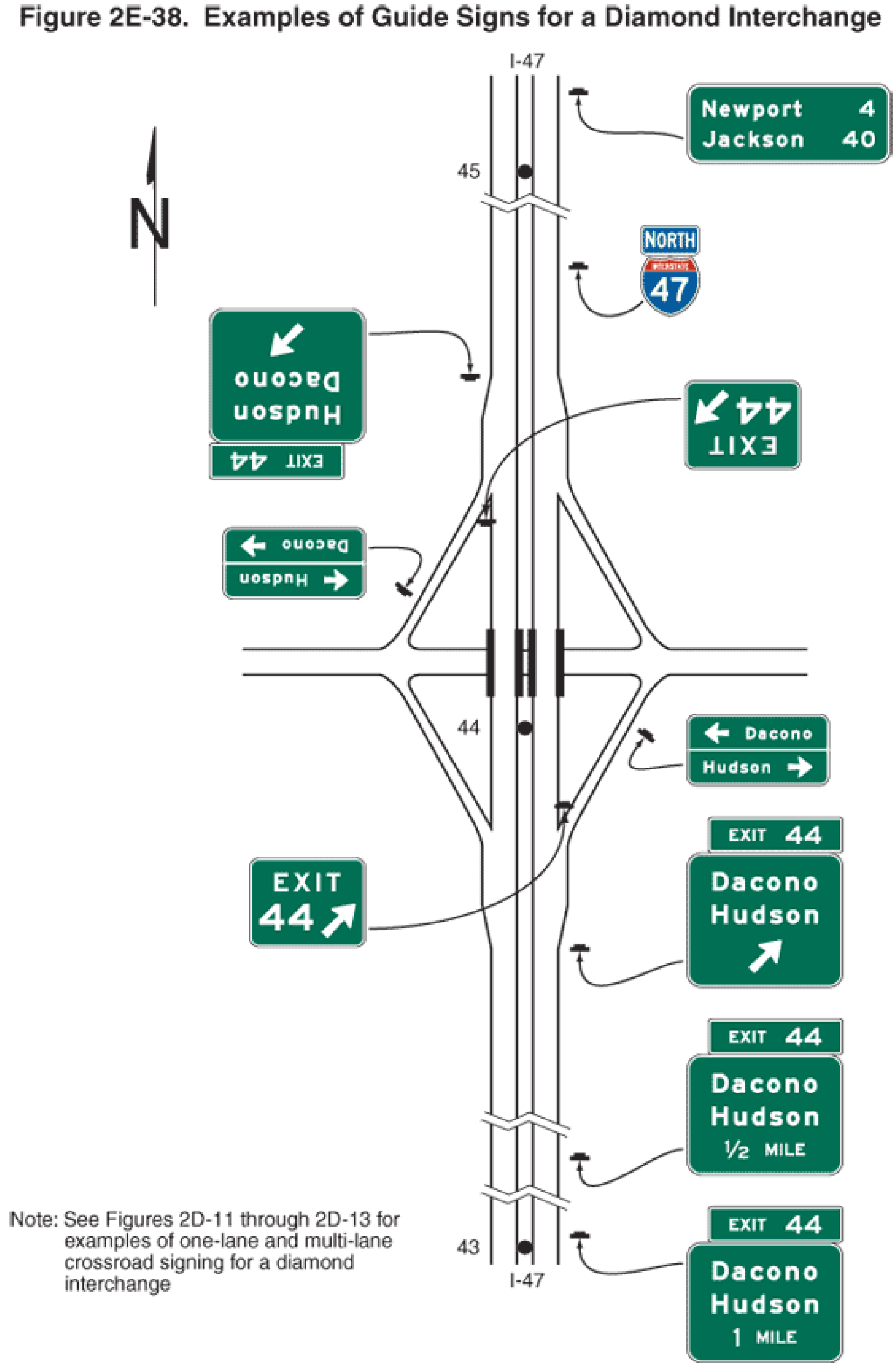


Exhibit 2-27 Signing of a major or intermediate interchange, example 1, MUTCD (2009) (45)

Figure 2E-35. Examples of Guide Signs for a Full Cloverleaf Interchange

Exhibit 2-28 Signing of a major or intermediate interchange, example 2, MUTCD (2009) (45)

If the distance between interchanges is more than 1 mile but less than 2 miles, the first advance guide sign may be placed closer than 2 miles to the exit gore to avoid overlap with signing from the previous exit. For minor interchanges, only one advance guide sign, placed 0.5 to 1 mile from the exit gore, should be used. The MUTCD also lists an equivalent metric distance for each sign location specified above.

Major interchanges are interchanges with other expressways, other freeways, high-volume multilane highways, principal urban arterials, or certain major rural routes. Minor interchanges have a sum of exit volumes of less than 100 vehicles per day in the design year. All other interchanges are classified as intermediate. Freeway-to-freeway interchanges fall into the category of "major interchanges" and have no special sign spacing requirements, although the MUTCD states that signs for such interchanges shall be mounted overhead.

The MUTCD accounts for interchanges located so close together that regular guide signs placed at the distances specified above would overlap with signing for other interchanges. If spacing between interchanges is less than 800 feet, interchange sequence signs should be used instead of advance guide signs. These signs list multiple exits on one sign and are generally used to supplement advance guide signs in places such as large urban areas where guide signs cannot be adequately spaced. Interchange sequence signs contain only two message units per exit, road name and distance, while an advance guide sign might contain four: exit number, route number, street name, and distance to exit. As a result, replacing three side-by-side advance guide signs with an interchange sequence sign would reduce the number message units in half. This would allow for more signs, which would then allow for closer spacing of interchanges.

If used, the MUTCD states that interchange sequence signs shall be placed before the first advance guide sign for the first interchange in the sequence. An example of interchange sequence signs from the MUTCD (Figure 2E-30) at closely spaced exits is shown in Exhibit 2-29.

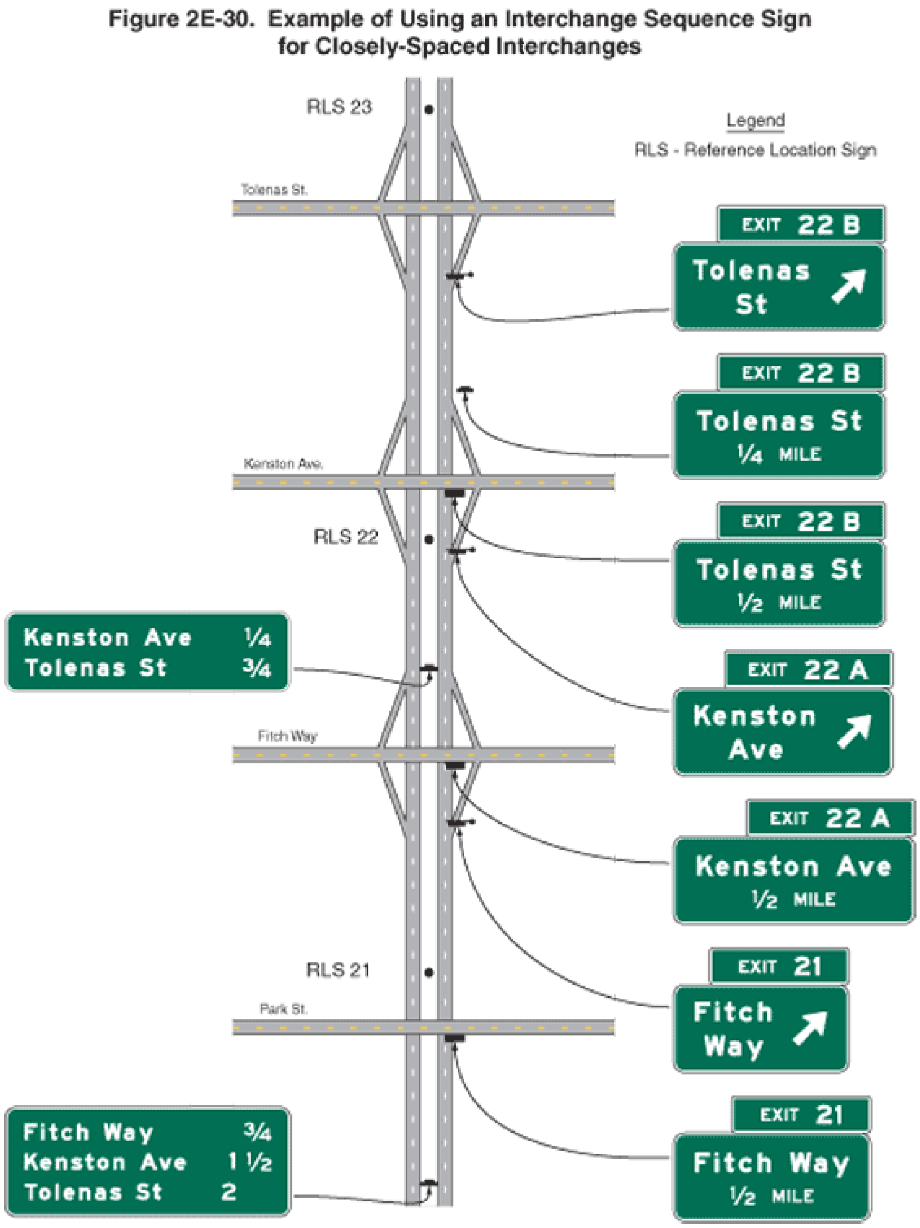


Exhibit 2-29 Interchange Sequence Signs, MUTCD (2009) (45)

If spacing permits and undue repetition will not occur, the MUTCD states that a fixed sequence of signs should be displayed after an interchange. Often this will be in a rural area. A route sign should be displayed 500 feet beyond the end of the acceleration lane, followed at 1,000 feet by a speed limit sign, and 1,000 more feet by a distance sign. If spacing does not permit all of these signs or is in a rural area where traffic is primarily local, the MUTCD states some or all post-interchange signs should not be used.

2.1.5.2.2 State Sign Guidance

A number of states publish their own version of the MUTCD or other sign guidance documents. These documents are not intended to override FHWA's MUTCD but rather supplement the information. California's MUTCD (48) and Texas's Freeway Signing Handbook (2) provide additional information on freeway signing. At the present time, these state-level documents are still based off of the 2003 MUTCD and are in the process of being updated to reflect the 2009 MUTCD.

California requires advance guide signs even when interchanges are closely spaced. The requirements state that when the distance between interchanges is less than 2 miles, the advance guide sign shall be placed at the first available location. California also seems to favor advance guide signs that are 0.5 and 1 mile before an exit and not 2 miles. Figures from FHWA's MUTCD that show an advance guide sign 2 miles in advance of an exit are omitted or replaced in the California document by figures that only show advance guide signs 1 mile in advance of an exit.

Texas's Freeway Signing Handbook is meant to supplement the Texas MUTCD (50). The Texas MUTCD is similar to FHWA's MUTCD with regard to freeway exit sign spacing. The Texas Freeway Signing Handbook reinforces the placement of advance guide signs prior to interchanges. One advance guide sign should be placed 0.5 to 1 mile prior to a minor interchange. Two, but preferably three, advance guide signs should be placed 0.5, 1, and 2 miles prior to an intermediate or major interchange. When spacing between interchanges is less than 800 feet, the Texas Freeway Signing Handbook states interchange sequence signs should be used. Texas uses these signs in urban areas with populations of 100,000 or more people. Post-interchange sign spacing guidelines do not differ from the FHWA MUTCD.

2.1.5.3 IMPACTS OF SIGNING ON RAMP AND INTERCHANGE SPACING

Although the FHWA MUTCD refers to spacing in terms of the interchanges, it is the spacing of exit ramps that is most impacted by signing considerations. Drivers on a freeway make navigational decisions at exit ramps, not at crossroads or entrance ramps. An exit sign should be placed at the exit gore, and advance guide signs should be placed 0.5 and 1 mile prior to the gore. Individual guide signs should only contain information for one exit, and the ITE Freeway Handbook recommends a maximum of three guide signs in any one location (9). For example, a guide sign assembly could consist of three signs: one marking an exit gore, one placed half a mile in advance of a second exit, and one placed one mile in advance of a third exit. If exit ramps were spaced a half mile apart, this pattern could be repeated without presenting too many message units to drivers. Ramps spaced less than a half mile apart would require more than three guide signs in the same location or an "overlap" of multiple series of signs for different interchanges.

Although overlapping a series of signs would not necessarily violate the MUTCD's minimum recommended spacing of 800 feet between advance guide signs, it would violate driver expectancy by simultaneously presenting two sign sequences. In situations such as this, the MUTCD recommends the use of interchange sequence signs.

However, ideal conditions to create continuous half mile advance guide sign spacing often do not exist. The MUTCD states signs should not be placed where horizontal or vertical sight distance makes it difficult for drivers to see them, nor should overhead signs be placed within 800 feet of an overhead bridge. Also, it may be necessary to present other information to drivers, which could necessitate a break in the half mile spacing of guide sign assemblies. Thus, while it may be possible to adequately sign a series of exit ramps one-half mile apart with advance guide signs, it is unlikely that this could be sustained for more than several exits due to other factors that impact sign placement.

2.1.5.4 SIGNING SUMMARY

Freeway drivers are dependent upon signs to locate exits and navigate to their destinations. Documents such as the MUTCD provide guidance for the number of signs that precede an exit and the distance before the exit where they are placed. At most interchanges, the MUTCD recommends advance guide signs be placed 0.5, 1, and optionally 2 miles prior to the an exit. Sign assemblies should not contain more message units, or information, than a driver is able to process. Exit ramps should be spaced far enough apart that advance guide signs can be positioned as recommended by the MUTCD and the number of message units will not exceed what drivers are able to process.

2.1.6 Vehicle Fleet

Much of the published research related to ramp and interchange spacing was conducted from the mid 1950s to the mid 1970s, when many of America's freeways were being built. Today's vehicle fleet is quite different than the one on the road half a century ago. Certain characteristics of vehicles, such as acceleration of automobiles and power of trucks, are a factor in some aspects of ramp and interchange design. If automobile acceleration and truck power have changed over time, guidelines for on-ramp lengths and merge areas need to be revisited to reflect current vehicle characteristics.

2.1.6.1 AUTOMOBILES

During the 1970s and early 1980s, cars gradually became lighter, more aerodynamic, and less powerful for fuel economy reasons compared to vehicles of the 1950s and 1960s (51). However, pickup trucks, vans, and sports utility vehicles have become increasingly popular since the early 1980s, and as a result, the average size of vehicles in the automobile fleet has increased in recent decades (52).

Literature reviewed for NCHRP 3-88 indicates that acceleration capabilities of vehicles have increased since the 1930s. A 2000 study by Long documented that automobiles in the early 1990s had higher maximum acceleration rates than those from the 1930s (53). The literature review results suggest the increase in maximum acceleration rates has not been constant over the decades. A 1983 study by Fancher identified a decrease in maximum acceleration between 1958 and the early 1980s but found that acceleration of the fleet of the early 1980s still exceeded acceleration of the fleet of the 1930s (51). In fact, low powered cars in the 1983 fleet were able to accelerate faster than implied by design curves for intersection sight distance calculations, which were developed decades earlier. A study by Harwood et al in 1999 identified an increase in maximum acceleration of passenger cars between the early 1980s and 1999 (54). Studies in the 1930s also identified a decrease in acceleration capability with increasing speed. This rate of change, unlike the acceleration rate itself, appeared to have remained nearly constant through the early 1990s, according to Long's study (53).

Although acceleration rate values for cars in the 1990 AASHTO Green Book were larger than previous editions, Long found that much of the acceleration data in the 1990 and 1994 AASHTO Green Books still appeared to be based on studies conducted in the late 1930s (53). Since Long's study, AASHTO has published the 2001 and 2004 editions of the Green Book, which have not included any new acceleration data (7, 8). Therefore, even though several studies have identified an increase automobile acceleration rates since the 1930s, the 2004 Green Book may not fully reflect this change.

However, the changes in maximum acceleration discussed above may not play a large role in determining driver behavior. Fancher suggested that drivers do not normally use the maximum acceleration capability of their vehicle and instead accelerate at a rate that seems comfortable to them. If a typical driver's accelerate preferences have not changed since the 1930s, then long-standing guidelines may be more relevant today than changes in maximum acceleration would suggest (51). Although the studies in the 1930s measured maximum acceleration, "normal" acceleration rates were developed by assuming drivers typically use only limited portions of their vehicle's capability.

2.1.6.2 HEAVY VEHICLES

Heavy vehicle acceleration characteristics are typically described in terms of the weight-to-horsepower ratio. The literature search for *NCHRP Report 505: Review of Truck Characteristics as Factors in Roadway Design* (55) found that, in general, truck weight-to-horsepower ratios steadily decreased between 1949 and 1984 as engines became increasingly powerful. Increases in heavy vehicle weight have been offset by increases in engine power. There have been at least two studies of weight-to-horsepower ratio since 1984. In 1997, Harwood et al found that weight-to-horsepower ratios of high-performing trucks had changed little since 1984 but that weight-to-horsepower ratios of low-performing trucks continued a decreasing trend (54). However, Harwood et al's conclusions were based on data collected in the field at only one location in California. Field data collected for NCHRP Report 505 found that since 1984 weigh-to-horsepower ratios decreased substantially at western sites and stayed about the same at eastern sites. NCHRP Report 505 does not theorize on why this geographic difference was found, but it may be attributable to increased weight limits in western states, including the use of "triple" and "Rocky Mountain double" trailers.

In 1993, Fancher suggested changes to the truck fleet can be thought of in terms of grade; heavier trucks may effectively make a three percent downgrade seem like four-percent, and more powerful engines may effectively make a three-percent upgrade seem like two-percent (51).

2.1.6.3 SUMMARY

Changes to the vehicle fleet throughout the mid and late 20th century may be relevant to interchange and ramp spacing considerations. Current automobiles have been found to accelerate faster than those in the 1930s. However, the change has not been constant and a decrease in acceleration rates appears to have taken place in the 1960s and 70s. AASHTO Policy does not fully reflect these changes. Acceleration rates were increased in the 1990 Green Book relative to earlier AASHTO Policies, but studies since 1990 have still found that automobiles are able to accelerate faster than these rates. Since 1990, there have been no major changes to acceleration rates in subsequent editions of the AASHTO Green Book. Overall, automobiles on the road today accelerate faster than those on the road at the time many studies of ramp and interchange spacing were conducted. During this same time, trucks have become more powerful.

Studies report weight-to-horsepower ratios of trucks decreased during the second half of the 20th century. Trucks have become larger and heavier, and engine power has increased at an even faster rate. Increasingly powerful trucks and faster accelerating automobiles may influence on-ramps and merging area design considerations as current and future vehicle characteristics may be different than the characteristics used at the time of developing current ramp and interchange design guidelines.

2.1.7 Safety

2.1.7.1 DEFINITION OF RESEARCH PROBLEM

Freeway interchanges, by their definition, coincide with increased lane changing, acceleration and deceleration on the freeway mainline. Traffic operations are adversely affected and decline with higher interchange and ramp densities (i.e., shorter spacing). The effects are captured at both the interchange level (e.g., free-flow speed decreases as interchange density increases) and at the ramp level (e.g., speed decreases as weaving length decreases) by algorithms in the HCM.

Analogous relationships between interchange and ramp density and safety are not as well established, but are of equal importance. For example, the Federal Highway Administration policy statement on Additional Interchanges to the Interstate System states as a condition of approval that "the proposed access point does not have a significant adverse impact on the *safety* and operation of the Interstate facility" (*emphasis added*) (56). Operational measures (e.g., speed variation, lane changing, conflicts) and the higher cognitive and decision making demands on drivers at these locations are often used as surrogates to deduce lower expected levels of safety in areas with increased interchange and ramp presence. However, accidents are random and complex events often attributable to driver behavioral patterns that are not yet understood. There are some existing hypotheses and accompanying research results that indicate safety may be higher in complex driving scenarios and lower in simple driving scenarios due to driver attention and awareness patterns. In addition, selecting operational surrogates as safety indicators may be highly specific to certain roadway features and accident types. Given these complexities, it is clear that "the concept of safety must be linked to accidents" (57).

Safety will be defined for this study as the number of accidents, or accident consequences, by kind and severity, *expected* to occur on an entity during a specified time period (57). The *expected* number of accidents on an entity is representative of a long-term average. Its concept is important, as it captures the need for appropriate analytical techniques that account for the randomness of accident occurrence. These thoughts are consistent with seminal work in the field of highway safety and the concepts in the first edition of the *Highway Safety Manual* (HSM).

2.1.7.2 REVIEW OF PREVIOUS WORK

Published literature relevant to NCHRP 3-88 objectives generally fell into two categories:

- Studies that provide insight into the safety effects of interchange and ramp presence; and
- Studies that provide insight into the safety effects of interchange and ramp spacing.

Results from the first category, while not directly related to this project can be used by planners and designers to estimate the expected safety consequences of additional access points along a freeway segment or corridor. They also provide insights into general trends of accident frequencies and severities near interchanges and ramps. Results from the second category have direct relevance to this project.

Many of the studies reviewed had higher-level objectives than a detailed look at interchange- and ramp-related issues. These objectives included, for example, applying and testing new model estimation techniques or developing general freeway safety models. The information presented below is therefore more than a traditional literature *review*. It is a critical literature *analysis*. In cases where appropriate details were available (e.g., relevant model parameters, raw data tables and descriptive statistics), additional analyses that were more in line with the NCHRP 3-88 project objectives were conducted and presented in easy-to-interpret tables and figures. Footnotes and references to distinguish between the original work and the new analyses by the NCHRP 3-88 team are used throughout the text.

2.1.7.2.1 Safety Effects of Interchange and Ramp Presence

Three studies allowed the project team to examine the aggregate safety effect of interchange and ramp presence by estimating expected accident frequencies and rates inside of *interchange areas* and comparing them to the same safety measures outside of interchange areas. Interchange area definitions vary by study, but generally include a bi-directional stretch of freeway mainline, adjacent auxiliary lanes and roadside bounded by the furthest upstream and downstream freeway-ramp terminals for a given interchange (see Exhibit 2-30).

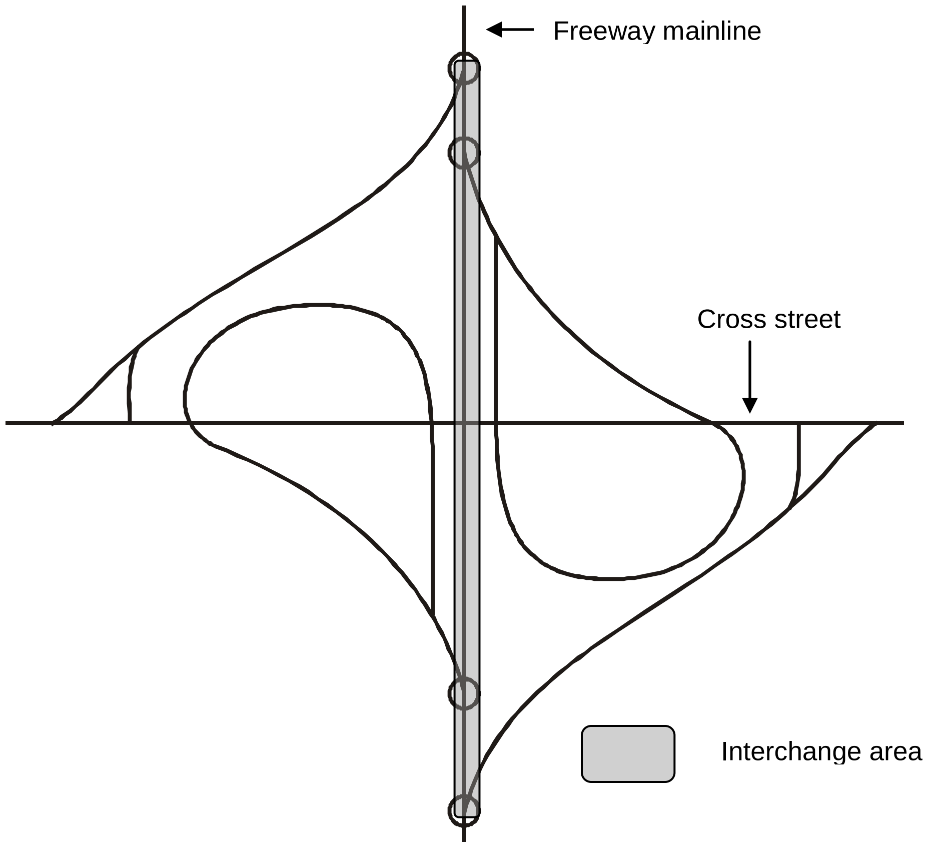


Exhibit 2-30 Illustration of interchange area concept

Torbic et al. incorporated two types of freeway segment models into the Interchange Safety Analysis Tool (ISAT): 1) freeway segments within interchange areas and 2) freeway segments outside of interchange areas (58). The models were estimated as part of *SafetyAnalyst* research efforts using data from California (1997-2001), Minnesota (1995-1999), Ohio (1997-1999) and Washington (1993-1996). Interchange areas were defined by limits extending from approximately 0.3 miles upstream of the first ramp gore of an interchange to approximately 0.3 miles downstream of the last ramp gore of the same interchange[1].

Accidents occurring on both the freeway mainline and the adjacent roadside as well as on speed-change lanes adjacent to freeway mainline lanes were included in the analysis. Accidents occurring on the ramp proper were excluded. Models for total accidents and fatal plus injury (F+I) accidents were estimated for the following freeway types:

- 4-lane rural;
- 6-lane rural;
- 4-lane urban;

1 The authors use gore and painted nose synonymously.

- 6-lane urban; and
- 8-lane urban.

All of the freeway segments models had the following functional form:

$$N = \exp(a) \times ADT^{b} \times SL$$

where: N = expected number of accidents per year;

ADT = average daily traffic (veh/day);

SL = segment length (mi); and

$a, b =$ parameters estimated using available data.

Torbic et al. estimated models with negative binomial regression, which was discussed in-terms of accident modeling by Miaou [2] (58, 59). Negative binomial regression represents the current state of safety modeling practice and is central to work related to the forthcoming first edition of the HSM Estimation results are presented in Torbic et. al (58) The NCHRP 3-88 project team conducted a post-hoc analysis of the model results to determine if, and to what extent, the presence of an interchange decreases safety. Results are visually represented in Exhibit 2-31, which shows the percent difference in expected accidents between freeway segments within interchange areas and freeway segments outside of interchange areas using the ISAT models. The percent difference is computed as:

$$\frac{N_{within} - N_{outside}}{N_{outside}} \times 100\%$$

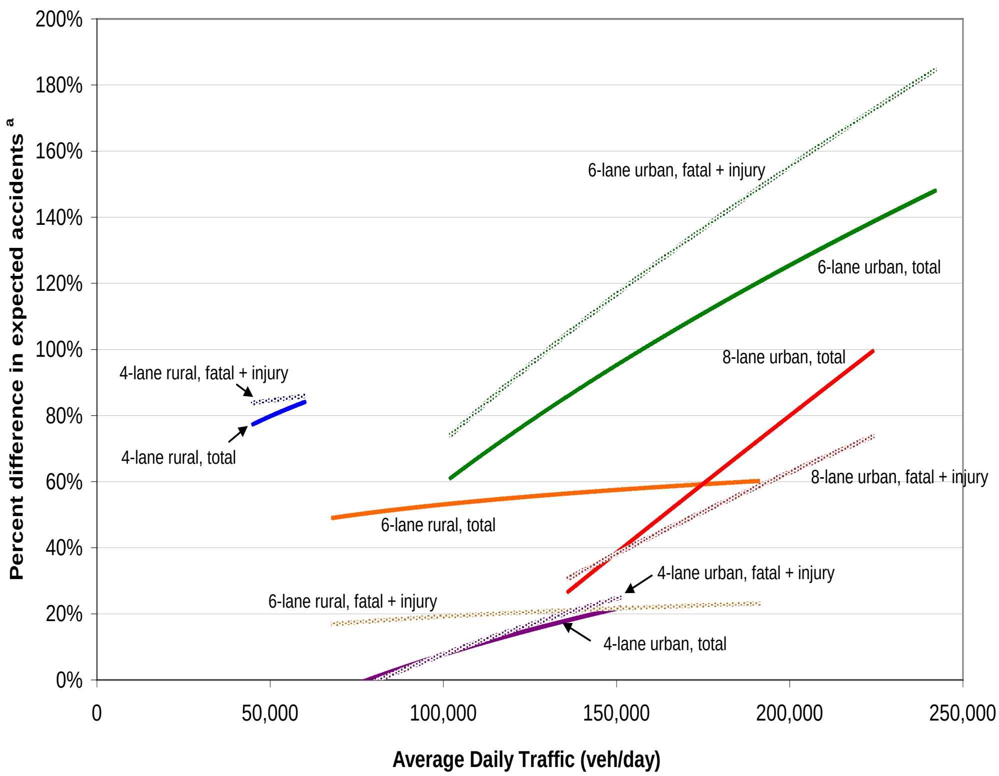
where: N_{within} = the expected number of accidents per year on a freeway segment of length L within an interchange area; and

$N_{outside}$ = the expected number of accidents per year on a freeway segment of same length L outside of an interchange area.

The graph shows results varying with freeway type. The percent difference is positive in almost all cases, indicating that segments within interchanges are

2 The negative binomial regression model is used to address overdispersion in accident data (i.e., the variance of the count is greater than the expected value). The magnitude of overdispersion is estimated along with the model coefficients.

less safe[3]. In general, this difference increases with increasing traffic volume. Accident severity increases within interchange areas for 4-lane rural and 6-lane urban freeways (i.e., the percent increase in fatal plus injury accidents is greater than the percent increase in total accidents). Accident severity decreases within interchange areas for 6-lane rural and for most traffic volumes on 8-lane urban freeways. Accident severity is approximately equal within and outside of interchange areas for 4-lane urban freeways. The authors do point out model weaknesses for 6-lane rural and 4-lane urban freeways and recommend future research for these freeway types. Other omitted variables potentially contributing to the variability in results include ramp traffic (i.e., number of entering and exiting vehicles) and proximity to adjacent upstream or downstream interchanges.



a $\frac{N_{within} - N_{outside}}{N_{outside}} \times 100\%$

Exhibit 2-31 Comparison of safety for freeway segments within interchange areas to freeway segments outside of interchange areas using ISAT models

Kiattikomol et al. conducted an analysis similar to Torbic et al. using data from North Carolina (NC) and Tennessee (TN) freeways (2000-2002) in

3 The percent difference for 4-lane urban freeways becomes negative for traffic values less than 77,000 vehicles per day, indicating that freeway segments within interchange areas are safer at lower volumes.

medium to large urban areas[4] (60, 58). Interchange areas in North Carolina extended 1,500 feet on each side of the crossroad (i.e., all North Carolina freeway segments within interchange areas were 3,000 feet long). This distance was considered adequate to capture the entrance and exit areas for the sample of primarily diamond type interchanges. Lengths of Tennessee freeway segments within interchange areas varied; details regarding their definition were not provided. Details regarding the locations of accidents included in the analysis (e.g., mainline, speed-change lane, ramp proper) were also not included in the cited publication.

Models for fatal plus injury accidents, injury accidents and property-damage-only (PDO) accidents were estimated for the following freeway types:

- 4-lane urban;
- greater than (>) 4-lane urban;

Models for North Carolina freeway segments outside of interchange areas and all Tennessee freeway segments had the following functional form:

$$N = a \times SL^{b1} \times ADT^{b2}$$

where: N = expected number of accidents per 3 years;

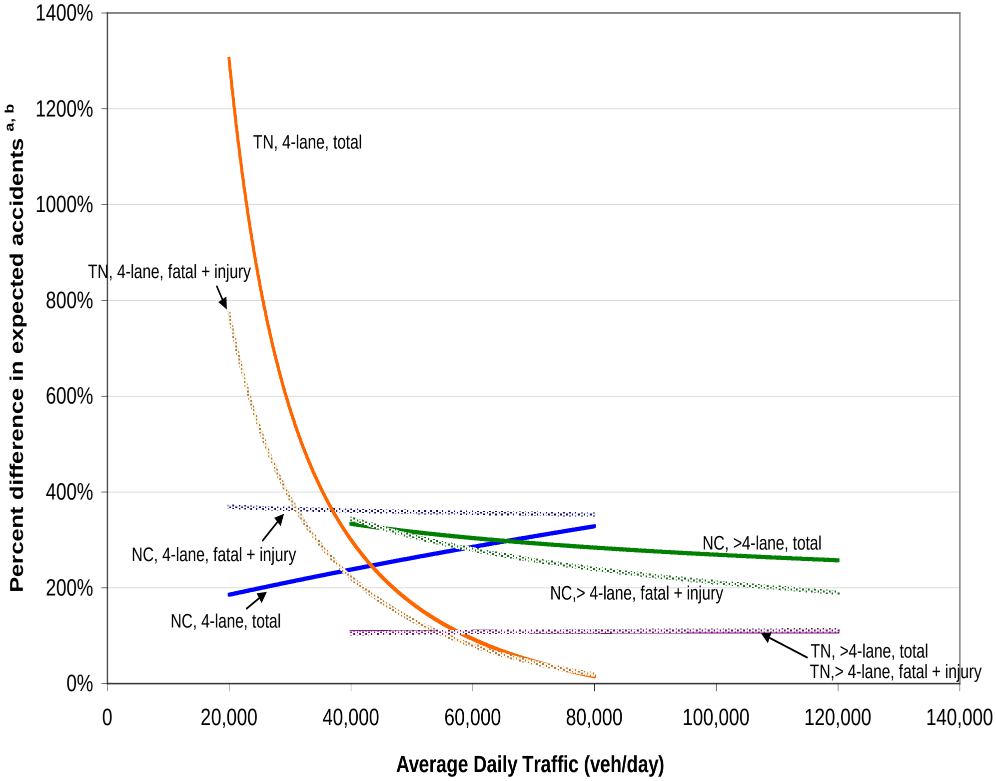
SL = segment length (mi);

ADT = average daily traffic (veh/day); and

$a, b1, b2 =$ parameters estimated using available data (Note that $b1$ is restricted to equal 1.0 in all models from Torbic et al. (58)

Models for North Carolina freeway segments inside of interchange areas were similar, but excluded the segment length variable because all such segments were 3,000 feet long. Models were estimated with negative binomial regression and results are presented in Kiattikomol et al. (60). A similar type of post-hoc analysis as that reported above was conducted by the NCHRP 3-88 project team for comparison purposes. Results are shown in Exhibit 2-32.

4 The authors point out that the urban areas in these states are smaller, perhaps more rural in character, than larger cities of the Northeast, Midwest and Pacific Coast.



[a] $\frac{N_{within} - N_{outside}}{N_{outside}} \times 100\%$

[b] For this comparison, lengths of segments inside and outside of interchange areas were set equal to the mean length of the interchange segments (0.57 for both North Carolina models; 1.0 for Tennessee 4-lane; 0.88 for Tennessee >4-lane.

Exhibit 2-32 Comparison of safety for freeway segments within interchange areas to freeway segments outside of interchange areas using North Carolina and Tennessee models

The percent difference in accidents is positive in all cases (i.e. segments within interchange areas are less safe); a comparable finding to Torbic et al. (58). However, this difference decreases quickly with increasing traffic volumes for TN 4-lane freeways. It decreases moderately with increasing traffic volumes for NC >4-lane freeways. These patterns are opposite those for NC 4-lane freeways and for all freeway types modeled by Torbic et al. (58). Accident severity within interchange areas is slightly less than or equal to severity outside of interchange areas for TN 4-lane, TN >4-lane and NC >4-lane freeways. Accident severity is higher within interchange areas for NC 4-lane freeways; the difference becomes smaller with increasing traffic volumes. The effects of ramp traffic or proximity to adjacent interchanges were not captured in the models.

Exhibit 2-33 summarizes freeway accident rates by adjacent interchange unit and area type provided in a synthesis by Twomey et al. (61). If interchange area segments are defined as those segments adjacent to and in-between the speed change lanes[5], then accident rates of 93 accidents per MVM and 174 accidents per MVM were observed on segments inside of rural and urban interchange areas, respectively. Accident rates for typical freeway segments outside of interchange areas in rural and urban settings are in the general range of 25-45 and 45-75 accidents per 100 MVM, respectively[6]. This reflects approximately 110 to 300 percent more accidents on segments within interchange areas compared to segments outside of interchange areas. The accident rates in Exhibit 2-33 are much higher for urban areas, a finding the authors attribute to shorter speed change lanes at these locations. The difference may also be attributable to an increased number of lower severity, multiple vehicle collisions in urban areas (which tend to increase with ADT at a faster rate than single vehicle accidents).

Interchange unit[1]	**Rural**			**Urban**		
	100 MVMT[2]	Number of accidents	Accident rate[3]	100 MVMT[2]	Number of accidents	Accident rate[3]
Deceleration lane	2.51	348	137	5.83	1,089	187
Area between speed change lanes	6.52	554	85	11.87	1,982	167
Acceleration lane	3.68	280	76	8.40	1,461	174
Total	12.71	1,182	93	26.10	4,532	174

[1] Data for other units were provided by Twomey et al. (60), but are not relevant to this discussion.
[2] MVMT = million vehicle miles traveled
[3] Expressed in terms of accidents per 100 MVMT

Exhibit 2-33 Accident rates by interchange unit and area type

Three additional studies looked at safety effects of ramp and interchange presence through binary, indicator variables (i.e. variable = 1 if a ramp is present on a defined segment; variable = 0 otherwise).

Abdel-Aty et al. modeled accident frequencies using data from a 36-mile stretch of urban freeway in Florida (63). The freeway section was equipped with loop detectors, allowing the safety effects of real-time traffic parameters (e.g., average speed, peak 15-minute volume, temporal variability of speed and volume) to be tested. Four accident categories were modeled, with each category consisting of two sets of mutually exclusive accidents:

[5] A definition similar to those provided by Torbic et al. (57) and Kiattikomol et al. (59)
[6] Roughly approximated using data from Torbic et al. (57) and Bonneson et al. (61)

- accident type: single-vehicle or multiple vehicle
- accidents by traffic conditions: peak or off-peak
- accidents by pavement condition: dry or wet
- accidents by light condition: daytime or dark
- accident severity: PDO or injury

Models within each category were estimated simultaneously using seemingly unrelated negative binomial regression, which accounted for error correlation between the accident types in each category. The presence of an entrance or exit ramp within a defined influence area increased the expected accident frequency for all eight accident types. Respective regression parameters were only reported for two categories; magnitudes were estimated by the NCHRP 3-88 project team and are summarized in Exhibit 2-34. The coefficient of speed variation was the only real-time traffic parameter appearing in any of the final model specifications. In addition, average daily traffic estimates were found to be better explanatory variables than more disaggregate measures of volume (e.g., peak 15-minute volume). These findings supported the use of aggregate measures of traffic volume in the safety research discussed in Chapter 3.

Ramp variable	Multiple vehicle accidents[1]	Single vehicle accidents	Daytime accidents	Dark-hour accidents
Presence of exit ramp	+50%	+61%	+46%	+60%
Presence of entrance ramp	+54%	+26%	+72%	+50%

[1] Numbers represent the expected increase in accidents given the presence of an exit or entrance ramp. The effect of both an exit and entrance ramp would be multiplicative (). The method does not distinguish between the presence of only one ramp and multiple ramps of the same type at a given location (i.e. the expected accident frequency would be the same if there was one exit ramp or multiple exit ramps at a given location).

Exhibit 2-34 Safety effects of ramp presence using regression parameters estimated by Abdel-Aty et al, 2006. (63)

Donnell and Mason investigated the frequencies and severities of two types of median related accidents on Pennsylvania Interstates:

- cross median collisions: a vehicle traveling in one direction on a divided facility leaves its designated roadway to the left, traverses the entire width of the median, enters the opposing roadway and collides with a vehicle traveling in the opposite direction; and,
- median barrier collision: a vehicle traveling in one direction on a divided facility leaves its designated roadway to the left and collides with a median barrier (64-66).

Frequencies were modeled using negative binomial regression. Severities were modeled with logistic regression. Although not conclusive, results indicated that the expected frequency of cross median collisions increased in areas up to 800 feet downstream of an entrance ramp on rural Pennsylvania

Interstates (not including the Pennsylvania Turnpike) (64)[7]. The expected frequency of median barrier collisions decreased on segments with entrance ramps on the Pennsylvania Turnpike, but increased on segments with an entrance ramp on other Pennsylvania Interstates (66). Severities of median barrier collisions decreased on segments with entrance ramps; similar effects on cross median collision severity were not reported (65).

Kraus et al. investigated two types of freeway accidents in southern California resulting in at least one severe occupant injury or fatality:

- in-lane accidents: rear-end impact of a stopped, stalled or slowed vehicle in a normal traffic lane by a second vehicle traveling in the same traffic lane; and,
- off-road accidents: vehicle leaves the traveled way and impacts a roadside object, overturns off the roadway or re-enters the traveled way and strike another vehicle (68).

Two years (1984-1985) of accidents were merged with 69 homogenous freeway segments. Each freeway segment appeared 6 times in the dataset, once for each combination of time of day (12a.m.-6a.m.; 6a.m.-6p.m.; 6p.m.-12a.m.) and day of week (weekday; weekend). Poisson regression models were estimated for in-lane accidents, off-road accidents to the left and off-road accidents to the right. Estimation results indicated that expected frequencies of in-lane accidents and off-road accidents to the right resulting in severe injuries or fatalities were 16% lower on segments with frequent interchanges. A segment was defined as having frequent interchanges if 20% of its total length was occupied by interchange related features. It is unclear whether this finding is attributable to lower accident frequencies, a shift in the proportion of severe accidents or a combination of both.

2.1.7.2.2 Safety Effects of Interchange and Ramp Spacing

The aforementioned synthesis by Twomey et al. (61) is sometimes cited in discussions on safety effects of ramp and interchange spacing [see (69) or (58) for example]. The cited work is not a direct analysis of spacing, but of freeway accident rates by interchange ramp proximity on Interstates. Interchanges had an exit ramp upstream of the cross street and an entrance ramp downstream of the cross street for each direction of travel. Ramp proximity was defined as either the upstream distance from the exit ramp nose on the exit side of the interchange or the downstream distance from the entrance ramp on the entrance side of the interchange.

Exhibit 2-35 displays a new, graphical analysis of the results conducted by the NCHRP 3-88 project team. The analysis indicates that accident rates

[7] A follow-up study showed minimal association between entrance ramp presence and expected frequency of cross median collisions (66). The definition of entrance ramp presence was significantly changed to include both segments with the entrance ramp and upstream segments within 1500 of the entrance ramp.

increase with ramp proximity (i.e., shorter distances from ramps) at a higher rate in urban areas than in rural areas. The finding is likely a result of increased vehicle interaction due to higher traffic volumes on the mainline and ramps. There are also minimal differences in accident rates between the exit and entrance sides of interchanges in urban areas. The close proximity of adjacent upstream and downstream interchanges in urban areas is one possible explanation (i.e. the downstream area of one interchange can also be considered the upstream area of the next interchange). Accident rates in rural areas decrease as ramp proximity decreases at a higher rate downstream of the interchange compared to upstream.

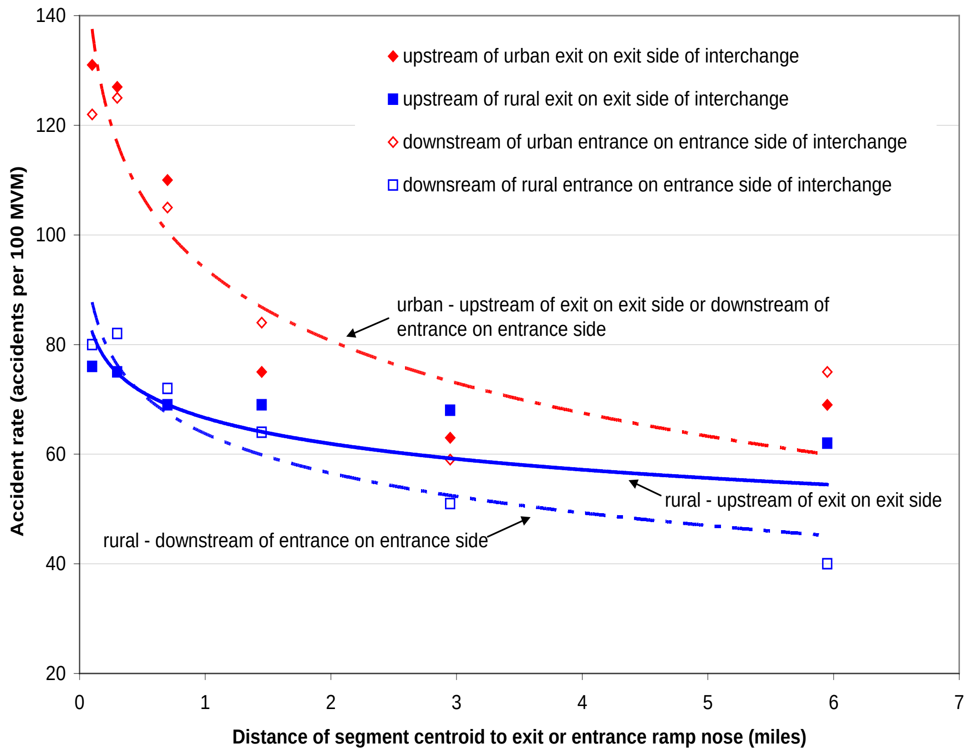


Exhibit 2-35 Analysis of accident rates by ramp proximity reported by Twomey et al., 1991 (61)

The remainder of published findings summarized below provided insights into the safety effects of ramp and interchange spacing in one of two ways:

- The boundaries of freeway segments were defined by like points on consecutive interchanges or ramps and those segments were analyzed (i.e., the length of the freeway segment is also the interchange or ramp spacing); or,
- The safety effects of a ramp or interchange count or density on a freeway segment of length L were estimated through a multivariate regression model (the inverse of these types of variables represents an average interchange or ramp spacing).

The findings are presented in this same respective order.

Cirillo examined the relationship between accident rates and weaving area lengths using Interstate data from 20 states (70). Approximately 700 urban weaving segments were included in the dataset. New analyses of the accident rates conducted by the NCHRP 3-88 team are summarized in Exhibit 2-36. Trends show that, for a given level of traffic volume, accident rates tend to increase as weaving area lengths decrease. Results also show that, for a given weaving area length, accident rates decrease as volume decreases. Cirillo aggregated accident rates by five levels of one way mainline ADT in the original work (ADT < 10,000; 10,000 ≥ ADT < 20,000; 20,000 ≥ ADT < 30,000; 30,000 ≥ ADT < 40,000; 40,000 ≥ ADT), but reported a limited sample size in the lowest volume area category. The NCHRP 3-88 project team found more consistent general trends when the three lowest volume categories were combined into one (ADT < 30,000). This change is reflected in Exhibit 2-36.

Results from a later study showed opposite trends; accidents rates decreased as weaving length decreased (71). The sample size was limited to 21 locations. The locations were not selected randomly, but were included due to poor accident histories (a possible selection bias problem). Traffic volumes were not considered in the analysis other than their use in accident rate calculations. Non-linear trends between accidents and volumes are well established. Segregating accident rates by level of traffic volume is desirable if accident rates are the safety measure of choice. The results reported by Cirillo, while older, are likely more reliable.

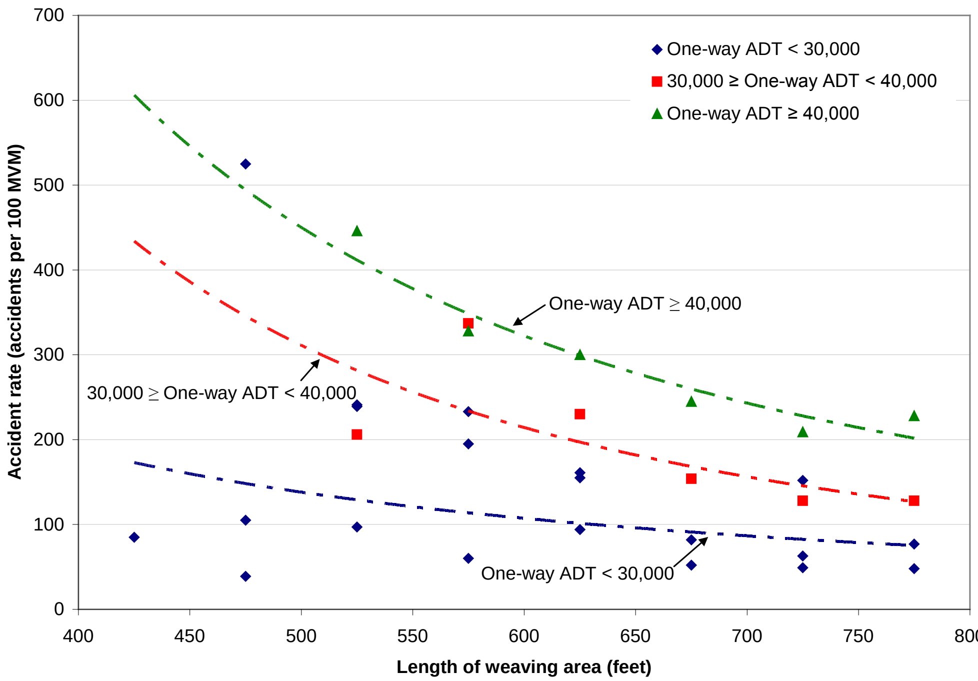


Exhibit 2-36 Analysis of accident rates by weaving areas length reported by Cirillo, 1970 (70)

Bared et al. modeled the safety effects of interchange spacing using California freeway data (1998-2002) (72). Interchange spacing was defined as the smallest distance between gore points of ramps from consecutive interchanges[8]. Negative binomial regression models for total accidents and fatal plus injury accidents were estimated using data from 58.5 miles of California Interstates; number of lanes varied from 6 to 14. Reported models had the following functional form:

$$N = a \times ADT^{b1} \times SL^{b2} \times \left(\sum RampADT\right)^{b3}$$

where: N = expected number of accidents per year;

ADT = average daily traffic on the freeway mainline (veh/day);

SL = segment length, defined as interchange spacing (mi);

$\sum RampADT$ = the sum of ADT for the two entrance ramps and two exit ramps associated with a defined interchange spacing segment (veh/day); and

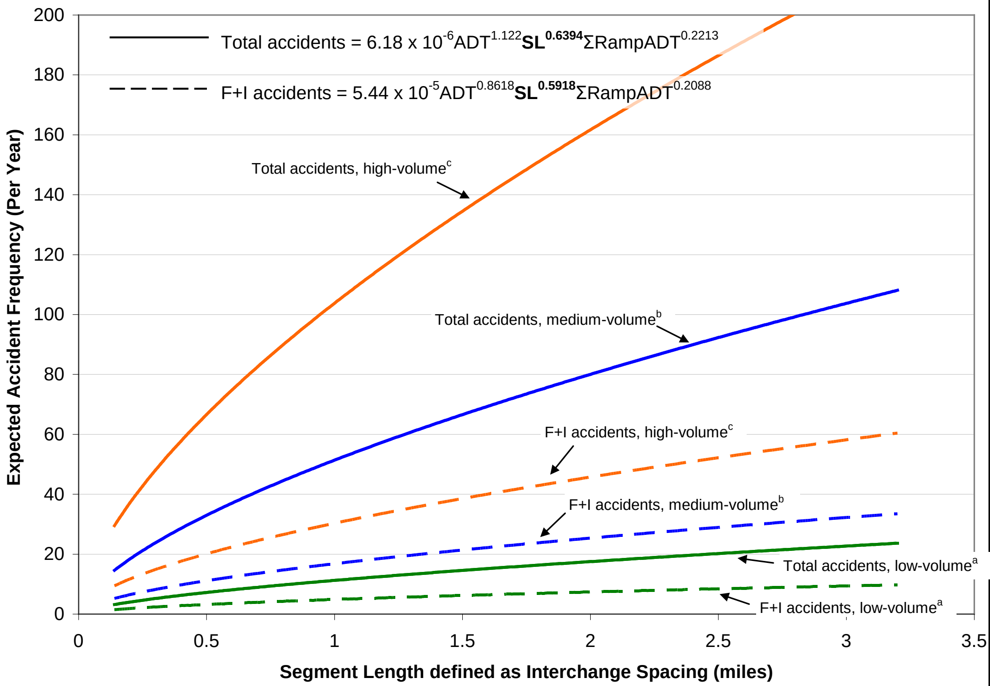
$a, b1, b2, b3 =$ parameters estimated using available data

Model results are summarized and illustrated in Exhibit 2-37. The model parameters generally make intuitive sense. However, a closer look at the segment length variable reveals potential challenges associated with their study objective: determining the safety effect of interchange spacing.

The traffic and segment length components of an accident frequency model represent measures of exposure; respective regression parameters generally have a value around one. The parameter for ADT may be slightly greater than or less than one, depending on the crash type of interest. The parameter for segment length is sometimes constrained to equal one. In the model reported by Bared et al., the parameter associated with segment length represented the net effect of several potential confounding factors (72). Exposure was the most predominant, resulting in an overall positive effect of segment length. However, the interchange spacing effect is confounded with the exposure effect because every segment in the database is defined with an entrance gore on one side and an exit gore on the other side. Shorter segment lengths represent reduced exposure, but increased ramp interaction; two factors expected to have opposite effects on accident frequency. The segment length, as defined by Bared et al., may also be correlated with additional interchange related features that influence safety (72). For

8 The authors define gore point and ramp nose synonymously.

example, shorter segment lengths are likely associated with an increased presence of auxiliary lanes between the entrance and exit ramps of two consecutive crossroads; a feature not captured in the data.



[a] Low volume: ADT = 66,600 veh/day; ΣRampADT = 6,900 veh/day

[b] Medium volume: ADT = 188,000 veh/day; ΣRampADT = 34,100 veh/day

[c] Low volume: ADT = 274,000 veh/day; ΣRampADT = 120,700 veh/day

Exhibit 2-37 Summary of freeway models from Bared et al, 2006 (72).

One possible solution was explored by Bared et al. and is recreated in Exhibit 2-37. The expected number of accidents predicted from the regression models in Exhibit 2-37 are normalized (i.e., divided by) the segment length. The resulting rate, with units of accidents per mile per year, follows an intuitive trend: the expected number of accidents per unit length increases as interchange spacing decreases. The procedure assumes the segment length parameter associated with exposure is equal to one and that the difference between the originally estimated segment length parameter and one is attributable to the interchange spacing effect. This concept is illustrated by:

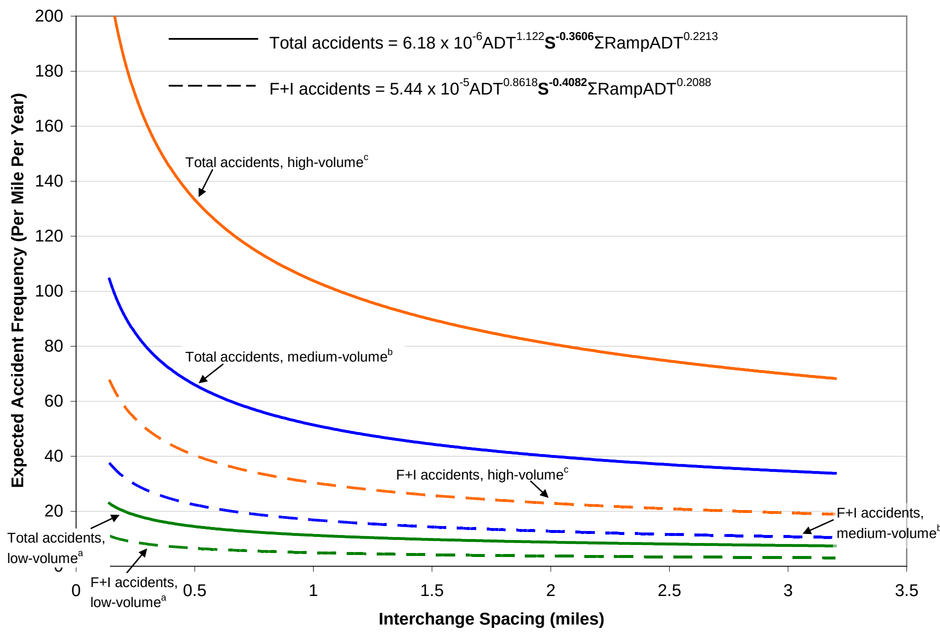
$$\frac{N}{SL} = a \times ADT^{b1} \times S^{(b2-1.0)} \times \left(\sum RampADT\right)^{b3}$$

where: $\frac{N}{SL}$ = expected number of accidents per mile per year;

S = interchange spacing (miles); and

$ADT, \sum RampADT, a, b1, b2, b3 =$ same as previously defined.

The slope of the line representing the expected accident frequency versus interchange spacing relationship approaches zero as interchange spacing increases, indicating minimal safety influence from the ramps at the segment termini (i.e., from a safety perspective, the segment operates as a normal freeway segment without deleterious interchange or ramp effects). The interchange spacing at which this occurs becomes longer as mainline and ramp volumes increase. The normalizing technique is promising if one can be fairly certain that effects other than exposure and interchange spacing are not fully or partially captured in the segment length definition.



[a] Low volume: ADT = 66,600 veh/day; ΣRampADT = 6,900 veh/day

[b] Medium volume: ADT = 188,000 veh/day; ΣRampADT = 34,100 veh/day

[c] Low volume: ADT = 274,000 veh/day; ΣRampADT = 120,700 veh/day

Exhibit 2-38 Summary of freeway models from Bared et al. with results normalized for segment length, 2006 (72)

Pilko et al. (68) conducted a follow-up effort to the study by Bared et al. (72) with some notable changes:

- the size of the California dataset was increased to include 95 spacing observations representing 134 freeway miles (compared to 53 observations representing 58.5 miles);

- a Washington freeway dataset consisting of 100 spacing observations representing 144 freeway miles was added and used for model estimation and validation;
- mainline traffic was specified as vehicles per lane per day;
- ramp volumes were expressed at the ratio of ramp ADT to mainline ADT for the California models;
- cross section variables representing median width, median type and HOV lane presence were included in some models; and
- the definition for interchange spacing was changed to represent the distance between crossroads of consecutive interchanges.

Model estimation results are summarized in Exhibit 2-39. The graphical displays in Exhibit 2-37 represent general trends that are also seen when the models in Exhibit 2-39 are plotted. Discussion and analysis associated with Exhibit 2-38 are also applicable. Therefore, the figures and analysis are not repeated here.

Data and Specification	Accident Types	Expected accident frequency per year
CA only	TOTAL	$= 4.97 \times 10^{-5} \left(\frac{ADT}{LN}\right)^{1.39} SL^{0.57} \exp(1.50 * RRatio + 0.37 * HOV - 0.01 * MW + 0.27 * MT)$
	F+I	$= 1.81 \times 10^{-5} \left(\frac{ADT}{LN}\right)^{1.37} SL^{0.57} \exp(1.42 * RRatio + 0.34 * HOV - 0.01 * MW + 0.35 * MT)$
CA for WA validation	TOTAL	$= 3.61 \times 10^{-5} \left(\frac{ADT}{LN}\right)^{1.11} SL^{0.52} \sum RampADT^{0.34} \exp(0.0072 * MW)$
	F+I	$= 1.64 \times 10^{-5} \left(\frac{ADT}{LN}\right)^{1.07} SL^{0.51} \sum RampADT^{0.35} \exp(0.0051 * MW)$
Joint CA and WA	F+I	$= 1.63 \times 10^{-6} \left(\frac{ADT}{LN}\right)^{1.37} SL^{0.62} \sum RampADT^{0.26} \exp(0.0032 * MW)$

ADT = average daily traffic on freeway mainline (veh/day);

LN = number of lanes at the segment midpoint (includes through lanes, HOV lanes and auxiliary lanes greater than 0.2 miles long;

SL = segment length, defined as interchange spacing (mi);

$RRatio$ = the sum of ADT for the two entrance ramps and two exit ramps associated with a defined interchange spacing segment divided by average daily traffic on the freeway mainline

HOV = indicator for presence of an HOV lane (1 = present);

MW = median width (feet);

MT = indicator for median type (1 = unpaved, 0 = paved);

$\sum RampADT$ = the sum of ADT for the two entrance ramps and two exit ramps associated with a defined interchange spacing segment

Exhibit 2-39 Summary of reported models in Pilko et al., 2007 (69)

Hadi et al. estimated the safety effects, defined by frequencies of total accidents, injury accidents, and fatal accidents, of design elements for various types of urban and rural facilities in Florida (73). Four years (1988-1991) of accident data were aggregated and combined with roadway and traffic data from the Florida Department of Transportation Roadway Characteristics Inventory. The freeway models had the following general form:

$$N = a \times \exp(b_1 ADT + b_2 SL + b_3 I + BX)$$

where: N = expected number of accidents per four years;

ADT = average daily traffic on the freeway mainline (veh/day);

SL = segment length (mi);

I = number of interchanges on the segment;

a = constant term estimated using available data;

b_1, b_2, b_3 = parameters associated with ADT, SL and I respectively estimated using available data;

X = k x 1 vector of other design elements influencing N on freeways; and

B = 1 x k vector of parameters associated with variables in X estimated using available data.

The parameter associated with the number of interchanges on a segment was positive in all freeway models in which the variable was included in the final specification, indicating that more interchanges on a freeway segment (i.e., a smaller average interchange spacing) is associated with higher expected accident frequencies of all severities. The magnitudes of the unit increases, expressed in terms of percent, are summarized in Exhibit 2-40. The interchange variable is not included in models for injury crashes on 6-lane urban freeways or fatal crashes on all freeway types. It is unclear whether this represents a shift to less severe crashes as the number of interchanges increases, inflation of standard errors due to a low number of severe crashes (i.e., excess number of zeros) or a combination of both.

Freeway type	Expected unit % increase in total accidents[1]	Expected unit % increase in injury accidents	Expected unit % increase in fatal accidents
4- and 6-lane rural	+24%	+24%	n/a[2]
4-lane urban	+32%	+27%	n/a[2]
6-lane urban	+20%	n/a[2]	n/a[2]

[1] The expected increase in accidents given the addition of one interchange to a freeway segment. The effect is multiplicative (e.g., the expected increase in accidents given the addition of two interchanges on a 4-lane rural freeway would be 1.24 * 1.24 ≈ 54%).

[2] sample sizes were not sufficient to estimate the interchange effect for these combinations of accident and freeway types

Exhibit 2-40 Summary of interchange effect estimated by Hadi et al. 1995 (73)

Milton et al. modeled accident severities using a mixed logit approach (74). Accident data (1990-1994), weather information and roadway characteristics were merged for multilane divided highways in Washington State. Estimation results showed that the probability of a disabling injury or fatality resulting from an accident was lower for segments with increased interchange density, expressed as the number of interchanges per mile. The finding was attributed lower speeds and smaller collision angles in the vicinity of multiple interchanges.

Anastasopoulos et al. estimated a tobit model of accident rates on Indiana Interstates (75). Accidents rates for 337 Interstate segments were computed using five years (1995-1999) of aggregated accident data, i.e.:

$$Acc\_rate_i = \frac{\sum_{Year=1}^{5} Accidents_{Year,i}}{\left[\sum_{Year=1}^{5} ADT_{Year,i} \times L_i \times 365\right] / 100{,}000{,}000}$$

where: Acc_rate_i = the accident rate for segment *i* expressed in units of accidents per 100 million vehicle miles traveled;

$\sum_{Year=1}^{5} Accidents_{Year,i}$ = the number of accidents observed over a 5-year period (1995-1999) on roadway segment *i*; and

$\sum_{Year=1}^{5} ADT_{Year,i} \times L_i \times 365$ = total vehicle miles traveled over a 5-year period (1995-1999) on roadway segment *i*.

Estimation results showed that a unit increase in the number of interchange ramps per lane mile of Interstate increased the expected accident rate by 22.36 accidents per million miles and increased the probability of having an accident rate above zero by 16.87%.

2.1.7.3 SAFETY SUMMARY

A total of twelve studies, and sixteen subsequent papers and reports provided insights relevant to NCHRP 3-88 project objectives. The literature generally fell into two categories:

- Studies that provide insight into the safety effects of interchange and ramp presence; and
- Studies that provide insight into the safety effects of interchange and ramp spacing.

Results from the first category, while not directly related to this project, can be used by planners and designers to estimate the expected safety consequences of additional access points along a freeway segment or corridor. They also provided insights into general trends of accident frequencies and severities near interchanges and ramps, which helped guide the safety research conducted for this project (see Chapter 3). Results from the second category have direct relevance to this project as they capture not only safety effects of interchange and ramp presence, but the safety effects associated with interchange and ramp spacing and density measures.

2.1.7.3.1 Safety Effects of Interchange and Ramp Presence

The presence of an interchange, or interchange ramp, was associated with an expected increase in accident frequency. Results from *interchange area* modeling efforts were similar in direction, but sporadic in magnitude; expected accident frequencies on freeway segments within interchange areas were anywhere from zero to 1200% higher than for segments outside of interchange areas. Common magnitudes ranged from 100 to 300% (Torbic et al., 2007; Kiattikomol et al., 2008; Twomey et al., 1991). Three studies looked at safety effects of ramp and interchange presence through binary, indicator variables (i.e. variable = 1 if a ramp is present on a defined segment; variable = 0 otherwise) and found similar trends across a number of accident types (Abdel-Aty et al., 2006; Donnell and Mason, 2002, 2006a; Kraus et al., 1993). Magnitudes, in terms of percent difference, were estimated by the NCHRP 3-88 team using the reported regression parameters when the required information to perform the calculation was available.

2.1.7.3.2 Safety Effects of Interchange and Ramp Spacing

Three studies took a direct look at the relationship between interchange or ramp spacing and safety (Cirillo, 1970; Bared et al., 2006; Pilko et al., 2007). In all three, the boundaries of a sample of freeway segments were defined by like points on consecutive interchanges or ramps and those segments were analyzed (i.e., the length of the freeway segment is also the interchange or ramp spacing). Cirillo (1970) reported accident rates by volume level and length, which were subsequently re-analyzed by the NCHRP 3-88 project team. Findings were illustrated in Exhibit 2-36. Bared et al. (2006) and Pilko et al. (2007) used negative binomial regression to model expected accident frequency as a function of freeway and traffic characteristics, including segment length (i.e., interchange spacing). The studies found that accident rates (in terms of accidents per 100 MVM or expected accidents per mile per year) increased as spacing decreased. Results from all three studies indicated that incremental improvements in safety with increased ramp or interchange spacing diminish as the spacing becomes longer. From a safety perspective, this finding indicates that, for a long spacing, the segment operates as a normal freeway segment without deleterious interchange or ramp effects (a concept which has a traffic operations analog in the *HCM*).

The findings reported by Cirillo (70) are relevant, but 40 years old. The studies by Bared et al. (72) and Pilko et al. (69) use more modern analytical techniques, but with noted assumptions and limited applicability. The segments analyzed included only those where an entrance ramp from one interchange was followed by an exit ramp from an adjacent, downstream interchange. Measures of exposure and spacing were confounded in their model specifications and an assumption of linearity between segment length and accidents was required for practical interpretation of their findings. The normalizing technique is promising if one can be fairly certain that effects other than exposure and interchange spacing are not fully or partially captured in the segment length definition. This will require considering of a number of other variables potentially correlated with interchange and ramp spacing (e.g., presence of an auxiliary lane). Overall, the studies by Bared et al. (72) and Pilko et al. (69) are a first step on which to build an investigation of interchange and ramp spacing.

Several studies reported safety effects of a ramp or interchange count or density on a freeway segment of length *L* through a multivariate regression model (the inverse of these types of variables represents an average interchange or ramp spacing) (73, 74, 75). This technique is analogous to the interchange density, speed adjustment factor in the freeway segment analysis methodology of the HCM and is relevant to more corridor-level safety analyses of interchange spacing. Estimation results showed that expected accident frequencies and accident rates increased as the interchange and ramp count or density increased (i.e. as the average spacing decreased). Hadi et al., Anastasopoulos et al., and Milton et al. reported lower accident severities for segments with increased interchange density, expressed as the number of interchanges per mile (73, 74, 75). The finding was attributed lower speeds and smaller collision angles in the vicinity of multiple interchanges and was consistent with loosely supported trends from two other studies (65, 68). Overall, little is known regarding the effects of interchange and ramp spacing on accident severity; a gap that was addressed by the research conducted as part of this project (see Chapter 3).

2.2 FOCUS GROUP SUMMARY

In addition to the literature review, the project team facilitated a focus group "consisting of planners, designers, and operators of freeways and interchanges and other interested parties to assist in identifying concerns or needs in the current practice of ramp and interchange spacing." As outlined in this task, the project team submitted a memorandum to the NCHRP panel for their approval and suggestions for the focus group meeting approach, participants and discussion topics.

The team conducted the focus group via telephone, which was cost effective way to engage a wide range of individuals. The invited focus group participants were developed based on a review of researchers and authors from existing relevant research on this topic area and the team's familiarity with practicing planners, designers and operators of freeways and interchanges. Recognizing the diverse range of individuals that this topic area will potentially influence, the team included members from some of the primary agencies or organizations involved in this area of research such as AASHTO, MUTCD, and FHWA. Other invited participants included staff from state highway agencies and other research firms. Focus group participants are noted in the acknowledgements section at the beginning of this document.

Six people from the focus group invitation list were able to participate in the conference call. There were four state agency staff, one federal highway administration representative, and a representative from the private consulting field. The team conducted follow-up calls to other specific individuals who expressed interest in participating, but were unable to due to scheduling conflicts. For those that were unable to participate, a list of discussion questions and topics was sent via email and input was requested.

The focus of the group discussion provided the opportunity to hear a diverse range of perspectives in applying current ramp and interchange spacing criteria. In addition, these perspectives allowed the team to further understand some of the challenges and opportunities of applying the current criteria in contemporary and future practice. The following bullets summarize the discussion topics and focus group input.

2.2.1 General Challenges and Needs

- One of the challenges that state agencies face is the multiple requests for interchange access in urban areas. Many developments would like to have ramp access for their property, which requires ramps to be closely spaced.
- During ramp design, the ability to meet the standards sometimes results in longer ramps that then become closely spaced with the upstream or downstream existing ramps.
- Some state agencies have designed braided ramps due to close cross street spacing.
- Many agencies are working to eliminate all of the left-hand exits to better meet driver expectations and recommended ramp design characteristics.

- Spacing considerations should consider whether the facility is a system or service interchange. The spacing guidance may need to be separated for each type.
- State agencies would appreciate more guidance on when to use frontage roads, collector-distributor roads, or ramp braiding.
- Oregon Department of Transportation uses operational experience as the primary factor for making decisions about interchange access. ODOT often tries to find an existing similar situation for comparison purposes and to determine if that type of situation should be implemented again in another location.
- State agencies need additional information about how the geometry of the mainline and ramps can affect the spacing.
- For the *Guidelines*, it would be helpful if information about the various tradeoffs between ramp and interchange spacing is provided.

2.2.2 Other Considerations – Signing, Human Factors, and Vehicle Fleet

- When considering human factors, the driver age and purpose should be considered. Older drivers and tourists require additional time to make decisions.
- Signing is an important factor, but it often gets left out of the decision making process or is one of the last factors to be considered. In some cases, this results in limited spacing to provide adequate signing.
- Signing plans need to be designed for the unfamiliar driver. Unfamiliar drivers can impact the operations of many other vehicles if decisions are not clear and appropriate.
- State agencies need additional guidance on how to sign interchanges and how to integrate the signing in with the overall geometric design.
- Signing guidance should reference the MUTCD, but not so much that it becomes out-of-date as the MUTCD gets revised.
- Lane drops require different signing needs, due to the need for additional signs in advance of the exit.
- When considering vehicle fleet, the current one-mile spacing used by many agencies is often difficult to achieve when there are a large percentage of trucks. Therefore, designers need more guidance on the spacing impacts associated with trucks, particularly if there are steep grades.

2.2.3 Analysis Techniques

- State agencies typically use the Highway Capacity Software to conduct preliminary analyses and then CORSIM or another type of detailed analysis software is often needed for complex designs.
- Using 20 years forecast volumes in the analysis often leads to failing levels-of-service. Therefore, state agencies often look at the "worst" level-of-service or a comparative analysis.

The feedback and input from the focus group participants provided the team with additional insights regarding the needs of practitioners and state agencies. Many of the discussions during the focus group were similar to the input received from the panel, such as the challenge that state agencies are faced with when receiving multiple requests for interchange access in urban areas due to developments desire to have ramp access for their properties.

2.3 PANEL INPUT SUMMARY

The team solicited input from the NCHRP panel to collaborate and generate ideas for the work plan and guidelines development. Each panel member has a diverse range of experience with operations, design, and safety of ramp and interchanges. In addition, the panel has participated in group discussions to generate ideas and outline the objectives of this specific research problem statement. To conduct the most effective research work plan and develop the most comprehensive guideline document for ramp and interchange spacing, the team took advantage of the individual knowledge and the collective joint conversations that the panel had to discuss the execution of this project and final guidelines document.

The team requested panel input on the applying current ramp and interchange spacing criteria, as well as, the challenges and opportunities of applying the current criteria in contemporary and future practice. The panel input for each of the discussion questions is shown below.

What are the historical challenges in applying current ramp and interchange spacing criteria?

One of the most significant challenges in applying current ramp and interchange spacing criteria is the lack of information on the critical considerations for determining the appropriate interchange and ramp spacing. The primary resource that designers rely on is the guidance found in the AASHTO *"Policy on Geometric Design of Highways and Streets"* (Green Book). Exhibit 10-68 (Recommended Minimum Ramp Terminal Spacing) is commonly referenced, but there is almost no supplemental guidance for using the minimum recommended values. Therefore, designers often use the stated values in this table, rather than considering the specifics of their project needs.

Additional guidance on the following considerations would be beneficial for designers to make more informed decisions about each specific project characteristic.

- Operational impacts of closely spaced ramps with high volumes
- Operational impacts of high truck volumes
- Variations in acceleration and deceleration lengths
- Two lane entrance and exit ramps
- Ability to provide appropriate guide signing for all types of users

What are the challenges and opportunities of applying the current criteria in contemporary and future practice?

A significant challenge is that many agencies are under tremendous pressure to consider new interchanges on high volume urban and suburban freeways to accommodate growth. These proposed new interchanges may present challenges with regard to complying with the existing interchange and ramp terminal spacing criteria.

An opportunity is the ability to utilize new traffic analysis tools, such as micro-simulation models, to better understand the impacts of ramp spacing on traffic operations under a variety of conditions. The notes within Exhibit 10-68 of the AASHTO Green Book state that the values provided in the exhibit should be checked in accordance with procedure outlined in the Highway Capacity Manual. An opportunity for future practice is to expand this advisory to include other available traffic analysis tools, such as micro-simulation models.

When is the guidance needed? What are the decisions being evaluated when interchange or ramp spacing is a key consideration?

The interchange and ramp terminal spacing guidance is frequently referenced for situations involving a proposed new interchange on an existing freeway and there are existing interchanges closely adjacent to the proposed interchange. The guidance is used to help assess the safety and operational impacts of the proposed new freeway access. Design decisions such as whether to use braided ramps and/or collector-distributor systems are often based upon the ability to meet the "recommended minimum" ramp spacing volumes. These decisions can greatly effect project cost and therefore this guidance can have substantial impacts to transportation agencies.

What are the knowledge gaps when making a decision that involves interchange and ramp spacing?

There are numerous knowledge gaps, including:

- Effect of variations in ramp and mainline volumes on appropriate minimum ramp terminal spacing
- Effect of truck volume variations
- Knowledge of a driver's expectations regarding separation distances (ramp terminal spacing)
- Knowledge of what constitutes "adequate signing" for situations involving close ramp spacing
- Effect of variations in facility operating speed and suggested minimum ramp terminal spacing
- Spacing impacts due to decision sight distance

What might be the quantitative information a decision maker or designer would like to have access to before making a decision?

Design decisions on ramp terminal spacing should be based on an understanding of the influencing factors and applying a "risk managed" approach. Although there is commonly a strong desire among practitioners for having published numerical values for "minimums", it is critical that any such published values include supporting information to help guide a designer through a process of considering the risks for using the stated minimum values.

How do human factors, vehicle fleet, and signing considerations affect the decision making?

Human factors, vehicle fleet and signing considerations are critical in making decisions regarding appropriate ramp and interchange spacing and there is a significant knowledge gap in these areas. For example, in a typical urban freeway pattern of interchanges spaced approximately every mile, how problematic is it (from a human factors perspective) to then have an instance of two exit ramps spaced 1000 feet apart? Do drivers become "trained" by the preceding pattern of exit spacing and then have difficulties with an instance of a significantly shorter spacing? Does "adequate signing" overcome this violation in driver expectation or is the use of "typical" signing less effective for the unexpected condition? Should some type of "atypical" signing be used for the "atypical" condition?

Chapter 3
Research Activities and Findings

Chapter 3 **RESEARCH ACTIVITIES AND FINDINGS**

This chapter presents the findings of the Operations and Safety Work Plans. The panel approved these work plans during the February 2009 Panel Meeting in Washington DC. The NCHRP Project 3-88 research team (3-88 project team) spent the balance of the project executing these plans. These work plans identified and evaluated critical factors associated with varying ramp and interchange spacing dimensions. The work plan execution has also assisted the 3-88 project team with developing the *Guidelines* that are summarized in Chapter 4.

Traffic operations have long been considered when planning and designing freeway facilities and associated ramps and interchanges. Interchanges and ramps should be located with sufficient space to allow exiting and entering maneuvers to occur with few impacts to speed and capacity of the mainline freeway. The 2004 AASHTO Green Book provides ramp and interchange spacing guidance that is based on limited, decades-old operational and design considerations. The 2000 HCM provides procedures for calculating the level of service at ramp junctions, weaving segments, and basic freeway segments. The basic freeway segment procedure identifies a reduction in mainline freeway speed as the density of interchanges on a freeway increases. However, the HCM provides no guidance regarding the maximum or desirable spacing of ramps and interchanges; it simply acknowledges that spacing has an impact on traffic operations.

The 3-88 project team analyzed *interchange* spacing considerations by reviewing data from NCHRP Project 3-92: Production of the 2010 *Highway Capacity Manual*. NCHRP Project 3-92 proposes to update the density factors that are used to predict speed on a basic freeway segment. The NCHRP Project 3-92 researchers found ramp density to have a greater impact on freeway speeds than interchange density. Thus, ramp spacing became the focus of NCHRP Project 3-88, with interchange spacing remaining a key element.

The 3-88 project team analyzed the impact of *ramp* spacing on mainline freeway speed with microscopic simulation models of selected ramp combinations, a crash dataset created for the project, sensitivity tests of existing HCM analysis procedures, and new analysis of data sets from two other NCHRP projects. The 3-88 project team calibrated simulation models with field data to assess freeway operational performance with various freeway and ramp volumes while considering a range of ramp spacing values. Under a variety of traffic volumes, the 3-88 project team modeled different spacings of entry-entry and entry-exit ramp combinations and measured the impact on mainline freeway speed. The 3-88 project team created a crash database specifically for this project to assess the impact of ramp and interchange spacing on crash frequency. The high-quality dataset allowed a large range of potential safety-influencing features to be considered and included in the model.

3.1 ANALYSIS OF OTHER NCHRP DATA SETS

The 3-88 project team reviewed and analyzed data from three other NCHRP projects. Field data collection was a relatively limited part of NCHRP Project 3-88, and field-calibrated simulation models played a large role in the traffic operations work plan. Using data from other projects created much broader and diverse datasets without incurring the significant costs associated with field data collection. These datasets provided the 3-88 project team with additional means of analyzing the effects ramp and interchange spacing have on freeway operation, specifically speed. Reviewing these datasets also increased the 3-88 project team's understanding of the outcomes, findings, and limitations of previous spacing-related operational research. The three datasets utilized were from NCHRP Project 3-37 Capacity of Ramp-Freeway Junctions, NCHRP Project 3-75 Analysis of Freeway Weaving Sections, and NCHRP Project 3-92 Production of 2010 *Highway Capacity Manual*.

3.1.1 NCHRP Project 3-37 Capacity of Ramp-Freeway Junctions

NCHRP Project 3-37 was conducted in the early 1990s by Polytechnic University (Brooklyn, NY), with the final report issued in March 1994 (76) The purpose of NCHRP Project 3-37 was to create new analytical models for analyzing ramp-freeway junctions for the 1994 HCM. At the time, the existing models for ramp-freeway junctions were based on limited datasets collected in the early 1960s.

3.1.1.1 Project 3-37 Background and Key Findings

NCHRP Project 3-37 collected data at 42 single-lane onramps ("merge locations"), 16 single-lane offramps ("diverge locations") and 10 special sites with features such as double-lane ramps, system interchanges, or metered ramps. These sites were in 15 cities in 10 states.

At each site most data, including speed and volume, was collected by the NCHRP Project 3-37 researchers with video cameras. Five cameras were used at each site and spaced 500 feet apart to provide 2,000 feet of coverage. At merge sites, coverage began 500 feet upstream of the ramp-freeway junction and ended 1,500 feet downstream of the junction. At diverge sites, coverage began 1,500 feet upstream of the ramp-freeway junction and ended 500 feet downstream of the junction. For both merge and diverge sites, the ramp-freeway junction was defined as "the point at which the edges of the ramp lane and the freeway lane meet." This is often referred to as the painted gore, although NCHRP Project 3-37 did not use that term. Data at each site was collected in 15-minute bins, resulting in a total of 341 15-minute bins of data. Speeds reported in the datasets were from the station downstream of a merge or upstream of a diverge that reported the lowest average speed throughout the data collection period.

NCHRP Project 3-37 defined the ramp influence area, or the portion of the freeway in which turbulence due to a ramp exists. The ramp influence area includes only the right two lanes plus the acceleration lane or deceleration lane associated with the ramp, and extends 1,500 feet upstream of an offramp and 1,500 feet downstream of an onramp. The choice of 1,500 feet is somewhat arbitrary, as the NCHRP Project 3-37 researchers did not collect data further than 1,500 feet away from a ramp.

Because the influence area only contains two lanes, an important step in the methodology developed in NCHRP Project 3-37 is the prediction of the volumes in lanes 1 and 2 (V_{12}). The NCHRP Project 3-37 researchers developed several equations to predict V_{12} based on different geometric configurations. On six-lane freeways (three lanes each direction), some of these equations, summarized in Exhibit 3-1 below, consider distance to and volumes on adjacent ramps. When adjacent ramps were found to impact V_{12}, there was generally a direct relationship with ramp volume and an inverse relationship with distance to the ramp. Adjacent ramps were not found to have an effect on V_{12} on eight-lane freeways, and on four-lane freeways there is no need to predict V_{12} as it is simply the total volume of the freeway.

	Onramp	**Offramp**
Upstream on	No impact	Increases V_{12}
Upstream off	Increases V_{12}	No impact
Downstream on	No impact	No impact
Downstream off	Increases V_{12}	Increases V_{12}

Exhibit 3-1 Impacts of Adjacent Ramps on V_{12} on Six-Lane Freeways (76)

Once V_{12} is determined, the methodology no longer considers adjacent ramps in the remaining steps to determine ramp-freeway junction level of service.

3.1.1.2 NCHRP Project 3-37 Data Analysis for NCHRP Project 3-88

The primary objective of the traffic operations research for NCHRP Project 3-88 was to examine the impacts of ramp and interchange spacing on mainline freeway speed. The 3-88 project team reviewed the NCHRP Project 3-37 datasets and determined that they included sufficient data to analyze the impacts of ramp spacing on speed, but not to analyze the impacts of interchange spacing on speed.

The 3-88 project team analyzed two sets of data – one from the Project NCHRP 3-37 merge sites and one from the NCHRP Project 3-37 diverge sites. NCHRP Project 3-37 “special” sites (multilane ramps, ramp meters, etc.) were excluded. The 3-88 project team chose to keep the merge and diverge datasets separate because of the way in which the data had originally been collected. Since NCHRP Project 3-37 was focused on single ramps, speeds were collected immediately downstream of merging ramps and immediately upstream of diverging ramps. Combining the datasets and analyzing speeds between ramps would have created an inconsistency with where the speeds were collected along the freeway.

For each site, the NCHRP Project 3-37 datasets provided the distance from the study ramp to the nearest downstream ramp and upstream ramp. For this project, the 3-88 project team used the distance to the downstream ramp as the "distance between ramps" for merge sites and the distance to the upstream ramp as the "distance between ramps" for the diverge sites. This choice was made by the 3-88 project team for two reasons. First, it places the speed collection points between the ramps (or within the distance being measured). Second, if full, conventional interchange forms are at the sites, it places the speed collection points between interchanges rather than within them. Generally, the pairing of downstream ramps with merge sites and upstream ramps with diverge sites created EN-EX combinations. When it did not, the 3-88 project team excluded the site from further analysis. There were not enough EN-EN, EX-EX, or EX-EN combinations from which meaningful conclusions could have been drawn to apply to NCHRP Project 3-88.

For all analysis, the 3-88 project team chose distance between ramps to be the independent variable and mainline freeway speed to be the dependent variable. Many variables are known to affect freeway speed, and the 3-88 project team made an effort to identify impacts on speed that may have been a reflection of these variables rather than ramp spacing. First, for both the merge and diverge datasets, data was segregated by freeway level of service (LOS). LOS was determined by computing density from the volume and speed of the freeway as if it were a basic segment. For each LOS, data in 15-minute bins was plotted onto a graph. Three versions of each graph (with the same data points) were then created. One indicated whether each point represented stable or unstable flow, a second indicated the number of lanes on the freeway, and a third indicated different ranges of ramp volumes. In many cases, volume was only available from one ramp (the one that had been studied in NCHRP Project 3-37), so the volume of the second ramp was not considered. All of these plots are included in Appendix B

The 3-88 project team observed few trends in the data that are applicable to NCHRP Project 3-88. Freeways operating at LOS E experienced a wide range of speeds between ramps regardless of spacing, and freeways operating at LOS F experienced lower speeds than other levels of service. Most of the eight-lane freeways experienced slower speeds between the ramps than the four- or six-lane freeways, but the small sample of eight-lane freeways makes it difficult to draw conclusions for use in NCHRP Project 3-88. Ramp volumes (entering volumes from the NCHRP Project 3-37 merge sites and exiting volumes from the NCHRP Project 3-37 diverge sites) had no apparent impact on speeds.

Most notable was the lack of any apparent relationship between ramp spacing and freeway speeds between the ramps. This may be due to the range of ramp spacings in the dataset. NCHRP Project 3-37 does not seem to have prioritized close ramp spacing when selected data collection sites, which is not surprising since the purpose of the project was to analyze single ramps. Of the 40 sites analyzed by the 3-88 project team, 27 had ramp spacings between 2,000 and 5,280 feet, 11 had ramp spacings of over 5,280 feet, and only two had spacings under 2,000 feet.

The 3-88 project team considered including lane width, shoulder width, and speed limit in the analysis but was unable to do so. Lane width and shoulder width were not in the dataset. An undefined variable in the dataset believed to be speed limit or free-flow speed had the same value at nearly every site.

3.1.1.3 Summary of Analysis of NCHRP Project 3-37 Data

The 3-88 project team considered data from NCHRP Project 3-37, which studied operations in ramp-freeway junction areas, to investigate what impact, if any, ramp spacing has on mainline freeway speed. The 3-88 project team only analyzed EN-EX combinations with single-lane ramps, as these comprised a majority of the NCHRP Project 3-37 dataset. Most of the sites had ramp spacings that were several times larger than the current AASHTO minimum of 1,600 feet, with one site having a ramp spacing of over 17,000 feet. Within this range of spacings, there was no apparent impact of ramp spacing on freeway speeds. These findings suggest that if ramp spacing has an impact on freeway speeds, it is only when ramps are spaced closer than most of data from NCHRP Project 3-37. Future analysis should focus on this closer range of spacing, perhaps with spacings of 3,000 feet or less.

3.1.2 NCHRP Project 3-75: Analysis of Freeway Weaving Sections

NCHRP Project 3-75 was conducted by Polytechnic University in partnership with KAI, with the final report issued in January 2008 (77). The purpose of NCHRP Project 3-75 was to "calibrate new and/or updated models for prediction of performance in freeway weaving sections" for use in the upcoming 2010 HCM. Draft chapters for the 2010 HCM were produced as part of this effort as well (78, 79)

3.1.2.1 NCHRP Project 3-75 Background and Key Findings

NCHRP Project 3-75 collected data at 14 locations in six different states. Most sites were not between the loop ramps at a cloverleaf interchange, but rather between diagonal ramps at different interchanges. The sites were a mixture of Type A, B, and C weaving. One site was on a collector-distributer roadway, and another was at a two-sided weaving section (one ramp was on the left side of the freeway). The 3-88 project team did not analyze any of the data from these two sites, as they both contain conditions that are outside the scope of NCHRP Project 3-88.

The NCHRP Project 3-75 researchers collected data at most sites using aerial photographs taken from a fixed-wing aircraft. Data was collected at these sites for two hours. The NCHRP 3-75 researchers collected data differently at several other sites. Researchers from the Next Generation Simulation (NGSIM) project provided reduced data for two sites, a state DOT provided video data for one site, and the NCHRP Project 3-75 researchers experimented with a ground-based data collection system at one site.

Weaving sections, by definition, have an auxiliary lane between the entrance ramp and the exit ramp; all of the data collection sites for NCHRP Project 3-75 have an auxiliary lane. In this respect, NCHRP Project 3-75 fundamentally differs from NCHRP Project 3-88.

The weaving procedures developed by the NCHRP Project 3-75 researchers are largely new and replaced models that are decades old. The weaving methodology of the 2000 HCM is based upon the weaving methodology of the 1985 HCM with only minor changes. The 1985 methodology itself is based on data collected from 1963 and 1983. The NCHRP Project 3-75 researchers felt that the age of this data and the methodologies developed from it may limit its effectiveness in analyzing weaving sections today, and elected to concentrate their efforts on new data collected and new methodologies developed as part of NCHRP Project 3-75.

Major differences between the weaving procedures of the 2010 HCM and those of the 2000 HCM include eliminating different types of weaving (A, B, and C) and eliminating the 2,500 foot maximum weaving length. In place of the different weaving types, several calculations involving lane changing are performed. Interchange density, which has never previously been used in HCM weaving procedures, is a term in these lane changing calculations. In place of the 2,500-foot limit on the length of a weaving section, an equation is used. The equation requires two variables as inputs: the ratio of the weaving volume to total volume at the site, and the number of lanes from which a weaving maneuver may be made by changing only one or zero lanes. In most situations, this equation allows for weaving analysis to be applied to sections longer than 2,500 feet.

The 2010 HCM also defines the length of a weaving section differently than previous editions. The 2000 HCM defines the length of a weaving section as the distance from a point on the entry gore where the right-most edge of the freeway pavement is two feet from the left-most edge of the ramp pavement to a point on the exit gore where these edges are 12 feet apart. The NCHRP 3-75 researchers believed this definition was based on typical loop ramp designs from decades ago, and wanted to replace it because most weaving sections on modern freeways do not involve loop ramps.

The NCHRP Project 3-75 researchers considered four definitions of weaving length:

- Short length (LS) – the distance between the end points of barrier markings (such as solid stripes) that prohibit or discourage lane-changing;
- Base length (LB) – the distance between the points where the left edge of the ramp travel lane(s) and the right edge of the freeway travel lanes meet;
- Long length (LL) – the distance between physical barriers in the merge and diverge gore areas; and,
- Average length – the average of the short length and base length.

The first three of these definitions are depicted below in Exhibit 3-2.

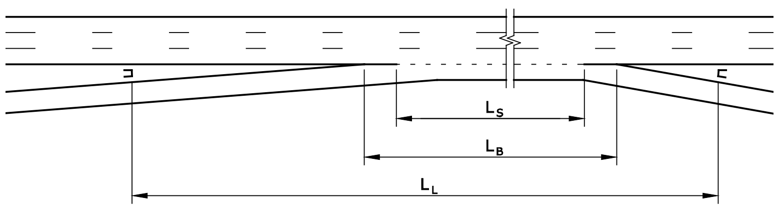


Exhibit 3-2 Possible Definitions of Weaving Segment Length. NCHRP Project 3-75 and the 2010 HCM chose L_S and NCHRP Project 3-88 chose L_B

Statistical analysis performed by the NCHRP Project 3-75 researchers ultimately found that the short length (L_S) best fit the data that was collected. This was somewhat of a surprise to the NCHRP Project 3-75 researchers; videos recorded for NCHRP Project 3-75 showed barrier markings to not be well-observed in the field. However, the short length was ultimately used in all procedures developed in NCHRP Project 3-75. In cases where there is no barrier marking beyond the painted gore, the short length is simply equal to the base length.

3.1.2.2 NCHRP Project 3-75 Data Analysis for NCHRP Project 3-88

The 3-88 team examined the dataset from NCHRP Project 3-75 and determined that it was suitable for investigating the impact of ramp spacing on mainline freeway speed. The 3-88 project team analyzed the NCHRP Project 3-75 data in a manner similar to the NCHRP Project 3-37 data. The 3-88 project team aggregated the 5-minute bins of NCHRP Project 3-75 data into 15-minute bins, and then computed the LOS of the basic freeway segment upstream of the weaving section. The 3-88 project team planned on segregating the data by freeway LOS, but this was ultimately not done because nearly all time periods had LOS C conditions on the freeway.

The 3-88 project team then plotted all of the NCHRP Project 3-75 data onto a single graph, with ramp spacing as the independent variable and speed of all vehicles in the weaving section as the dependent variable. The base length was used to define ramp spacing when creating these graphs for consistency with other elements of NCHRP Project 3-88.

The initial plot of ramp spacing versus the speed of all vehicles in the weaving section, shown in Exhibit 3-3, did not reveal any relationship between the two variables. A subsequent graph that only considered the speed of vehicles remaining on the freeway through the entire segment (i.e., not entering or exiting) also did not reveal any trends. Different versions of these graphs were then created to explore what impact other variables might have on the results. One graph created by the 3-88 project team indicated the number of upstream lanes at each site, and other graphs indicated ranges of onramp volumes, ranges of offramp volumes, ranges of total ramp volumes, interchange densities, 2000 HCM weaving type, and free-flow speed (FFS) at the sites. These graphs can be seen in Appendix A. None of these variables appear to have an impact on speed.

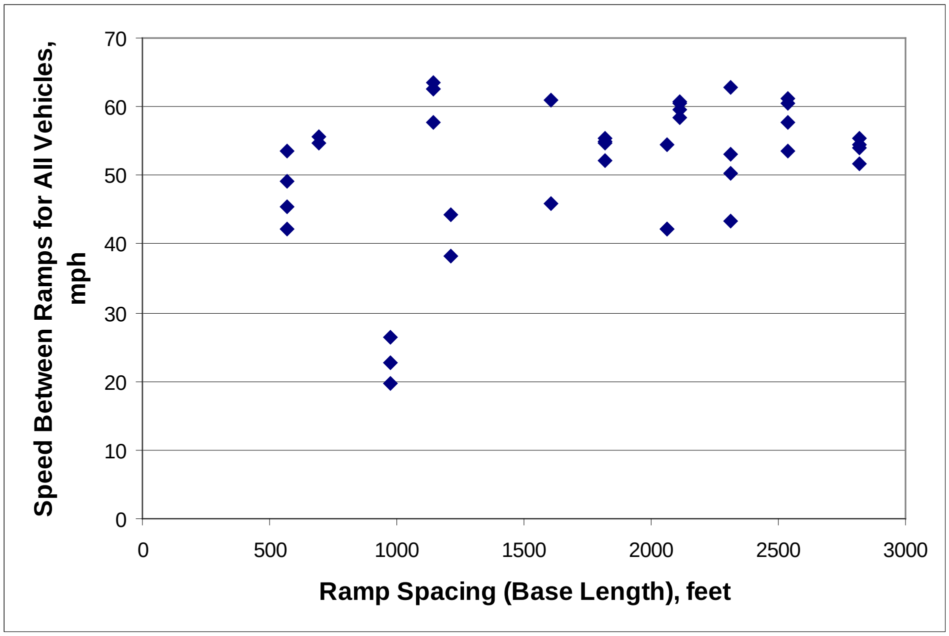


Exhibit 3-3 Ramp Spacing (weaving section length) Versus Speed at NCHRP 3-75 Data Collection Sites (15-minute bins).

The presence of FFS in the dataset also allowed the 3-88 project team to investigate the *reduction* in speed in the weaving section. In theory, such an analysis minimizes the impact of freeway conditions themselves, and instead highlights the impact of closely spaced ramps on freeway conditions. The 3-88 project team prepared a graph of ramp spacing versus the reduction from FFS, shown in Exhibit 3-4. Once again, multiple versions of this graph were prepared, with indications for the number of upstream lanes, the range of ramp volumes, etc. These graphs can be seen in Appendix B. Ultimately, none of these graphs revealed any relationship between ramp spacing and a reduction in freeway speed.

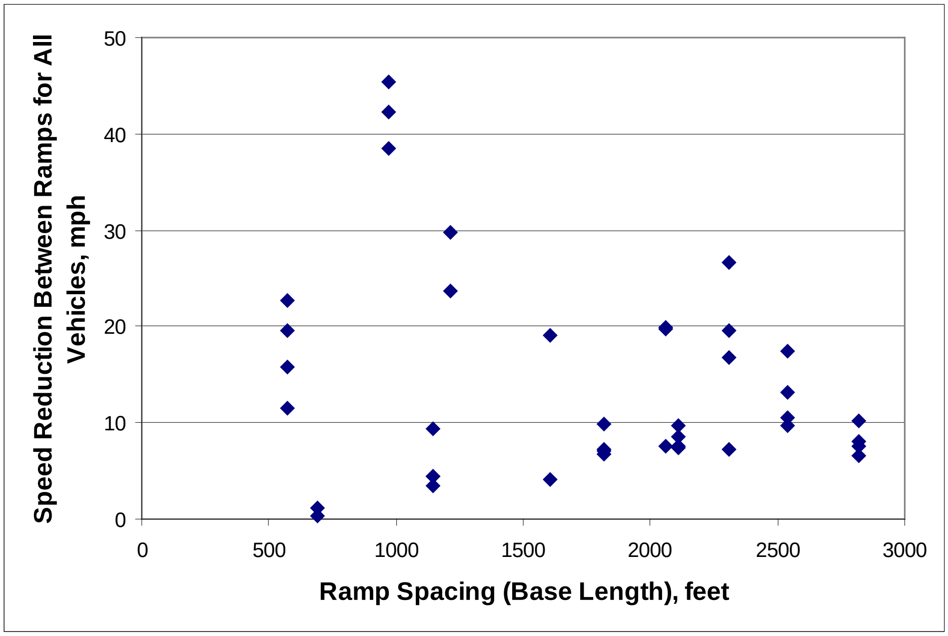


Exhibit 3-4 Ramp Spacing (weaving section length) Versus Reduction in Speed at NCHRP Project 3-75 Data Collection Sites (15-minute bins).

3.1.2.3 Summary of Analysis of Project 3-75 Data

Data from NCHRP Project 3-75, which studied operations in weaving segments, was used to investigate what impact, if any, ramp spacing has on mainline freeway speed. Most data was collected between diagonal ramps serving different interchanges, not between loop ramps at the same interchange. Although the NCHRP Project 3-75 researchers ultimately incorporated ramp spacing (i.e., the length of the weaving section) into weaving analysis procedures they developed, the 3-88 project team did not feel that the relationship between ramp spacing and speed was strong enough to use in design-based guidance and recommendations.

3.1.3 NCHRP Project 3-92: Production of the 2010 Highway Capacity Manual

NCHRP Project 3-92 is being led by KAI. The scope of NCHRP Project 3-92 includes producing the next edition of the HCM and conducting miscellaneous research projects that are needed to supplement analysis procedures in some chapters. One research project conducted by Polytechnic University was to recalibrate the freeway speed-flow curves that are in the 2000 HCM (5). Interchange density is one factor that affects FFS in the methodology of the 2000 HCM, and the NCHRP Project 3-92 researchers reevaluated its impact. The 3-88 project team speculated it may be able to incorporate any new findings related to the impact of interchange density on FFS into NCHRP Project 3-88.

Ultimately, the NCHRP Project 3-92 researchers chose to remove interchange density from the FFS prediction model and replace it with ramp density. Within the NCHRP Project 3-92 dataset, the relationship between FFS and interchange density was counterintuitive: as interchange density increased, FFS also increased. The NCHRP Project 3-92 researchers found that the relationship between FFS and ramp density, while weak, was intuitive: as ramp density increased, FFS decreased.

The 3-88 project team noted that NCHRP Project 3-92's focus on ramp spacing versus interchange spacing may be consistent with the 3-88 project team's perspective that emphasizes ramp spacing values over interchange spacing.

3.1.4 Summary of Analysis of Previous NCHRP Datasets

The 3-88 project team reviewed datasets from three previous NCHRP projects that were related to ramp and interchange spacing: NCHRP Project 3-37 Capacity of Ramp-Freeway Junctions, NCHRP Project 3-75 Analysis of Freeway Weaving Sections, and NCHRP Project 3-92 Production of 2010 *Highway Capacity Manual*. Overall, the 3-88 project team felt that, in these datasets, the relationship between ramp spacing and freeway speed was not strong enough to be the basis of any design guidance.

3.2 HCM METHODOLOGIES

Federal and state design guidance for ramp spacing values generally provide a single minimum recommended ramp spacing dimension for each possible ramp combination (EN-EX, EN-EN, etc). Little guidance is available to designers with regard to how minimum ramp spacing needs may vary under different traffic-volume scenarios. The 3-88 project team explored applying HCM principles that incorporate traffic volumes to consider their influence on ramp spacing values.

The HCM provides two sets of methodologies for analyzing the impacts of ramps on a freeway's operation. The impact of an exit or entrance ramp is analyzed with the HCM's ramp-freeway junction procedure. The impact of an entrance ramp followed closely by an exit ramp, with an auxiliary lane between the ramps, is analyzed with the HCM's weaving procedures. When no auxiliary lane exists, or when a different combination of ramps is present (such as an entry followed by an entry), the HCM's ramp-freeway junction procedures are used to analyze each ramp-freeway junction separately, with the distance between the ramps being an input to the procedure in some cases.

The 3-88 project team investigated weaving and ramp-freeway junction procedures to see if, with known traffic volumes and a desired LOS, planning-level spacing guidance can be developed. The 3-88 project team found that, for most cases, such guidelines could not be developed due to the complexity of the methodologies or lack of spacing terms in the procedures. However, some findings, with limited applicability to these guidelines, are presented below. The 3-88 project team investigated ramp-freeway junction guidelines with the methodology of the 2000 HCM, which will be virtually unchanged in the 2010 HCM. Weaving guidelines were investigated using the draft procedures of the 2010 HCM, which has an entirely new weaving procedure. The weaving procedures were found to be too complex to form the basis of any simple, conceptual ramp spacing dimension guidelines.

3.2.1 Ramp-Freeway Junctions

The HCM provides a procedure for analyzing ramp-freeway junctions on two-, three-, and four-lane freeways. The procedure determines the LOS for the right two lanes of the freeway at a single merging or diverging ramp. On three- and four-lane freeways, the procedure includes a step that calculates the volume in the right two lanes given the freeway's directional flow. When analyzing an entry ramp on a three-lane freeway, the calculation of the volume in the freeway's right two lanes (and ultimately the LOS of the ramp-freeway junction) takes into account the distance to the next exit ramp downstream.

The four-lane, ramp-freeway junction procedure does not take adjacent ramps into account, primarily due to the small amount of data collected from four-lane freeways at the time the HCM methodology was developed. Thus, ramp spacing plays no role in the analysis for ramp-freeway junctions on two- or four-lane freeways, but it does on three-lane freeways. This is true for both merging ramp and diverging ramp procedures. Given the inconsistency in the two procedures and the limitation of having no ramp spacing value correlation, the 3-88 project team concluded there was limited value in pursuing HCM applications for two- or four-lane freeways.

Using the HCM procedures for a merge ramp-freeway junction on a three-lane freeway, the 3-88 project team solved the equations for the term representing distance to an adjacent downstream exit ramp.

3.2.1.1 Calculations

The calculation of minimum ramp spacing to achieve a desired LOS began with Equation 25-5 of the 2000 HCM (Equation 3-1 below), which determines the density of a merge influence area.

$$D_R = 5.475 + 0.00734 V_R + 0.0078 V_{12} - 0.00627 L_A \qquad \text{(Equation 3-1)}$$

where

DR = density of merge influence area (pc/mi/ln)
VR = on-ramp peak 15 minute flow rate (pc/h)
V_{12} = flow rate entering ramp influence area (pc/h)
L_A = length of acceleration/deceleration lane (ft)

The flow rate in Lanes 1 and 2 of a freeway immediately upstream of a merge (V_{12}) is given by:

$$V_{12} = V_F \times P_{FM} \qquad \text{(Equation 3-2)}$$

where

V_F = freeway peak 15 minute flow rate (pc/h)
P_{FM} = proportion of approaching freeway flow remaining in lanes 1 and 2

For a six-lane freeway with three lanes in each direction, P_{FM} is calculated using the following equation:

$$P_{FM} = 0.5487 + 0.2628 V_D / L_{down} \qquad \text{(Equation 3-3)}$$

where

V_D = demand flow rate on adjacent downstream immediately upstream of merge
L_{down} = distance to adjacent downstream ramp (ft)

From Equation 1,

$$V_{12} = \frac{D_R - 5.475 - 0.00734 V_R + 0.00627 L_A}{0.0078} \qquad \text{(Equation 3-4)}$$

From Equations 3-2 and 3-4,

$$P_{FM} = \frac{V_{12}}{V_F} = \frac{D_R \text{-} 5.475 \text{-} 0.00734 V_R + 0.00627}{0.0078 V_F}$$

$$\because P_{FM} = 0.5487 + 0.2628 V_D / L_{down}$$

$$L_{down} = \frac{0.2628 V_D}{P_{FM} \text{-} 0.5487}$$

$$L_{down} = \frac{0.00205 V_D V_F}{(D_R \text{-} 5.475 \text{-} 0.00734 V_R + 0.00627 L_A) \text{-} 0.00428 V_F} \qquad \text{(Equation 3-5)}$$

At this point it is necessary to choose a desired density to determine minimum “acceptable” ramp spacing. The 3-88 project team selected three densities for analysis – the maximum densities under LOS C, D, and E. For example, LOS C corresponds to a density of 28 to 35 pc/mi/ln. To calculate the minimum distance to the downstream ramp, D_R = 35 pc/mi/ln is substituted into equation 3-5. The 3-88 project team applied the upper value of the density range for each LOS grade.

Thus,

$$L_{down\ min,\ C} = \frac{0.00205 V_D V_F}{(29.525 - 0.00734 V_R + 0.00627 L_A) - 0.00428 V_F} \quad \text{Equation 3-6)}$$

where

$L_{down\ min,C}$ = minimum distance to adjacent downstream ramp to maintain a LOS "C"(ft)

Equation 3-6 contains a term for each relevant volume (both ramps and the freeway) as well as the length of the acceleration lane for the merging ramp. Assuming an acceleration lane length, the 3-88 project team created a chart that can be used to see if approximate entry-exit ramp spacing values will create a design that achieves LOS C. Similar charts were also developed for LOS D and E. For all charts the 3-88 project team assumed the following inputs:

- Peak-hour factor of 0.92
- Passenger-car equivalent for trucks of 1.5
- Driver population factor of 1.0
- Acceleration lane length of 600 feet
- For the freeway:
  - 60 mph free-flow speed
  - 10% trucks
  - 0% RVs
- For the ramps:
  - 5% trucks
  - 0% RVs

3.2.1.2 Outcome

Charts developed by the 3-88 project team are shown in Exhibits 3-5 through 3-7.

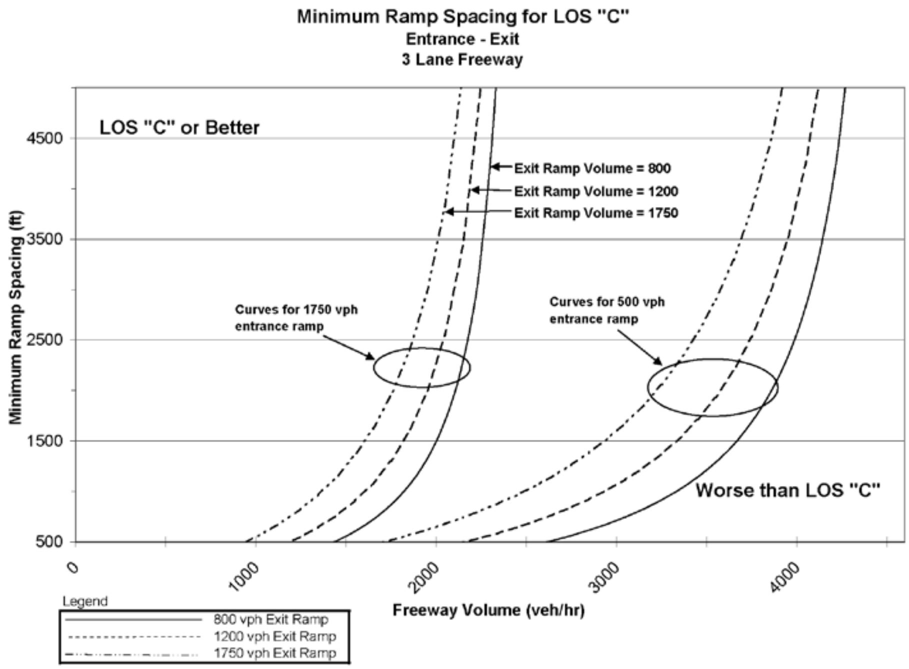


Exhibit 3-5 Minimum Ramp Spacing to Achieve LOS C on a Three-Lane Freeway

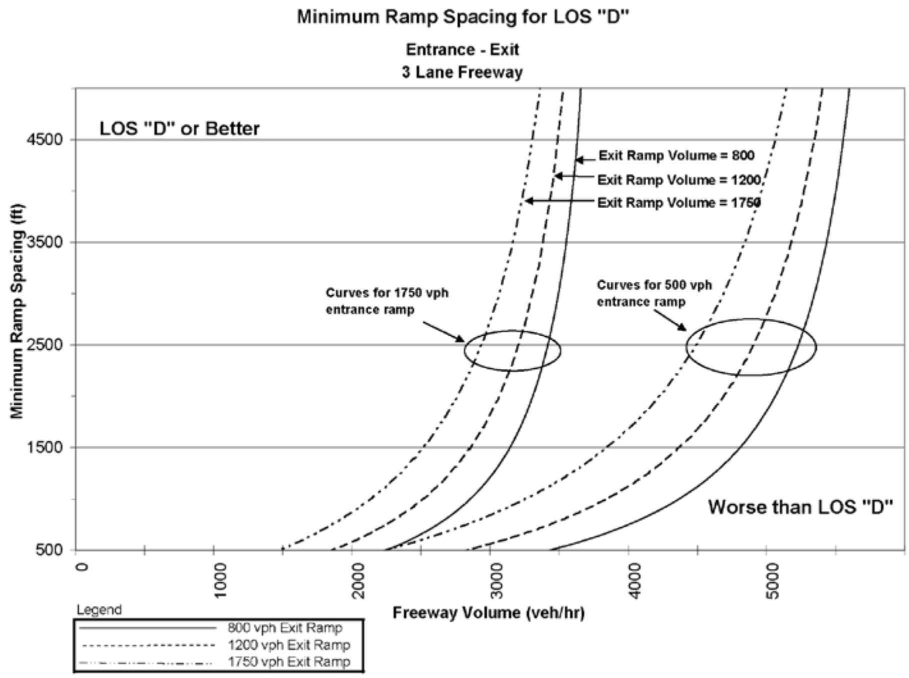


Exhibit 3-6 Minimum Ramp Spacing to Achieve LOS D on a Three-Lane Freeway

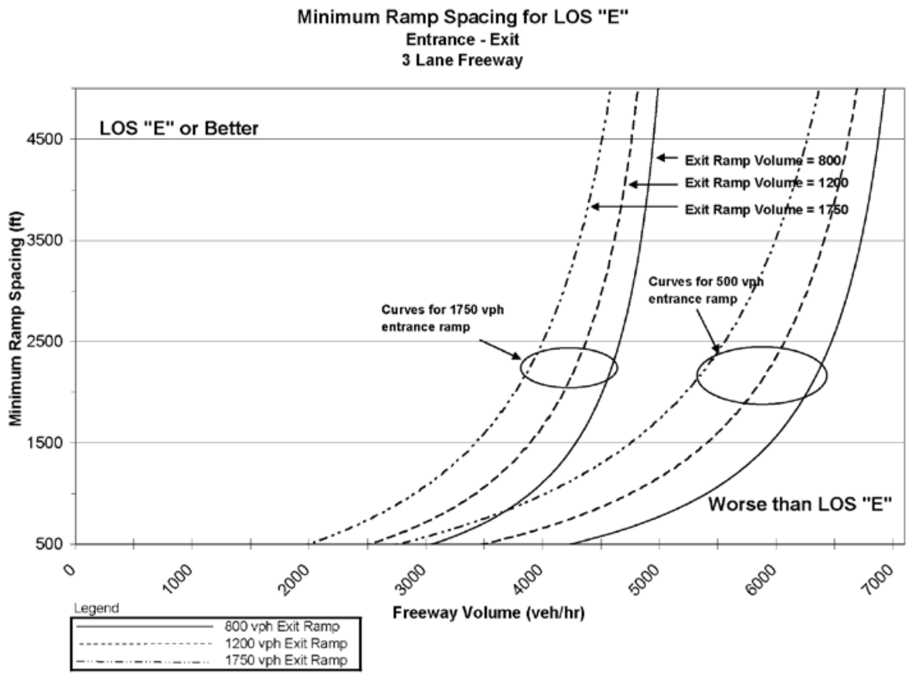


Exhibit 3-7 Minimum Ramp Spacing to Achieve LOS E on a Three-Lane Freeway

3.2.1.3 Applying the Charts

The charts shown above may be used in the initial planning stages of a project to see if conceptual designs are feasible from a traffic operations perspective. For example, if an agency desires LOS D for its facility, the user would apply the LOS D chart. A user of the chart should begin by finding the freeway volume being studied on the x axis. The user should then find the set of curves associated with the volume on the entry ramp. In the charts, curves are only provided for entry-ramp volumes of 500 vehicles per hour (vph) and 1,750 vph for ease of presentation.

For example: Using the LOS D chart (Exhibit 3-6), with a (three-lane) freeway volume of 3,000 vph and an entrance-ramp volume of 1,750 vph, proposed ramp spacing of 3,500 feet should result in LOS D or better operation on the freeway regardless of the volume on the downstream exit ramp. If the entrance ramp volumes were 1,250 or 800 vph, ramp spacings of 2,500 feet and 1,500 feet, respectively, would provide LOS D operation. For entrance- and exit-ramp volumes not shown in any of the exhibits, interpolation may be used.

3.2.2 Weaving

The 2010 HCM will include an entirely new weaving analysis procedure developed from a new dataset. Noteworthy differences in the 2010 weaving procedure in comparison to the 2000 weaving procedure include:

- A new way of measuring the length of a weaving section.
- Replacement of Type A, B, and C weaving with "ramp weaves" and "major weaves."
- A variable maximum weaving length based upon traffic volumes and configuration of the section, instead of a 2,500-foot threshold for all cases.

The 3-88 project team attempted to develop simple charts or guidelines (like those developed from the ramp-freeway junction procedures) to approximate the performance of weaving sections. However, the 3-88 project team was unable to do so due to the complexity of the methodologies and the number of variables involved. The methodology has several decision points where the results of one calculation determine which calculation should be performed next. The 3-88 project team concluded that, given the wide range of variables, there would be limited value in exploring the weaving application for planning-level ramp spacing guidance. The 3-88 project team suggests designers should simply conduct a complete HCM weaving analysis early in a project's development as the ramp configurations are being investigated.

3.3 SIMULATION MODELING

The 3-88 project team conducted simulation modeling to assess the impact of ramp spacing on freeway speed. Two ramp combinations were investigated: an entry ramp followed by another entry ramp (EN-EN), and an entry ramp followed by an exit ramp (EN-EX). A base model of each of these ramp combinations was constructed and calibrated with the same ramp spacing as the field data collection sites. The 3-88 project team varied spacing, and then collected point travel speeds at various locations within the model as a means of comparing different ramp spacings.

Traffic volumes for mainline through, entering, and exiting movements were varied to test the impact of ramp spacing under differing demands. For the EN-EX model, an auxiliary lane between the entry and exit ramps was later added so that the 3-88 project team could assess potential operational benefits an auxiliary lane.

The 3-88 project team's simulation modeling was conducted using VISSIM because of its ability to realistically reflect freeway merge, diverge, and operational characteristics. VISSIM's ability to model detailed unique driver behavior characteristics, vehicle fleet types and character allow the model to be calibrated to the site-specific conditions to be used in this evaluation. Additionally, project team members had prior experience with VISSIM and its widespread use would allow the study to be replicated by others.

3.3.1 Data Collection

The 3-88 project team collected data at one EN-EX and one EN-EN site in the Phoenix area. The project panel had previously concluded these ramp combinations are the highest priority for study as they have the greatest vehicle interaction. EX-EN and EX-EX ramp combinations have fewer merging and weaving maneuvers.

At each site, speed and volume data were collected for a 24-hour period with side-mounted digital wave radar on the freeway and with tubes on the ramps. This data is included in Appendix C. Video footage of each site was recorded to provide a visual record of traffic operations at each site, but was not used to capture speeds or volumes. Congestion did not occur at the EN-EX site. The EN-EN site experienced a greater range of volumes and congestion during peak periods. The data collected at both sites was used to calibrate the respective simulation models.

The EN-EX combination studied for this project was not a weaving segment, as there was not an auxiliary lane between the ramps. The 3-88 project team and project panel felt that the wealth of research on weaving segments made them less of a research priority than EN-EX combinations without auxiliary lanes.

3.3.2 Site Selection

The site-selection process began by establishing the characteristics of what might be considered "ideal criteria and features" of a potential data collection site, and then reviewing aerial photographs of selected freeways in 10 states. From this effort the 3-88 project team identified 16 EN-EX sites and two EN-EN sites as preliminary candidates for collecting data. A list of these sites and the site-selection considerations were provided in Interim Report 1. From this list the 3-88 project team recommended and the panel concurred on the two sites located in the Phoenix area: an entry ramp followed by an exit ramp on southbound SR 51 between Union Hills Road and Bell Road in Phoenix, and an entry ramp followed by an entry ramp on eastbound Loop 202 between Priest Drive and North Center Parkway in Tempe.

3.3.2.1 Selection Criteria

The sites were selected for several reasons:

- A thorough examination of the sites did not reveal any unusual geometrics or other features that would make them unsuitable for use in research. The sites are of modern design, and do not have low speed ramps, short merge areas, or other constrained features that are common on some older freeways.
- Overpasses between the ramps provided a vantage point for data collection at both sites.
- Data from the Arizona Department of Transportation's Freeway Management System (ADOT FMS) was available as a supplement to data collected by the 3-88 project team.

- Both sites are in the same metropolitan area, which minimized data collection costs.

Kittelson & Associates, Inc. (KAI) staff visited both data collection sites on March 30, 2009. The 3-88 project team conducted field visits to verify the site's basic geometric characteristics and identified suitable vantage points for video cameras. The 3-88 project team did not identify any fatal flaws with either site.

3.3.2.2 Crash History

The 3-88 project team obtained crash data and average annual daily traffic volumes (AADT) from ADOT as part of the review of the two traffic operations, data-collection sites. Crash data covered the three-year period beginning January 1, 2006, and ending December 31, 2008. The 3-88 project team obtained average crash rates and average injury crash rates for the freeway on which each site is located from the Maricopa Association of Governments (MAG). This data was used to evaluate the safety performance of the two Phoenix sites.

At both sites, the study segment was defined as beginning 0.3 miles upstream of the first ramp's painted gore and ending 0.3 miles downstream of the second ramp's painted gore. The 0.3 mile distance is consistent with the methodology of FHWA's Interchange Safety Analysis Tool (ISAT). At both sites, this segment definition resulted in a segment of 1.0 miles in length.

The southbound AADT at the EN-EX site is approximately 42,000 vehicles. This is the lowest-volume segment of SR 51, as it is near the northern end of the freeway and on the edge of the urbanized area. For comparison, the AADT at the EN-EN site serves approximately 101,000 vehicles in the eastbound direction. This is one of the highest-volume segments of Loop 202, as it is near downtown Phoenix, downtown Tempe, and Sky Harbor Airport.

The 3-88 project team calculated crash rates, in crashes per million vehicle miles of travel, for the study segments using the raw crash data and AADT provided by ADOT. Rates were calculated for all crashes and for injury crashes only. The injury crashes include possible injuries, non-incapacitating injuries, and incapacitating injuries. The rates are presented in Exhibit 3-8:

	EN-EX (SR 51)	EN-EN (Loop 202)
Crash Rate for Segment	0.54	1.71
Average Crash Rate for Entire Facility from MAG	1.58	1.50
Injury Crash Rate for Segment	0.15	0.50
Average Injury Crash Rate of Entire Facility from MAG	0.67	0.62

Exhibit 3-8 Crash Rates on Traffic Operations Study Segments (crashes/million vehicle miles of travel)

The crash rate at the EN-EX site is well below the facility average, while the crash rate at the EN-EN site is slightly higher than the facility average. The crash rate at the EN-EN site is higher than the facility average, which may correspond to the high traffic volumes at the site. This is not necessarily indicative of a crash problem at the study site. In general, the relationship between crashes and traffic volume is not linear.

The distribution of crashes by type at each site is provided in Exhibit 3-9. Forty-eight percent of crashes at the EN-EX site (SR 51) were single-vehicle crashes. Most of these single-vehicle crashes were collisions with the median barrier. These crashes were distributed throughout the segment. For at least the first 18 months of the crash data period, SR 51 had a dirt median with a cable barrier. By April 2009, (four months after the end of the three-year crash data period), ADOT had added a concrete barrier and HOV lanes to the median.

Seventy-one percent of collisions at the EN-EN site (Loop 202) were rear-end collisions. Many of the rear-end collisions occurred during the late afternoon, when volumes become high and stop-and-go traffic frequently occurs.

	EN-EN (SR 51)	EN-EN (Loop 202)
Single Vehicle	48%	11%
Sideswipe	28%	15%
Rear End	20%	71%
Backing	0%	1%
Other	4%	3%

Exhibit 3-9 Crash Types on Traffic Operations Study Segments

3.3.3 Data collection process

KAI staff engaged teaming partner Traffic Research & Analysis, Inc. (TRA) to determine data collection logistics and develop a detailed scope of work and budget. The 3-88 project team initially assumed that pneumatic tubes and video cameras would be used for all data collection, with tubes used to collect speed and volume on the ramps and video cameras used to collect speed and volume on the freeway. TRA suggested collecting data with side-mounted digital wave radar because of their previous success in obtaining accurate and precise data for ADOT. KAI independently investigated other applications of these tools and ultimately concurred with the TRA recommendation to use this equipment to collect the data.

3.3.3.1 Permitting

TRA frequently collects freeway data in the Phoenix area, and has permits from ADOT that allow them to mount their radar units along freeways. At the EN-EN site, the video cameras on the overpass had to be set up on the roadway shoulder because there was no sidewalk. TRA obtained permission from the City of Tempe, which maintains this roadway, to set up the cameras on the shoulder.

3.3.3.2 Equipment

Side-mounted digital wave radar measures speed and traffic volume by lane. The radar units are mounted on roadside objects such as signs, and measure freeway conditions at the mounting location. Exhibit 3-10 shows a close-up view of a radar unit and a roadside-mounted unit collecting data for this project.

Exhibit 3-10 Side-Mounted Digital Wave Radar Used by TRA for Data Collection. Left photo: Close-up view of the radar unit. Right photo: Radar unit collecting data at EN-EN site.

KAI staff contacted the Texas Transportation Institute (TTI), which had recently evaluated TRA's side-mounted digital wave radar units and found them to be satisfactory for counting vehicles on a freeway. (81) In comparison to a video counted by multiple people, the radar units had average volume errors of less than 5 percent. Lanes furthest from the mounting location (generally closest to the median, since the units are typically mounted on the right side of the road) had the highest errors – up to 10 percent at one test location. TTI found little difference in error count between high- and low-volume periods.

Based on this favorable review of the side-mounted radar, the 3-88 project team elected to use it for measuring speeds and volumes on the mainline freeway. Using side-mounted radar significantly reduced data collection costs because it eliminated the need for a person to manually count vehicles and compute speeds by watching a video recording. Video was recorded and used to qualitatively observe operational characteristics, such as lane changing, that could not be measured by the radar.

3.3.3.3 Scope of Data Collection

The 3-88 project team collected four hours of data, capturing both off-peak and peak conditions, at each site. On the freeway itself, speed and volume data was collected prior to the first ramp, between the ramps, and after the second ramp, with a video camera at each collection point.

Radar units eliminated the need for cameras at each of these three locations. With radar, the primary purpose of the video changed from collecting data at a specific location to providing a visual record of vehicular activity on the entire study segment. To best accomplish this, two cameras were placed on the overpass in the middle of each segment. One camera looked upstream towards the first ramp, and the other looked downstream towards the second ramp.

Radar also enabled speed and volume data to be collected for longer than four hours at each site. Radar units were set up the day before data collection was scheduled to occur, and taken down the day after. Since the units were continuously collecting data, an entire 24-hour day of data was downloaded instead of only four hours. Video was collected for four hours as initially planned, during both off-peak and peak conditions. Data was collected in 15-minute bins.

Exhibits 3-11 and 3-12 show the locations of data collection equipment (radar, tubes, and cameras) at the EN-EX and EN-EN sites, respectively. At the EN-EX site on SR 51, three radar units, two tubes, and two video cameras were used. At the EN-EN site on Loop 202, two radar units, two tubes, and two video cameras were used.

The data collection plan for the EN-EN site initially called for three radar units: one upstream of the first ramp, one between the ramps, and one downstream from the second ramp. However, the section of Loop 202 downstream from the second ramp is elevated, and there are no signs or other roadside objects on which a radar unit could have been mounted. There is also no vantage point from which a camera could have been set up to record traffic operations. Fortunately, an ADOT FMS detector is located there and the 3-88 project team was able to obtain speed and volume data from the detector for the same time period that all other data at the EN-EN site was collected.

3.3.3.4 Arizona Department of Transportation Freeway Management System (ADOT FMS)

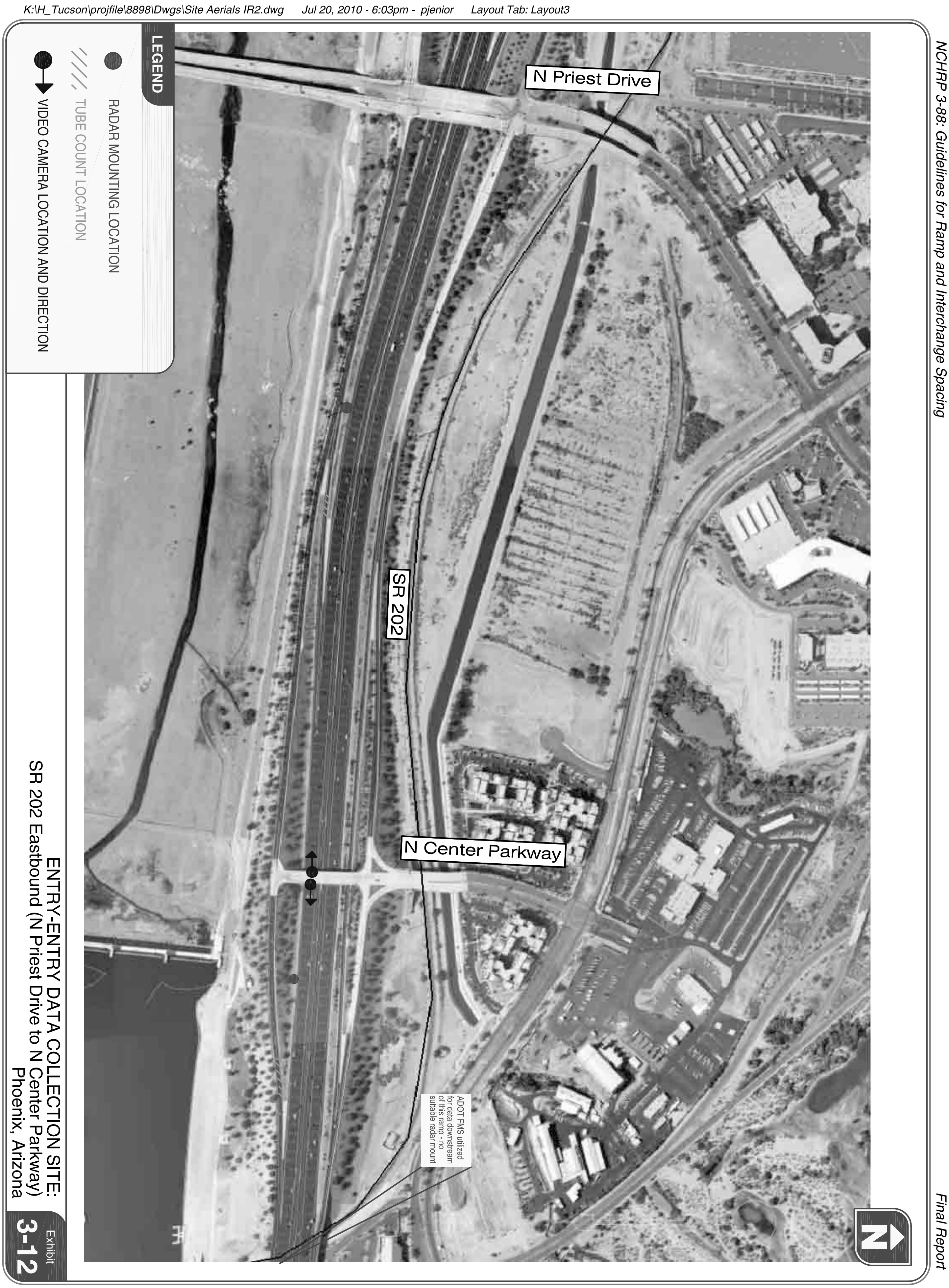
The Arizona Department of Transportation operates an extensive Freeway Management System (ADOT FMS) (82). This system collects data, including speeds and volumes per lane, on most segments of most freeways in the Phoenix metropolitan area through the use of loop detector stations. This data is primarily used to monitor traffic conditions in real time, but is also archived and made available to the public on an ftp site.

The EN-EX site on SR 51 lies outside of the ADOT FMS coverage area, although a station is located at an interchange approximately one mile downstream of the segment's end. The 3-88 project team compared average daily volumes from 2008, presented in 15-minute bins, at the downstream station with volumes collected for this project. This comparison confirmed

ENTRY-EXIT DATA COLLECTION SITE:
SR 51 Southbound (E Union Hills Drive to E Bell Road)
Phoenix, Arizona

Exhibit 3-11

K:\H_Tucson\projfile\8898\Dwgs\Site Aerials IR2.dwg Jul 20, 2010 - 6:06pm - pjenior Layout Tab: Layout1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NCHRP 3-88: Guidelines for Ramp and Interchange Spacing
Final Report
LEGEND
RADAR MOUNTING LOCATION
TUBE COUNT LOCATION
VIDEO CAMERA LOCATION AND DIRECTION
N Priest Drive
SR 202
N Center Parkway
ADOT FMS utilized for data downstream of this ramp - no suitable radar mount
ENTRY-ENTRY DATA COLLECTION SITE:
SR 202 Eastbound (N Priest Drive to N Center Parkway)
Phoenix, Arizona
Exhibit
3-12

that freeway volumes on the day of data collection were typical.

The EN-EN site on Loop 202 is well covered by ADOT FMS, with detectors located upstream of the first ramp, between the ramps, and downstream of the second ramp. Data from the ramps themselves is also available. The 3-88 project team used this data to verify that volumes on the day of data collection were typical.

3.3.3.5 As-Built Plans

As-built plans for both data collection sites provided the 3-88 project team with data that could not easily or accurately be measured in the field or from aerial photographs.

3.3.4 Data collection plan execution

TRA collected data at the EN-EX site on Tuesday, April 14, 2009, and at the EN-EN site on Thursday, April 16, 2009. A KAI team member was present during video data collection (scheduled from 2-6 p.m.) at both sites to observe the process and monitor traffic conditions. At the EN-EX site, data collection was conducted smoothly as scheduled.

3.3.4.1 Issues

At the EN-EN site, video data collection was conducted from 3:30-7:30 p.m. instead of 2-6 p.m. due to a crash on the freeway. Just before 2 p.m., a bicyclist riding on the freeway was struck by an automobile near the end of the taper of the first on-ramp. Numerous emergency vehicles responded to this crash, which forced drivers on the first onramp to cross the painted gore to merge, closed the freeway's right lane for a brief time, and distracted drivers. The last of these vehicles cleared the site around 3:30 p.m., and video recording was started then so that four hours could be captured before nightfall. No data collected prior to 5 p.m. was used for quantitative analysis or modeling due to the potential for lingering operational impacts related to the crash. Low traffic volumes at the end of the video data period allowed for off-peak conditions to be captured, and the 3-88 project team deemed this data adequate for its use.

Although several hours of video data from a crash-free period and nearly a full day of speed and volume data were captured at the EN-EN site on the first data collection day, a second day of data collection was scheduled at the site from 2-6 p.m. on Tuesday, May 5, 2009. The benefits of such data would have been limited, as crash-free data was collected during both peak and off-peak periods on the first day. Unfortunately, ADOT had begun a long-term construction project that included closing a lane on Loop 202 by the time the second day of data collection occurred. Data collected on this day is not suitable for analysis or modeling, and was not used.

The long-term nature of the construction project made it infeasible to collect additional data at the Loop 202 site. The 3-88 project team is confident that the data collected on April 16, 2009 is suitable for analysis and modeling purposes.

3.3.4.2 Data collection results

At the EN-EX site on SR 51, traffic volumes exceeded 1,150 vehicles per hour per lane during the peak on the segment between the ramps. The highest volume hour was during the AM peak. On-ramp volumes peaked at over 1,200 vehicles per hour, and off-ramp volumes peaked at over 500 vehicles per hour. No congestion was observed at this site.

At the EN-EN site on Loop 202, traffic volumes exceeded 1,950 vehicles per hour per lane during the peak on the segment between the ramps. The 3-88 project team observed congestion and decreases in speed. Volumes on the first onramp peaked at over 600 vehicles per hour, and volumes on the second onramp peaked at over 800 vehicles per hour.

3.3.5 Existing Conditions Model Construction

The 3-88 project team constructed VISSIM simulation models for the following two test sites:

- Entry-entry (EN-EN) site on Route 202 near North Priest Drive and North Center Parkway
- Entry-exit (EN-EX) site on Route 51 between East Union Hills Drive and East Bell Road

These locations both include four basic highway lanes, single-lane on- and off-ramps and no auxiliary lanes between ramps. At the EN-EN site ramp spacing is 2,180 feet, and at the EN-EX site ramp spacing is 2,100 feet, measured from painted gore to painted gore.

The 3-88 project team constructed the VISSIM model using as-built drawings, on-the-ground photography, and video data collection to ensure study-area models accurately reflect roadway plan, profile, and cross section, as shown in Exhibit 3-13. Only study-area ramps and freeway mainlines were modeled. Ramp-terminal operations and metering of traffic flows were beyond the scope of this project and were not included in the models. This represented a worst-case scenario for freeway operations, as ramp meters are intended to improve freeway operation.

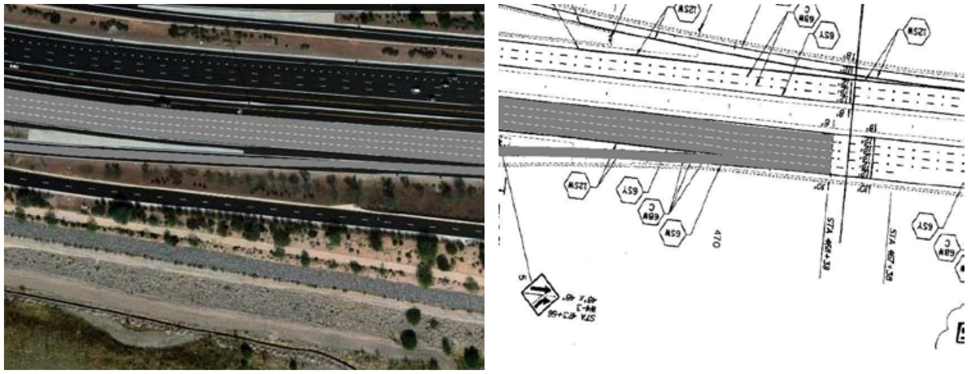


Exhibit 3-13 VISSIM Models Built Using Available Data Sources. Left photo: VISSIM model layered over existing high-resolution aerial photography. Right photo: VISSIM model layered over most recent striping plan.

The two base models built using existing geometric data and traffic volumes served as a validation tool to ensure that calibration could be conducted based on the field collected data.

3.3.6 Simulation Calibration

Good calibration of the simulation model is a key step to developing results in which one can be confident. The 3-88 project team collected a wealth of field data in the form of spot or point speeds from the two study sites in Phoenix. Field data collection is discussed in detail in section 3.1.1. Exhibit 3-14 shows the data collection points used to report speed for the two VISSIM simulation models. Data collected at these points match the field data collection point, and were used to calibrate the model to the existing point where speed data was collected.

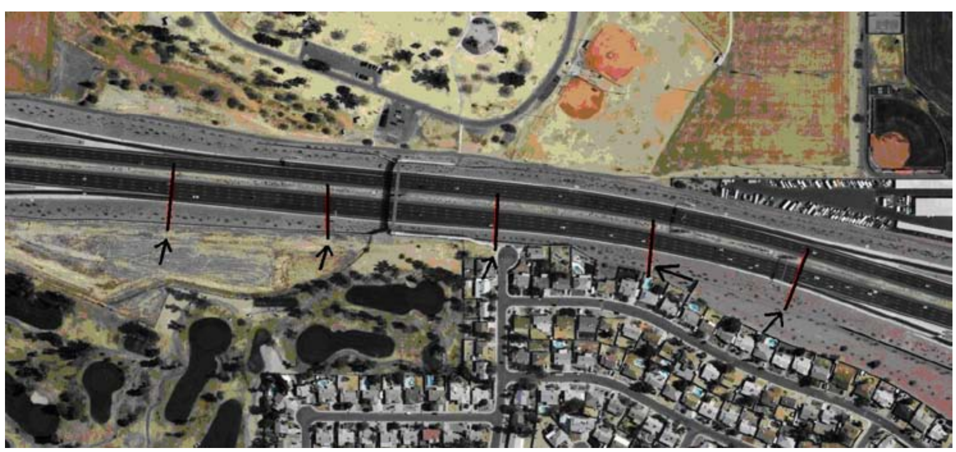


Exhibit 3-14 VISSIM data collection points were placed at both gore points (painted tips) and three additional intermediate collection points were evenly spaced between the gore points. EN-EX model pictured above

The 3-88 project team added operating characteristics to the simulation model to reflect test-site conditions. The following characteristics were field measured and included in the simulation model for calibration:

- *Weekday AM and PM peak hour traffic volumes* (mainline, entering ramp, and exiting ramp). Measured peak-hour traffic volumes were directly entered into VISSIM. For calibration, these exact volumes are generated within the peak hour. In later evaluation of ramp spacing alternatives, traffic volumes were allowed to vary to reflect day-to-day fluctuation in travel demand based upon random seeding.
- *Operating speed ranges* (mainline and ramps) during weekday AM and PM peak hours. Posted speeds along the site study areas were noted, but field-measured, free-flow, average speed ranges were collected and those speed ranges were input into VISSIM to develop reasonable desired speed profiles.
- *Vehicle fleet mix* (percent trucks and buses versus passenger cars). Field-measured fleet mix from each study area was input into VISSIM.
- *Driver behavior characteristics* (such as lane changing, gap acceptance/merging, car following distances) were generally compared between observed field video recordings and VISSIM simulation. The resulting VISSIM speeds were compared to the field measured speeds as an indicator of calibrated driver behavior in addition to animation visual inspection.

Thirty different random seed, traffic model runs were averaged to conclude in a single "VISSIM result" to compare to field-measured data to determine model calibration. Field measured data was collected on April 14 and 16 2009, as documented in the previous section of this report. The same approach of averaging 30 random seeds in VISSIM was used for alternative evaluation results presented in the following section.

For the purposes of this research effort, point speed on the freeway mainline was the primary calibration and performance measurement. The 3-88 project team set a desired calibration target of +/- 1 mph (1-2%) for three distinct, point-speed measurements when comparing field-measured averages and VISSIM-measured averages across all lanes. Both models were calibrated to these levels. This allowed for sufficient confidence to begin varying ramp spacing and traffic volumes, as described in the following section.

3.3.7 Alternative Ramp Spacing Evaluations

The 3-88 project team selected ramp spacings to model based on a combination of design literature including the AASHTO Green Book, established practices, and field ramp spacing. Ramp spacing is defined as painted tip of gore point to painted tip of gore point. This is consistent with the HCM 2010 and the of ramp spacing definition documented in the *Guidelines*.by the 3-88 project team

The 3-88 project team created four alternative ramp spacing VISSIM models to test the impacts of ramp spacing, as follows:

1. EN-EN site with ramp spacing of 700 feet
2. EN-EN site with ramp spacing of 2,500 feet
3. EN-EX site with ramp spacing of 1,000 feet
4. EN-EX site with ramp spacing of 2,500 feet

These ramp spacings represent reasonable ranges over which the 3-88 project team could investigate the sensitivity of speed to ramp spacing. The 3-88 project team assumed that ramps longer than 2,500 feet would have diminishing influence from upstream/downstream ramps, and ramps closer than 700 or 1,000 feet are closer than typically found on freeway systems.

For each of these four ramp spacing models, three mainline volumes entering the segment upstream of the first ramp were analyzed:

- 1,250 mainline entering vehicles per hour per lane (vphpl) (LOS B upstream of ramps and LOS C at highest-volume point within the segment studied);
- 1,500 mainline entering vehicles per hour per lane (LOS C upstream of ramps and LOS D at highest-volume point within the segment studied); and,
- 1,750 mainline entering vehicles per hour per lane (LOS D upstream of ramps and LOS F at highest-volume point within the segment studied).

The 3-88 project team selected these traffic volumes with the aid of Exhibit 13-6 of the 2000 HCM to represent different levels of service. For each ramp spacing model and mainline volume variant, a total of nine ramp-volume combinations were evaluated, as shown in Exhibit 3-15.

These ramp volumes represent combinations of three distinct types of ramp operation, up to capacity as defined in Exhibit 13-20 of the 2000 HCM (14). By looking at the nine combinations illustrated in Exhibit 3-15, a wide variety of intermediate ramp-volume combinations can then be inferred.

		Ramp 1 Volume (vph)		
		750	1250	1750
Ramp 2 Volume (vph)	750	1	2	3
	1250	4	5	6
	1750	7	8	9

Exhibit 3-15 Ramp-Volume Combinations

With three various mainline-volume scenarios and nine different ramp-volume scenarios for each mainline-volume scenario, this results in a total of 27 different simulation models per ramp spacing for each of the EN-EN and EN-EX geometries.

The EN-EX site in Phoenix where data was collected, as well as the models described above, do not have an auxiliary lane between the ramps. However, the 3-88 project team chose to create a second set of EN-EX models with an auxiliary lane. This allowed the 3-88 project team to investigate the operational influence of adding an auxiliary lane and better compare findings to the wealth of research that has been conducted on weaving sections. Including the auxiliary lane models, a total of 156 models were created and run for this project.

3.3.8 VISSIM Modeling Results

Using the calibration settings in the VISSIM model and the alternatives described in the previous section, the 3-88 project team adjusted the VISSIM models to meet the prescribed traffic volumes and ramp spacing for evaluation. For each alternative, the 3-88 project team conducted 30 simulation iterations or runs using a consistent set of random seed variables. These 30 results were then summarized and averaged for each point-speed location within VISSIM.

The 3-88 project team collected specific speed information at each of the five data collection points (see Exhibit 3-14), and then averaged the speeds across 30 runs. This resulted in a total data set of approximately 200,000 entries. Once the data collection period of the modeling was complete, the 3-88 project team compared reported speeds for each spacing alternative and volume scenario.

3.3.8.1 Measures of Effectiveness

The distinct measure of effectiveness for this evaluation is point speed. As shown in Exhibit 3-14, the point speed is measured at five distinct locations between ramp gore points for the EN-EN and EN-EX models, and under all ramp spacing alternatives. This means the measurement locations are closer together when ramp spacing is closer and further apart when ramp spacing is longer. This provides a relative comparison of speeds between each ramp spacing alternative.

The 3-88 project team used two evaluation approaches to convey the relative comparison of point speeds under various ramp volumes,:

1) **A comparison of the lowest speeds.** This evaluation simply compares the lowest speeds occurring within each mainline segment, regardless of the location within the segment. Exhibit 3-16 shows an example of this lowest-speed-reported comparison. The lowest speeds were chosen by the 3-88 project team for comparison in lieu of comparing the average speed within each mainline segment since averaging the speeds would have dampened the actual operational difference between each ramp spacing alternative.

For example, in the top left cell, the lowest point speed for a 1000-foot ramp spacing of 64 mph may be measured at the midpoint between gore points, while the lowest point speed for the 2,500-foot spacing (65 mph) was measured at the downstream ramp gore point. This comparison highlights the effect of ramp spacing on the lowest speed between gore points, but also shows absolute speeds that can be used in comparison to free-flow speed.

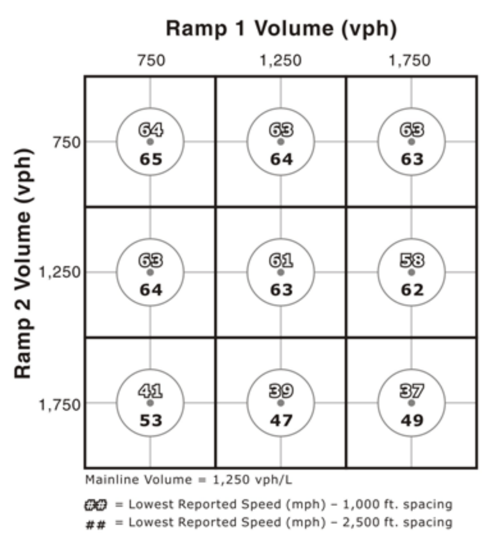


Exhibit 3-16 Example of Comparison of Lowest Speeds Reported

2) **The maximum corresponding point-speed difference**. This evaluation considers the speed difference between the two ramp spacing alternatives at

each measurement location. The 3-88 project team determined the speed differential at each of the five measurement points and the maximum speed differential is considered for each ramp-volume combination. The speed measurement points are equivalent in this comparison, regardless of ramp spacing,. Comparing lowest reported speed does not necessarily compare measurements at the same point. For example, if the speed occurring at the downstream gore point in the 1,000-foot model is 35 miles per hour, and in the 2,500-foot model is 50 miles per hour, then the corresponding point-speed difference is 15 miles per hour. Exhibit 3-17 shows an example of the maximum corresponding point-speed differentials for each volume scenario. From the nine data points shown in the exhibit, the 3-88 project team inferred expected trend zones showing the anticipated maximum speed differential at corresponding points under different ramp-loading conditions.

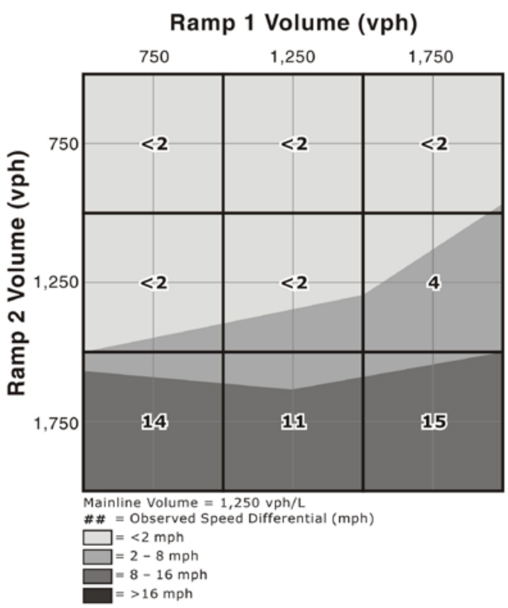


Exhibit 3-17 Example of Maximum Corresponding Point Speed Difference

3.3.8.2 Entry – Exit Analysis Results

Exhibits 3-18, 3-19 and 3-20 summarize the lowest-reported-speed comparisons and maximum corresponding point-speed differentials for the two EN-EX ramp spacing alternatives, 1,000 feet and 2,500 feet. The lowest reported speeds did not necessarily occur at the same measurement point for the two spacing alternatives. For the EN-EX model the average free-flow speed is 66 mph.

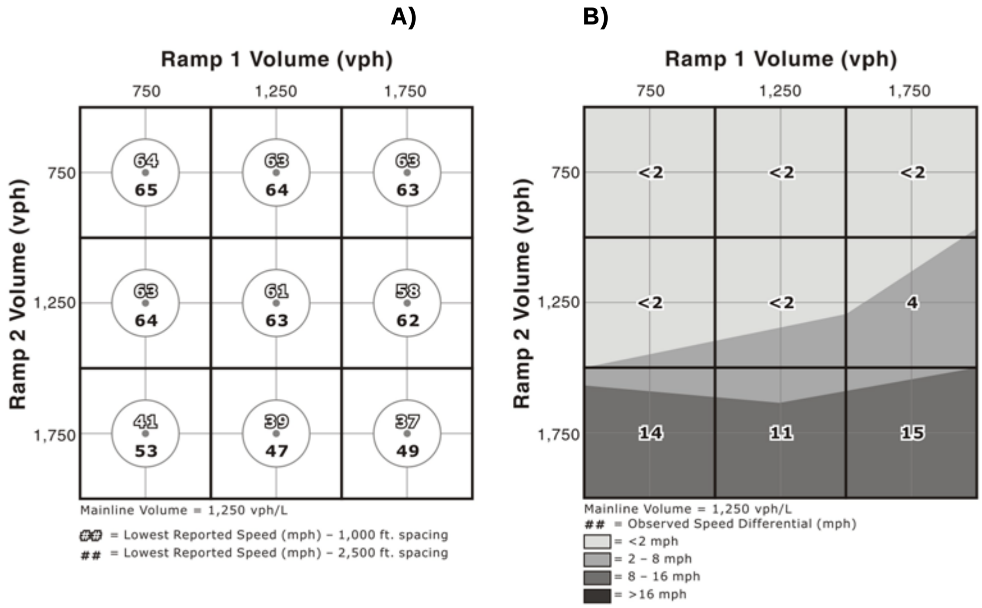


Exhibit 3-18 EN-EX Mainline Entering Volume 1,250 vphpl, 1,000-ft spacing and 2,500-ft spacing:
A) Comparison of Lowest Speed Reported,
B) Maximum Corresponding Point-Speed Difference

Simulation model results indicate the following:

- Ramp spacing does not significantly impact speed (i.e., >2 mph) at low to moderate exit volumes and uncongested conditions.
- The greatest ramp spacing effect (speed differential) occurs under congested conditions (i.e., speeds <50 mph).
- At the highest exiting (ramp 2) volume (1,750 vph), the lowest speed for the 2,500-foot spacing was 12 mph higher than the lowest speed for the 700-foot spacing.
- The largest observed point-speed differential at corresponding points is 15 mph.
- Speed differentials at corresponding points are slightly higher then the differential observed for the lowest speeds; however, they do show a consistency relative to ramp volumes.

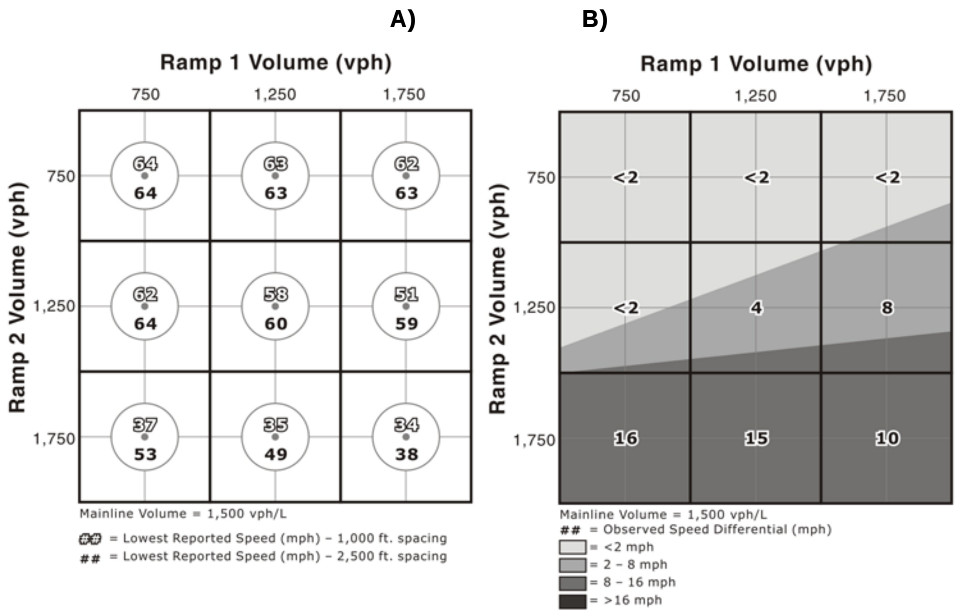


Exhibit 3-19 EN-EX Mainline Entering Volume 1,500 vphpl, 1,000-ft spacing and 2,500-ft spacing:
A) Comparison of Lowest Speed Reported,
B) Maximum Corresponding Point-Speed Difference

Simulation model results indicate the following:

- Comparing the lowest speeds, ramp spacing does not significantly impact speed (i.e., >2 mph) at low to moderate exit volumes and uncongested conditions; however, the maximum speed differences indicate a significant impact under moderate exiting volumes.
- The greatest ramp spacing effect (speed differential) occurs under congested conditions (i.e., speeds <50 mph).
- The greatest speed difference between the two spacing alternatives (16 mph) occurred at a low-entry volume and high-exit volume, not when both ramp volumes are high as in the previous data for a mainline entering volume of 1,250 vphpl. This suggests that at this mainline volume, along with high ramp volumes, the system's level of congestion is controlling speed and the effect of ramp spacing diminishes.
- Comparing the data between the 1,500 vphpl and 1,250 vphpl entering mainline-volume scenarios shows an increasing influence of ramp spacing across ramp volumes.

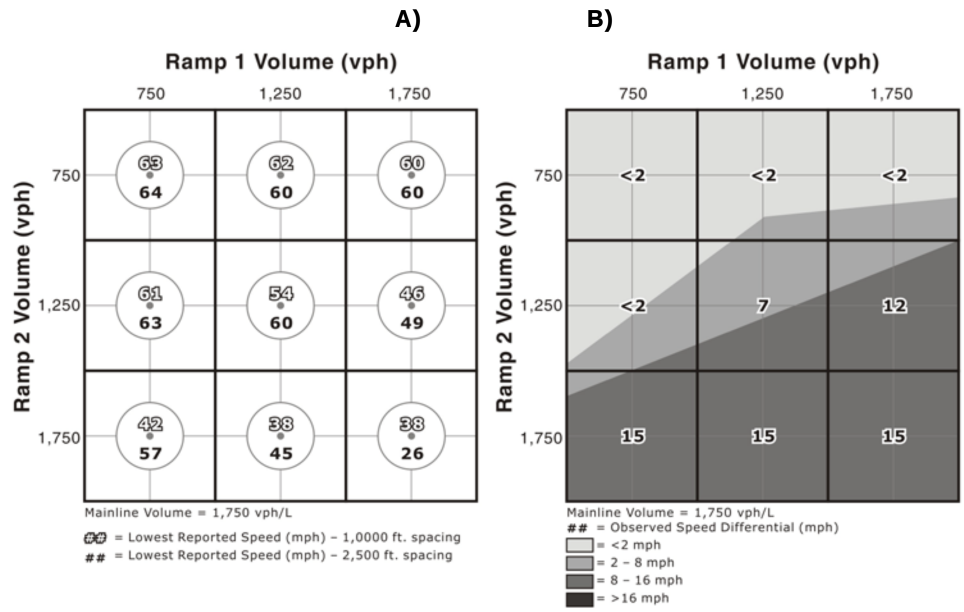


Exhibit 3-20 EN-EX Mainline Entering Volume 1,750 vphpl, 1,000-ft spacing and 2,500-ft spacing:
A) Comparison of Lowest Speed Reported,
B) Maximum Corresponding Point-Speed Difference

Simulation model results indicate the following:

- Comparing the lowest speeds, ramp spacing does not significantly impact speed (i.e., >2 mph) at low exit volumes and uncongested conditions.
- The greatest ramp spacing effect (speed differential) occurs under congested conditions (i.e., speeds <50 mph).
- As shown in Exhibit 3-20-A, the greatest difference in the speeds between the two spacing alternatives (15 mph) occurred at a low-entry volume and high-exit volume, not when both ramp volumes are high as in data for a mainline entering volume of 1,250 vphpl. This indicates that the system's level of congestion is controlling speed and the effect of ramp spacing diminishes as both entering and exiting volume increase to their highest levels.
- The largest observed point-speed differential at corresponding points is 15 mph.
- Speed differentials at corresponding points are higher then the differential observed for the lowest speeds; however, they do show a consistency relative to ramp volumes.
- Comparing the data between the 1,750 vphpl, 1,500 vphpl and 1,250 vphpl entering mainline-volume scenarios shows an increasing influence of ramp spacing across ramp volumes.

3.3.8.3 Entry – Entry Analysis Results

The 3-88 project team observed several general trends during the modeling and analysis of the EN-EN site.

- The lowest observed speeds generally occur at the gore point of the second entry ramp.
- The highest corresponding point-speed differentials generally occur at the first gore point or an intermediate measurement point between gore points.
- Longer ramp spacing can increase corresponding point speeds by up to 11 mph, but has diminishing impacts as mainline and ramp-traffic volumes increase towards capacity.

Exhibits 3-21, 3-22 and 3-23 document the lowest-reported-speed comparisons and maximum corresponding point-speed differentials for the two EN-EN ramp spacing alternatives, 700 feet and 2,500 feet. For the EN-EN model the average free-flow speed is 64 mph.

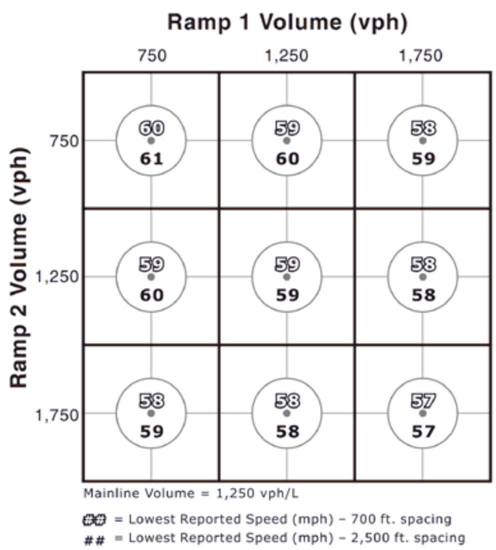


Exhibit 3-21 EN-EN Mainline Entering Volume 1,250 vphpl, 700-ft spacing and 2,500-ft spacing: Comparison of Lowest Speed Reported

Simulation model results indicate the following:

- The highest observed speed differentials were less then 2 mph for all ramp-volume combinations. As such, ramp spacing does not significantly impact mainline operations for the EN-EN ramp configuration when the mainline entering volume is low (1,250 vphpl).

The graph for corresponding speed differentials was omitted for this mainline volume due to it showing no speed differentials greater then 2 mph.

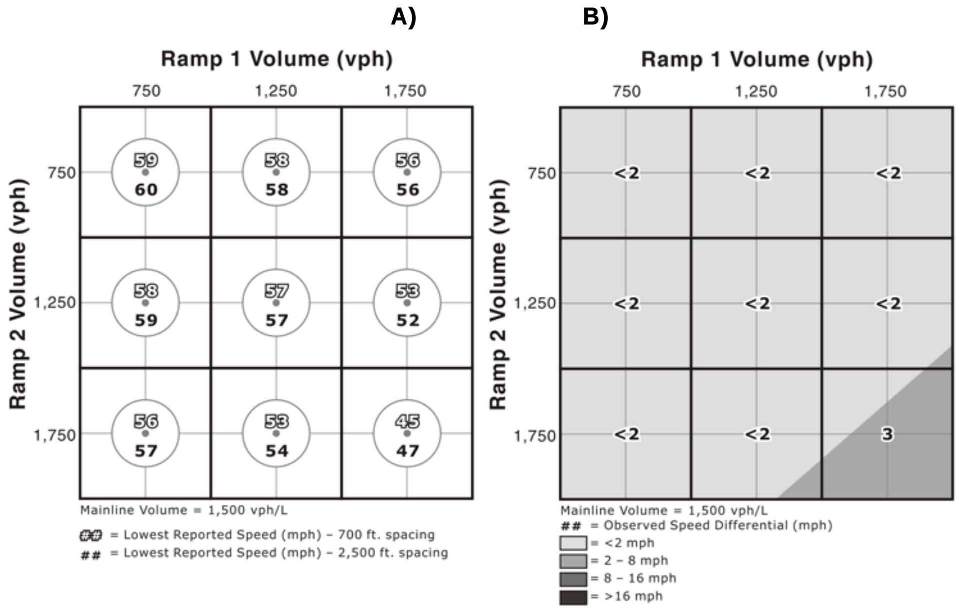


Exhibit 3-22 EN-EN Mainline Entering Volume 1,500 vphpl, 700-ft spacing and 2,500-ft spacing:
A) Comparison of Lowest Speed Reported,
B) Maximum Corresponding Point-Speed Difference

Simulation model results indicate the following:

- In comparing lowest speeds, the speed difference between the two ramp spacing alternatives was less then 2 mph for all ramp-volume combinations,
- The largest observed point-speed differential at corresponding points is 3 mph, but only for the highest ramp volumes.
- Similar to the previous data for an entering mainline volume of 1,250, ramp spacing does not significantly impact mainline operations for the EN-EN ramp configuration when the mainline entering volume is moderate (1,500 vphpl).

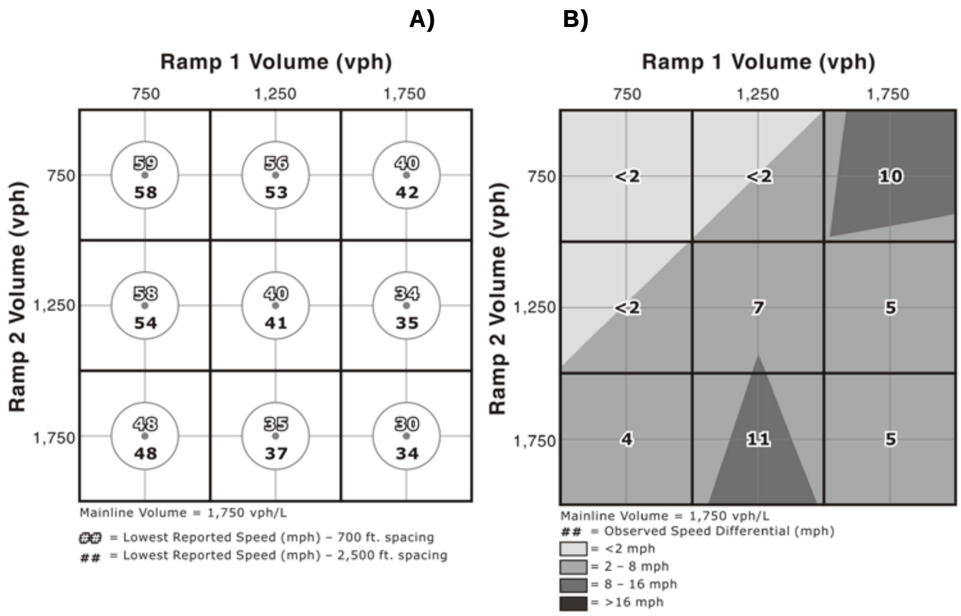


Exhibit 3-23 EN-EN Mainline Entering Volume 1,750 vphpl, 700-ft spacing and 2,500-ft spacing:
A) Comparison of Lowest Speed Reported,
B) Maximum Corresponding Point-Speed Difference

Simulation model results indicate the following:

- With an entering mainline volume of 1,750 vphpl, ramp spacing has a significant (>2 mph) effect on mainline speed at moderate and high ramp-volume scenarios.
- The greatest ramp spacing effect (speed differential) occurs under congested conditions (i.e., speeds <50 mph).
- The maximum corresponding point-speed differentials (Exhibit 3-23-B) indicate a larger ramp spacing affect than the speed differences between the lowest observed speeds (Exhibit 3-23-A). The uncharacteristic trend shown in Exhibit 3-23-B is primarily due to the varying speed profiles of the two ramp spacing alternatives under each ramp-volume scenario.

3.3.8.4 Auxiliary Lane Analysis Results

Comparisons of the EN-EX ramp configuration with and without an auxiliary lane between the ramps are shown in Exhibits 3-24 and 3-25. The 3-88 project team created models for both spacing dimensions previously analyzed: 1,000 feet and 2,500 feet. The data presented in these exhibits represent the increase in mainline speed resulting from adding an auxiliary lane.

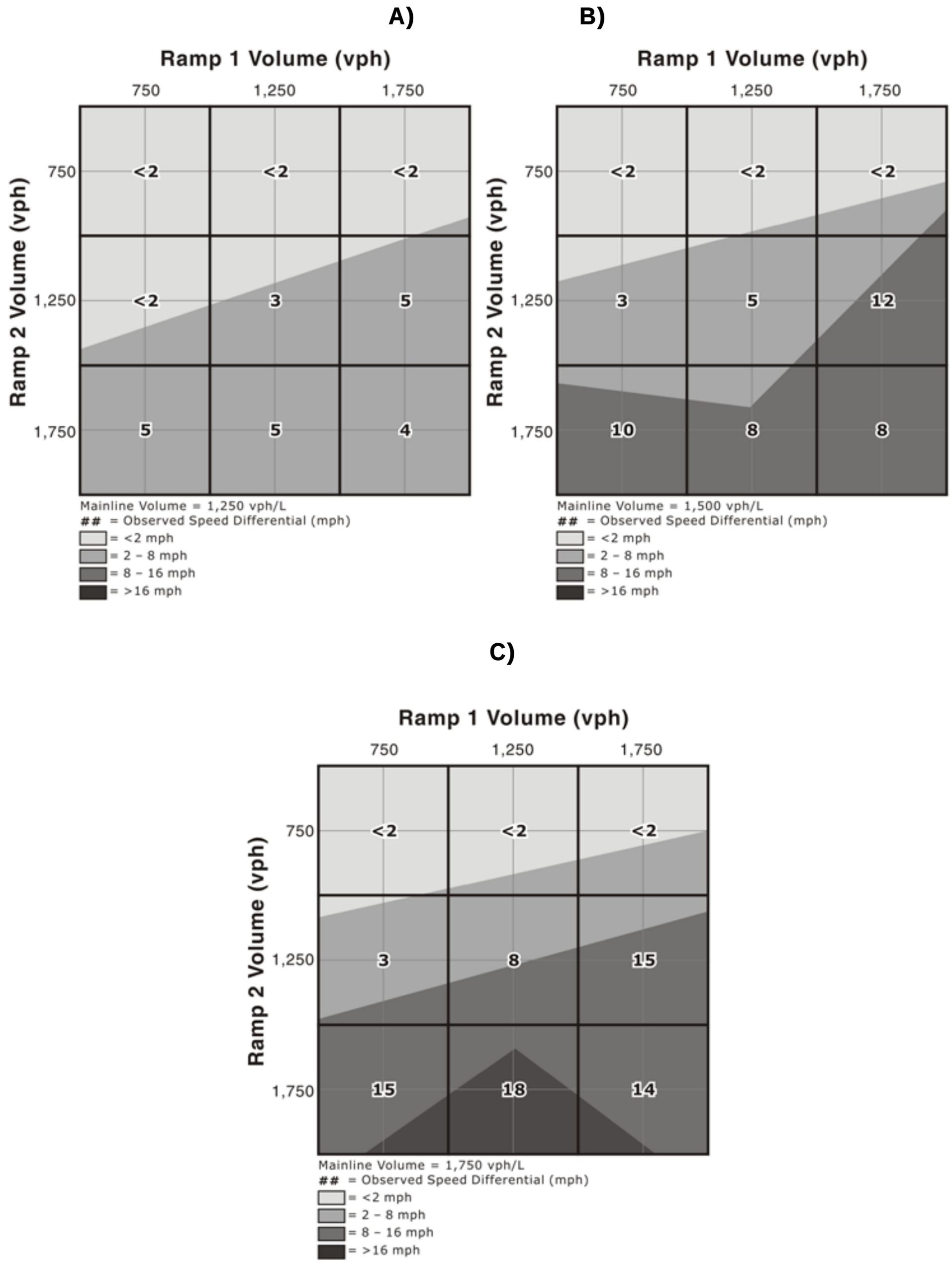


Exhibit 3-24 Effect of Auxiliary Lane on Mainline Speed (1,000-ft ramp spacing)
A) Mainline Entering Volume = 1,250 vphpl
B) Mainline Entering Volume = 1,500 vphpl
C) Mainline Entering Volume = 1,750 vphpl

Simulation model results for the 1,000-foot ramp spacing indicate the following:

- Adding an auxiliary lane results in higher mainline speeds for all mainline and ramp-volume combinations.

- In general, at low exit ramp volume (750 vph), the benefit of adding an auxiliary lane is relatively minor (< 2mph), regardless of the entry ramp volume.
- At moderate to high mainline entering and ramp volumes, the increased speeds resulting from an auxiliary lane are significant, reaching as high as 18 mph.

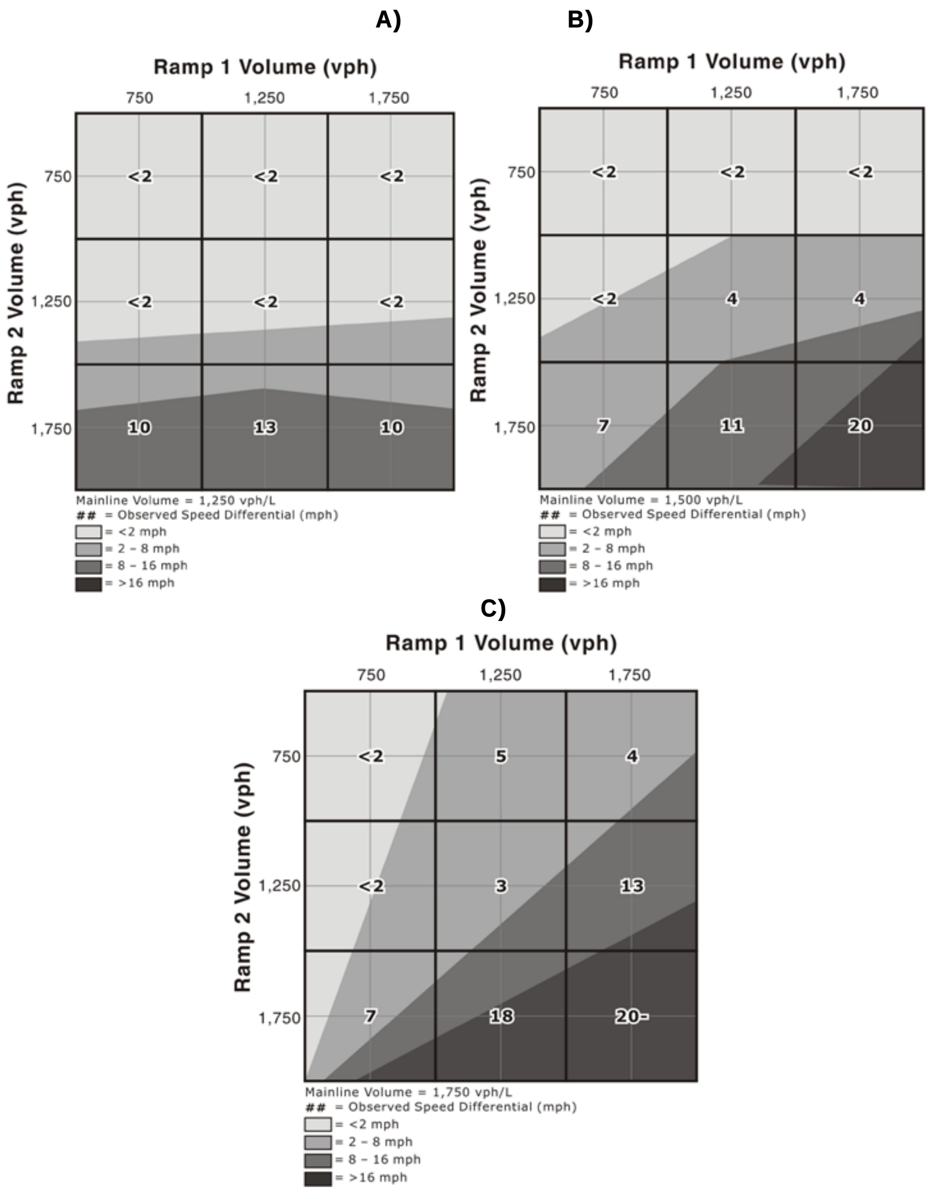


Exhibit 3-25 Effect of Auxiliary Lane on Mainline Speed (2,500-ft ramp spacing)
A) Mainline Entering Volume = 1,250 vphpl
B) Mainline Entering Volume = 1,500 vphpl
C) Mainline Entering Volume = 1,750 vphpl

Simulation model results for the 2,500-foot ramp spacing indicate the following:

- Adding an auxiliary lane results in higher mainline speeds for all mainline and ramp-volume combinations.
- At low (750 vph) to moderate (1,250) exit-ramp volumes and low mainline entering volume (1,250 vphpl), the benefit of adding an auxiliary lane is relatively minor (< 2mph), regardless of the entry-ramp volume (Exhibit 3-25A). Similarly, at moderate mainline entering volume (1,500 vphpl) and low exit volume, the benefit is minor (Exhibit 3-25-B).
- At high mainline and ramp volumes, the increased speeds resulting from an auxiliary lane are significant, reaching as high as 20 mph.
- In general, the increased speed provided by an auxiliary lane for the 2,500-foot spacing is less than provided for the 1,000-foot spacing at low to moderate ramp volumes. This makes sense since the longer spacing provides greater length for lane changing without an auxiliary lane present.

3.3.8.5 Summary of results

- EN-EN Models
  - The lowest mainline speeds within this ramp configuration occur at the second onramp.
  - At low to moderate mainline entering volumes (<1,500 vphpl), ramp spacing generally has little effect on speed within the mainline segment regardless of ramp-volume levels.
  - At high mainline entering volumes (>1,750 vphpl), ramp spacing has a significant impact on mainline segment speeds across moderate to high ramp volumes.
- EN-EX Models Without Auxiliary Lane
  - In general, the level of exiting volume has the greatest influence on mainline segment speeds.
  - At low mainline entering volumes (<1,250 vphpl), ramp spacing significantly affects mainline segment speed at high (>1,750 vphpl) exit-ramp volumes.
  - At moderate and high mainline entering volumes (>1,500 vphpl) ramp spacing significantly affects mainline segment speed at moderate and high exit-ramp volumes.
- Auxiliary Lane Models
  - Adding an auxiliary lane results in increased point speeds when compared to equivalent non-auxiliary lane conditions. The

benefit of an auxiliary lane is minor at low mainline and exit volumes; however, it becomes significant as traffic volumes increase.

- Adding an auxiliary lane on a longer ramp spacing (2,500 ft) generally has less benefit than adding an auxiliary lane to a shorter ramp spacing (1,000 ft).

3.4 SAFETY WORK PLAN

Freeway interchanges, by their nature, coincide with increased lane changing, acceleration and deceleration on and near the mainline. Traffic operations are adversely affected and decline with higher interchange ramp densities (i.e., shorter ramp spacing). The effects are captured at both the interchange level (e.g., free-flow speed and capacity decrease as interchange density increases) and at the ramp level (e.g., speed decreases as weaving length decreases) by algorithms in the 2000 HCM.

Analogous safety relationships are not as well established. The first addition of the *Highway Safety Manual* does not include a quantitative safety effect of ramp or interchange spacing. The literature review, summarized in Chapter 2, demonstrated that only two studies directly explored relationships between ramp spacing and safety. The first, by Cirillo, was dated by almost 40 years and did not consider key variables that likely influence the spacing-safety relationship (e.g., ramp volumes, number of though lanes) (70). The second, by Bared et al., used modern analysis techniques, but several limitations were identified (72). Therefore, the NCHRP 3-88 research approach for the safety work plan called for focused research effort to explore the safety effects of ramp and interchange spacing. A study by the Texas Transportation Institute that included a safety assessment of weaving length was published while the NCHRP 3-88 work plan was under way. The 3-88 project team compared the results of the Texas study to the results of this study in Section 3.4.6.

The remainder of this chapter describes the safety-related research effort of NCHRP 3-88.

3.4.1 Key Issues

Interchange spacing, defined from cross-street centerline to cross-street centerline, is not as meaningful as *ramp spacing*, defined from painted gore to painted gore, from a safety modeling and analysis standpoint. For a given interchange spacing, freeway segments between the cross streets may have different numbers, types, combinations and spacings of interchange ramps. In addition, cross streets associated with some ramps are difficult to identify for atypical interchange types, and may not be centered between exit and entrance ramps. As a result, the 3-88 project team focused on developing relationships between *ramp spacing* and safety. The relationships can be aggregated to determine interchange spacing effects for different interchange forms.

Much of the following safety discussion is related to the scenario of an entrance ramp from one cross street followed by an exit ramp to a downstream cross street (EN-EX). This is a common ramp-sequence scenario, and one in which operational analyses are frequently conducted and safety information is frequently needed. The 3-88 project team explored the scenario of two consecutive entrance ramps (EN-EN) from a safety perspective, but with lesser detail than the EN-EX. The following describe some of the challenges of other ramp scenarios:

- The scenario of an exit ramp followed by an exit ramp (EX-EX) was uncommon; in the the initial scan of 650 directional miles of freeway the 3-88 project team identified less than 20 such locations.
- An exit ramp followed by an entrance ramp (EX-EN) is common within a single interchange; observed spacing dimensions between these ramps did not significantly vary and generally ranged from 2,400-4,400 feet, far above the minimum recommended value of 500 feet identified in the AASHTO Green Book.

Data that included interchange ramp traffic and coded ramp locations referenced to a mainline milepoint, required elements for a safety analysis, were most readily available in data files from Washington State and California. The 3-88 project team explored data sets and supplemental data sources from both states in detail. The 3-88 project team discovered discrepancies between electronically coded data in California ramp files obtained through FHWA's *Highway Safety Information System* (*HSIS*) and video data observed through the University of California, Berkeley's Performance Measurement System (PeMS). Therefore, the 3-88 project team focused its data collection efforts on Washington State only. The 3-88 project team compared the safety findings using the Washington data to recently published ramp spacing/safety findings using Texas data to address potential concerns regarding the transferability of findings using data from Washington alone.

The Texas research objectives and strategy was consistent with the goal of the NCHRP 3-88 safety effort: To understand and quantify general accident trends associated with ramp and interchange spacing. The 3-88 project team felt that such an in-depth, comprehensive effort using data from one state was much more likely to provide greater insights into the safety phenomenon of interest than less comprehensive information from a greater number of spatially dispersed states.

3.4.2 Variable Notation and Definitions

The following variable notations and definitions are used throughout the remainder of the safety section:

a. L = segment length defined from physical entrance gore to physical exit gore (miles);

b. ln(L) = natural logarithm of the segment length;

c. ADT = two-way average daily traffic upstream of the entrance ramp in an EN-EX or EN-EN ramp sequence (veh/day);

d. DADT = one-way (directional) average daily traffic upstream of the entrance ramp in an EN-EX or EN-EN ramp sequence (veh/day);

e. ln(ADT) = natural logarithm of the ADT;

f. ADT_{EN} = average daily traffic on the entrance ramp of an EN-EX ramp sequence at the entrance ramp-freeway terminal (veh/day);

g. ADT_{EN-1} = average daily traffic on the first (upstream) entrance ramp of an EN-EN ramp sequence at the entrance ramp-freeway terminal (veh/day);

h. ADT_{EN-2} = average daily traffic on the second (downstream) entrance ramp of an EN-EN ramp sequence at the entrance ramp-freeway terminal (veh/day);

i. $\ln(ADT_{EN})$ = natural logarithm of the ADT_{EN};

j. $\ln(ADT_{EN-1})$ = natural logarithm of the ADT_{EN-1};

k. $\ln(ADT_{EN-2})$ = natural logarithm of the ADT_{EN-2};

l. ADT_{EX} = average daily traffic on the exit ramp of an EN-EX ramp sequence at the exit ramp-freeway terminal (veh/day);

m. $\ln(ADT_{EX})$ = natural logarithm of the ADTEX;

n. S = ramp spacing defined from painted entrance gore to painted exit gore (feet);

o. S^{-1} = inverse of ramp spacing (1/feet);

p. AuxLn = indicator variable for the presence of an auxiliary lane between an entrance ramp and exit ramp (1 = auxiliary lane present; 0 = no auxiliary lane);

q. %BarrL = the length of a barrier adjacent to the median shoulder divided by the total length of the segment (unitless decimal);

r. %BarrR = the length of a barrier adjacent to the right shoulder divided by the total length of the segment (unitless decimal);

s. MainEn = indicator variable for the vertical relationship between the cross street for the entrance ramp and the freeway mainline (1 = mainline over cross street; 0 = mainline under cross street);

t. MainEx = indicator variable for the vertical relationship between the cross street for the exit ramp and the freeway mainline (1 = mainline over cross street; 0 = mainline under cross street);

u. NoLn2 = indicator variable for the number of directional through lanes on the freeway segment (1 = two lanes; 0 = three or four lanes);

v. NoLn3 = indicator variable for the number of directional through lanes on the freeway segment (1 = three lanes; 0 = three or four lanes);

w. NoLn4 = indicator variable for the number of directional through lanes on the freeway segment (1 = four lanes; 0 = three or four lanes);

x. Total = expected number of crashes of all severities and types;

y. FplusI = expected number of crashes involving at least one occupant fatality or injury;

z. SingV = expected number of crashes involving only one motor vehicle;

aa. MultV = expected number of crashes involving more than one motor vehicle;

bb. Truck = expected number of crashes involving at least one large truck;

cc. Peak = expected number of crashes occurring during defined peak-hour time periods; and,

dd. α = overdispersion parameter of the negative binomial regression model.

3.4.3 Data Collection

The 3-88 project team collected data from Washington State using several different information sources: interchange diagrams available through Washington Department of Transportation's (WSDOT's) *Interchange Web Viewer*; freeway network maps and aerial photographs available through *Google Maps* and *Google Earth*; video logs that are part of WSDOT's *State Route Web*; and electronic crash, roadway, ramp and vehicle files provided by FHWA's *HSIS*. *Google Maps Street View* was also used to supplement or verify information collected from WSDOT's video logs. The NCHRP 3-88 project team used four primary steps in the data collection process:

1. Gather ramp locations and ramp-related features in both directions of freeway travel;
2. Define freeway segments for safety analysis;
3. Collect traffic and geometric data for defined freeway segments; and,
4. Determine crash frequencies and severities on each defined freeway segment.

Each of the four steps is summarized in the remainder of this section.

3.4.3.1 Ramp Locations and ramp-related features

The 3-88 project team used *Google Maps* to scan Washington State's freeway network and locate potential corridors of interest. The 3-88 project team observed and recorded ramp locations and ramp-related features for approximately 550 directional miles of Interstate 5 (I-5); 600 directional miles of I-90; 260 directional miles of I-82; 50 directional miles of I-405; 50 directional miles of State Route (SR) 167; 40 directional miles of SR 18; 20 directional miles of SR 512; 20 directional miles of SR 14; and 10 directional miles of SR 101. The 3-88 project team used some of these segments only for analysis of less common ramp combinations to increase sample size.

The 3-88 project team collected the general ramp type (characterized for this study as either diagonal, direct, semi-direct, turning roadway, or loop) as well as the interchange number and general interchange type (system or service) associated with each ramp using interchange diagrams and verified these elements with aerial photography from *Google Earth*. An example interchange diagram and corresponding satellite photograph is illustrated in Exhibit 3-26. The 3-88 project team marked each interchange number and name in *Google Earth* for quick future referencing if needed.

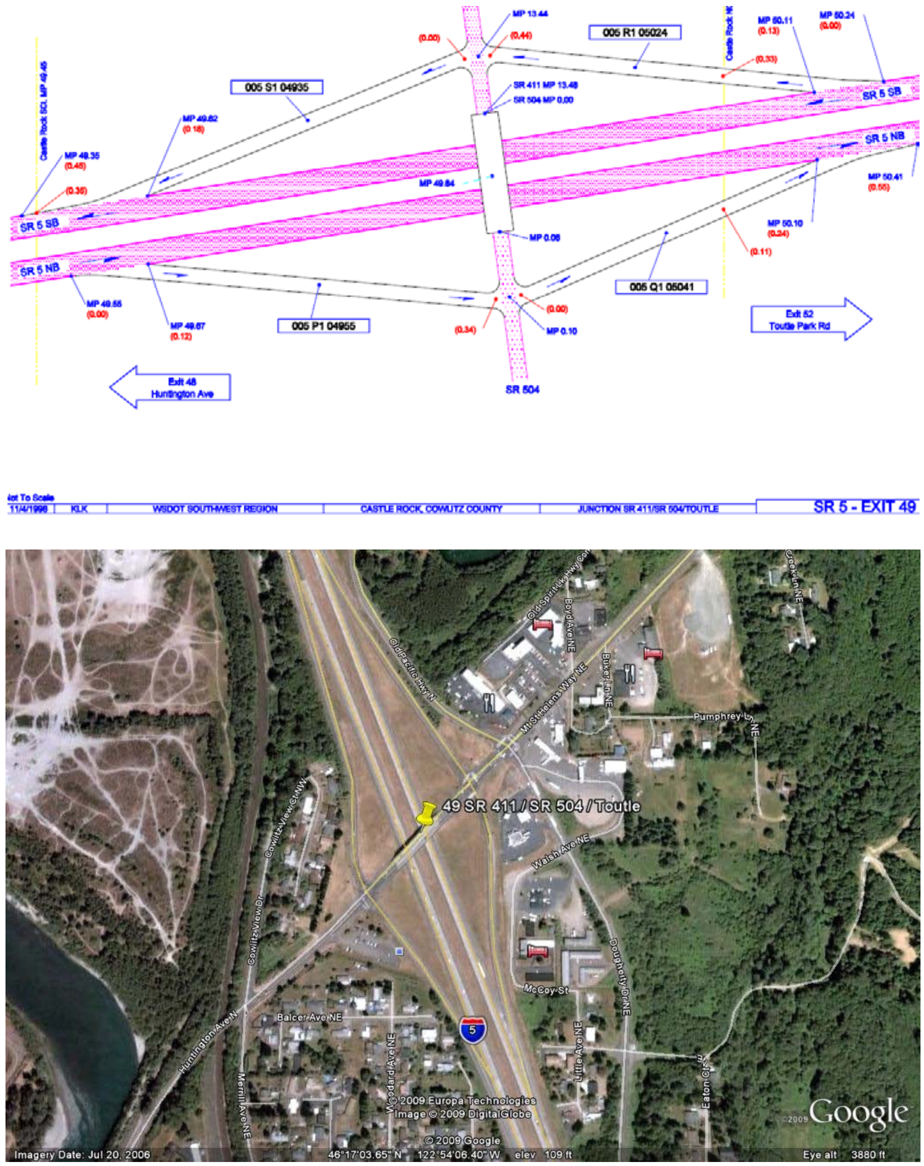


Exhibit 3-26 Example of Interchange Diagram and *Google Earth* Aerial Photography to Collect Interchange Number, General Interchange Type and Ramp Type

The 3-88 project team collected physical ramp-gore locations, associated cross-street locations, and the beginning or end of the acceleration or deceleration lane tapers from interchange diagrams and verified using WSDOT's *State Route Web* video logs. Painted ramp-gore locations were collected from the video logs and verified using a measurement tool in *Google Earth*. The 3-88 project team also obtained the vertical relationship between the freeway and cross street (i.e., freeway mainline under or over cross street) associated with each ramp from the interchange diagrams and verified the relationships with video logs and *Google Maps Street View*. Finally, the 3-88 project team recorded each ramp identification (ramp ID) number.. The ramp ID, along with the ramp milepost, were used to collect the daily exiting or entering traffic volumes from the *HSIS* Washington ramp files. Examples of the aforementioned ramp features, as they appear in the interchange diagrams and video logs, are illustrated in Exhibit 3-27.

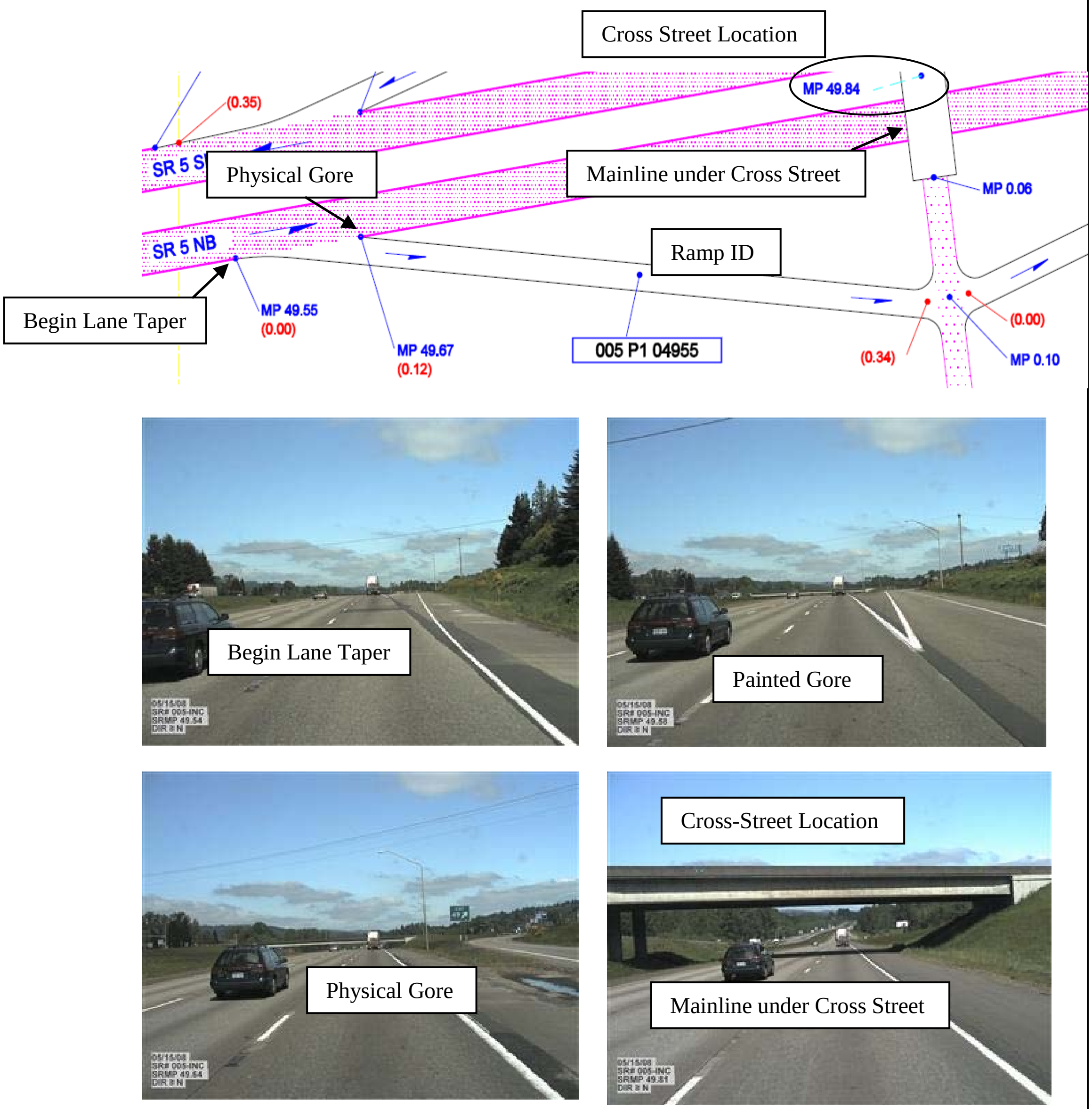


Exhibit 3-27 Example of Ramp Features Collected from Interchange Diagrams and Video Logs

Milepoints shown on WsDOT's video logs and interchange diagrams (see Exhibit 3-23) are based on a State Route Milepost (SRM) system, which includes sequential numbers, increasing from south to north or west to east, in 1/100th mile increments. The SRM system does not include adjustments that are effective over the entire route following realignments and accompanying route lengthening or shortening. Instead, the SRM includes "back" and "ahead" indicators, which are notations that distinguish "new milepoints" from "old milepoints" of the same value that are either upstream or downstream of the realignment locations (see Exhibit 3-28).

WSDOT's road data also include an Accumulated Route Mileage (ARM) for each route, also measured to 1/100th mile. The ARM starts at the beginning of each state route, increases from south to north or west to east, and is adjusted to account for previous route realignments. The ARM numbers are provided in the Washington roadway and crash files obtained by the 3-88 project team through HSIS and were used for segment length and spacing calculations and to link road and crash files. WSDOT's *State Route Web* includes both the SRM and ARM milepoints, which allowed the 3-88 project team to determine locations of previous route realignments and identify and correct for any potential crash miscounts over a three year period for a defined road segment. An example of the SRM and ARM numbers in *State Route Web* at a location where a route was lengthened during a previous reconstruction project is shown in Exhibit 3-28.

ACCUM MILES	MILE POST	FEATURE	LR	LANES DECR.	LANES INCR.	DESCRIPTION	
40.34	40.34	END SU LN	L	4	4	WEAVING/SPEED CHANGE 12A	
40.34	40.34	ON RAMP	L	4	4	N KELSO AVE (OLD SR 431)	
40.37	40.37B	BEG EQ		4	4	BEGIN BACK	
40.39	40.39B			3	4		
40.44	40.37	EQUATION		3	4	040.44B=040.37	(1)
40.44	40.37	UXING		3	4	BRYNION ST	
40.44	40.37	BRIDGE NUM		3	4	BRDG NUM 005/125	
40.52	40.45	MISC FEATR	L	3	4	GORE (S104034)	
40.53	40.46	END SU LN	R	3	3	WEAVING/SPEED CHANGE 12A	
40.53	40.46	OFF RAMP	R	3	3	FRONTAGE RD	(2)
40.63	40.56	MISC FEATR	R	3	3	GORE (P104046)	(3)

1) **Realignment and lengthening of the route by 0.07 mile**
2) **Beginning of an exit ramp taper and its ARM milepoint (Accum Miles) and SRM milepoint (Mile Post)**
3) **Physical gore of the exit ramp and its ARM milepoint (Accum Miles) and SRM milepoint (Mile Post)**

Exhibit 3-28 Example of mile post adjustment information

3.4.3.2 Freeway segments for safety analysis

The 3-88 project team then used the ramp data to define freeway segments; the freeway segments were the base observation units for the safety analysis. Each row in the ramp database, created through execution of steps described in the previous section, represented one ramp. Each row in the subsequent freeway segment database represented one ramp combination. The 3-88 project team created two segment databases - one for each ramp sequence studied. The 3-88 project team identified consecutive rows in the ramp database where an entrance ramp was followed by an exit ramp and combined them into one row (i.e., one EN-EX freeway segment). The beginning of the segment was defined by the milepost of the physical entrance ramp gore; the end of the segment was defined by the milepost of the physical exit ramp gore. Ramp spacing was defined as the distance from the painted entrance gore (i.e., the merging tip) to the painted exit gore (the diverging tip) for the EN-EX scenario. The EN-EX freeway segment boundaries and the defined ramp spacing dimension are shown in Exhibit 3-29.

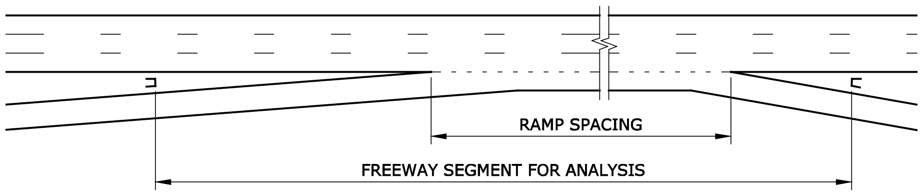


Exhibit 3-29 Illustration of Defined Segment Boundaries and Ramp Spacing for EN-EX

The 3-88 project team combined consecutive rows in the ramp database where an entrance ramp was followed by another entrance ramp to form an EN-EN segment. The freeway segment was defined from the physical gore of the first (upstream) entrance ramp to the end of the acceleration lane taper of the second (downstream) entrance ramp. The 3-88 project team defined the segment this way to capture crashes associated with merging activities at both ramp locations. Ramp spacing was defined as the distance between merging tips for the EN-EN scenario. The EN-EN freeway segment boundaries and the defined ramp spacing dimension are shown in Exhibit 3-30.

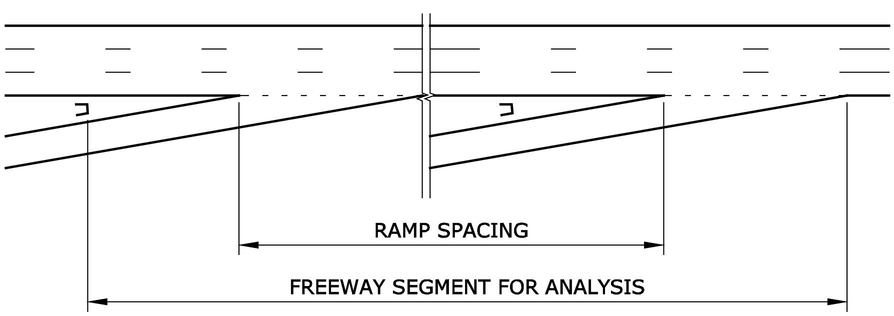


Exhibit 3-30 Illustration of Defined Segment Boundaries and Ramp Spacing for EN-EN

The 3-88 project team excluded segments from the dataset if the team identified construction activity on or near the segment from 2005 through 2008. The 3-88 project team identified temporary traffic control devices on the video logs or construction areas present on current and archived *Google*

Earth photographs for these segments. Missing traffic volume counts (discussed in section 3.4.3.3) for a segment also indicated possible construction activity; segments with missing volume counts were excluded.

The 3-88 project team did not spend any additional resources (e.g., time to personally interview Washington DOT personnel) to identify work zones from 2005-2008. Work zone presence is likely not correlated with traffic and geometric variables included in the safety models; higher levels of unexplained variability in expected crash counts, a less serious flaw than omitted variable bias (discussed in section 3.4.4), is expected if some work zones were missed during the screening process.

The 3-88 project team also excluded several other types of ramps from the dataset. The project team excluded rest-area ramps between entrance and exit ramps associated with two consecutive cross streets. The 3-88 project team also excluded segments with any type of ramp metering and high occupancy vehicle (HOV) facilities. Finally, the 3-88 project team excluded EN-EX weaving segments between cloverleaf ramps. These areas could have different safety performance characteristics than weaving areas between two consecutive interchanges, and the 3-88 project team did not have sufficient resources to develop a separate model for such areas. The final datasets used by the 3-88 project team to estimate the safety models described in section 3.4.5 consist of 155 EN-EX segments and 30 EN-EN segments.

3.4.3.3 Traffic and geometric data for defined freeway segments

The 3-88 project team collected traffic and geometric data for each defined freeway segment. Freeway mainline traffic volumes were collected from *HSIS* roadway files using route number and mainline milepost variables to identify the correct volume measurement. The mainline traffic volume assigned to each defined freeway segment represented the *directional* average daily traffic just upstream of the physical entrance ramp gore of the EN-EX and upstream of the first (upstream) physical entrance ramp gore of the EN-EN. The HSIS files included bidirectional traffic volumes. The 3-88 project team used the process described below to estimate directional traffic.

Each defined freeway segment was linked to its nearest Automated Data Collection (ADS) station. These traffic data collection stations are located throughout Washington State's highway system. Data collected by this automated system are summarized in WSDOT's annual traffic reports and include directional mainline traffic volumes. The 3-88 project team used the directional volume information to estimate a directional traffic volume ratio (D). The 3-88 project team then assumed that the directional traffic volume ratio for each defined freeway segment was the same or very close to the volume ratio at the nearest ADS station. All defined freeway segments had an estimated directional traffic volume ratio falling between 0.49 and 0.51.

The 3-88 project team determined entering and exiting traffic volumes using the ramp ID number and ramp milepost variables, and represented the average daily traffic on the entrance and exit ramp-freeway terminals, respectively. The number of through lanes was determined using *HSIS* roadway files and confirmed with video logs, *Google Earth* aerial photography, and *Google Maps Street View*. The presence of an auxiliary lane between an entrance and exit ramp was determined from the interchange diagrams and also confirmed with video logs. The number of lanes on the entrance and exit ramps (at the ramp-freeway terminal) was determined from video logs alone. Finally, the presence of a barrier (concrete or steel guardrail) adjacent to the right and median shoulders, as well as the respective barrier length, was collected using video logs. Descriptive statistics of the traffic and geometric variables for the 155 EN-EX and EN-EN segments are provided in Exhibit 3-31 and Exhibit 3-32, respectively. Safety models for EN-EN segments included only traffic volumes, segment length and spacing as variables because of the small sample size. Only descriptive statistics for those variables are included in Exhibit 3-32.

Variable	Mean	Standard Deviation	Minimum	Maximum
L	1.59	1.12	0.24	5.29
DADT	41,644	21,281	15,928	104,079
ADT_{EN}	5,799	4,935	113	31,395
ADT_{EX}	5,727	5,051	84	31,495
S	7,369	5,903	686	26,770
AuxLn	0.1871[a]	0.3912	0	1
%BarrL	0.5499	0.4296	0	1
%BarrR	0.3559	0.2897	0	1
MainEn	0.3613	0.4819	0	1
MainEx	0.3548	0.4800	0	1
NoLn2	0.3612	0.4819	0	1
NoLn3	0.4645	0.5004	0	1
NoLn4	0.1742	0.3805	0	1

[a] The mean of an indicator variable is interpreted as the proportion of segments with the indicator value equal to 1 (e.g., 18.59% of the 156 segments have an auxiliary lane present).

Exhibit 3-31 Descriptive Statistics of Traffic and Geometric Data from 155 EN-EX Segments

Variable	Mean	Standard Deviation	Minimum	Maximum
L	0.64	0.34	0.23	1.56
DADT	42,254	23,449	3,459	99,030
ADT_{EN-1}	8,774	6,220	208	21,649
ADT_{EN-2}	6,354	5,271	707	27,570
S	2,821	3,146	686	17,160

Exhibit 3-32 Descriptive Statistics of Traffic and Geometric Data from 30 EN-EN Segments

3.4.3.4 Crash frequencies and severities on each defined freeway segment

The 3-88 project team counted the number of crashes occurring on each freeway segment (i.e., between the physical entrance gore and exit gore for the EN-EX and the upstream physical exit gore and downstream end of acceleration lane taper for EN-EN) in the years 2005, 2006, and 2007 using the route number and milepost variables. The following crash counts included:

- Number of crashes of all severities and types;
- Number of crashes resulting in at least one occupant fatality or injury;
- Number of crashes involving only one vehicle (i.e., single-vehicle crashes);
- Number of crashes involving more than one vehicle (i.e., multiple-vehicle crashes);
- Number of crashes involving a large truck; and,
- Number of crashes occurring during predefined peak hours.

The 3-88 project team classified a vehicle as a large truck if it was coded in *HSIS* vehicle files as 1) *truck (over 10,000)*, 2) *truck tractor*, 3) *truck tractor & semi-trailer*, or 4) *other truck combinations*. The 3-88 project team defined peak hours as 7-10 a.m. and 3-6 p.m.

The 3-88 project team summarized the large truck and peak hour safety models in the *Second Interim Report* for NCHRP 3-88. The proportion of explained variation by the truck safety model was smallest (i.e., was the weakest of all safety models estimated), indicating the model specification for truck crashes was missing key variables. Truck-volume data available through *HSIS* were tested by the 3-88 project team, but the data quality appeared suspect and were ultimately excluded from the model. Any future comprehensive model of truck crashes should include truck volumes. The peak hour safety models were not any different that the safety models for total crashes. Only the safety models for the expected number of total crashes, fatal plus injury crashes, multiple vehicle crashes, and single vehicle crashes are included in this report as a result of these earlier findings.

The 3-88 project team included crashes in the analysis only if they were coded as occurring in the roadway or roadside of the freeway mainline and in the same direction of travel served by the interchange ramps. Crashes coded as having occurred on the ramp proper or in the opposing direction of freeway travel were not assigned to the segment of interest. The 3-88 project team used the *HSIS impact location* and travel direction variables to identify these appropriate crashes. One limitation of this approach is that it may not capture the complex interactions between cross-median, head on collisions. Descriptive statistics of the observed crash frequencies for the 155 EN-EX segments and 30 EN-EN segments are provided in Exhibit 3-33 and Exhibit 3-34, respectively.

Crash Type	Mean	Standard Deviation	Minimum	Maximum
Total	33.4	31.0	2	189
FplusI	11.5	11.4	0	65
SingV	11.7	10.1	0	60
MultV	21.8	25.4	0	141

Exhibit 3-33 Descriptive Statistics of Observed Crash Frequencies from 2005 through 2007 (inclusive) on 155 EN-EX Segments

Crash Type	Mean	Standard Deviation	Minimum	Maximum
Total	28.8	29.3	3	131
FplusI	10.1	11.8	1	54
SingV	6.2	4.1	0	17
MultV	22.5	26.9	0	120

Exhibit 3-34 Descriptive Statistics of Observed Crash Frequencies from 2005 through 2007 (inclusive) on 30 EN-EN Segments

3.4.4 Modeling Approach

The 3-88 project team explored the relationship between ramp spacing and safety using a negative binomial regression modeling approach. In 1986, Jovanis and Chang introduced the use of Poisson regression to model the relationships between crash frequency, traffic volumes, and weather conditions (83). Miaou later used the negative binomial regression model, a more general form of the Poisson regression model, to explore the relationship between crash frequencies, daily traffic, and highway geometric design variables (59). Negative binomial regression has become the most widely used technique to model crash frequency-geometric design relationships since that time. In the negative binomial model, the expected number of crashes of type *i* on segment *j* is expressed as:

$$\mu_{ij} = E(Y_{ij}) = \exp(X_j\beta + \ln L_j)$$

where: $\mu_{ij} = E(Y_{ij})$ = the expected number of crashes of type *i* on segment *j*;

X_j = a set of traffic and geometric variables characterizing segment *j* (including ramp spacing);

β = regression coefficients estimated with maximum likelihood that quantify the relationship between $E(Y_{ij})$ and variables in X;

L_j = length of segment *j*; and,

$\ln L_j$ = the natural logarithm of segment length.

The following crash frequencies were modeled by the NCHRP 3-88 project team:

- Expected number of crashes of all severities and types (Total);
- Expected number of crashes involving at least one occupant fatality or injury (FplusI);
- Expected number of crashes involving only one motor vehicle (SingV);
- Expected number of crashes involving more than one motor vehicle (MultV);

Ramp spacing was the primary variable of interest in the matrix of explanatory variables, X_j. However, the 3-88 project team included a number of other traffic and geometric variables to decrease unexplained variation in expected crash frequency and to try and minimize *omitted variable bias*. Omitted variable bias involves over- or under- estimating the safety effect of ramp spacing due to other variables that influence crash frequency and are correlated with ramp spacing, but are excluded from the model. Measures of the following explanatory variables were included in the NCHRP 3-88 EN-EX safety models:

- Segment length
- Freeway traffic
- Ramp traffic
- Ramp spacing
- Presence of an auxiliary weaving lane
- Barrier presence and length
- Vertical relationship between the freeway mainline and cross streets
- Number of freeway through lanes

The number of EN-EN segments included in the safety analysis by the 3-88 project team was much smaller than for the EN-EX sample. Model specifications for the EN-EN were less robust as a result. Measures of the following explanatory variables were included in the NCHRP 3-88 EN-EN safety models:

- Segment length
- Freeway traffic
- Ramp traffic
- Ramp spacing

The 3-88 project team included segment length, L, in the models as an offset variable (i.e., the regression coefficient for the natural logarithm of segment length is constrained to 1.0), and captures the linear increase in expected crash frequency with an increase in segment length due to increased exposure.

The 3-88 project team evaluated model fit using the McFadden Pseudo R-Squared. The McFadden Pseudo R-Squared (ϱ^2) is analogous to the R-squared value used to express the goodness of fit of a standard, ordinary least squares regression model. It is expressed as:

$$\varrho^2 = \frac{L(full)}{L(0)}$$

where: ϱ^2 = McFadden Pseudo R-Squared;

L(*full*) = log-likelihood of the model with explanatory variables; and,

L(0) = log-likelihood of the intercept-only model.

The McFadden Pseudo R-Squared may take a value between 0 and 1; the value moves closer to 1 as model fit improves.

3.4.5 Model Results

Model estimation results are summarized in Exhibit 3-35 (EN-EX) and Exhibit 3-36 (EN-EN). Models for EN-EX segments have the following form, which is consistent with the general modeling discussion in the section 3.4.4:

$$E(Y_i) = \exp\left(constant + 1.0*\ln(L) + b_2*\ln(DADT) + b_3*\ln(ADT_{EN}) + b_4*\ln(ADT_{EX}) + b_5*S^{-1} + b_6*AuxLn + b_7*\%BarrL + b_8*\%BarrR + b_9*MainEn + b_{10}*MainEx + b_{11}*NoLn2\right)$$

with all variables defined above and b_i equal to estimated regression coefficients listed in Exhibit 3-35. The EN-EX model can also be expressed as:

$$E(Y_i) = L^{1.0}\, DADT^{b2}\, ADT_{EN}^{\ b3}\, ADT_{EX}^{\ b4} \exp(constant + (b_5/S) + b_6*AuxLn + b_7*\%BarrL + b_8*\%BarrR + b_9*MainEn + b_{10}*MainEx + b_{11}*NoLn2)$$

For example, the model for the expected number of crashes of all types and severities (i.e., $E(Y_i)$ = Total) is expressed as:

$$E(Y_i) = Total = L^{1.0}\, DADT^{1.122}\, ADT_{EN}^{\ 0.1766}\, ADT_{EX}^{\ 0.0174} \exp(-10.75 + (448.6/S) - 0.2283*AuxLn + 0.1026*\%BarrL + 0.4243*\%BarrR + 0.1184*MainEn + 0.0221*MainEx + 0.1184*NoLn2)$$

Variable	Total	FplusI	SingV	MultV
Constant	-10.75*	-12.85*	-2.092**	-18.51*
Ln(L)	1.000	1.000	1.000	1.000
Ln(DADT)	1.122*	1.204*	0.3461*	1.677*
Ln(ADT_{EN})	0.1766*	0.1706*	0.0271	0.2809*
Ln(ADT_{EX})	0.0174	0.0366	0.0198	0.0486
S^{-1}	448.6*	171.1	-39.44	691.2*
AuxLn	-0.2283**	-0.2622**	-0.2241	-0.2788**
%BarrL	0.1026	0.2976*	-0.1072	0.2265**
%BarrR	0.4243*	0.3336*	0.3858*	0.4121*
MainEn	0.1184	0.1029	0.0861	0.1879**
MainEx	0.0221	0.0512	0.0727	0.0016
NoLn2	0.1184	0.1934	-0.0694	0.3657*
α	0.1643*	0.1643*	0.1262*	0.2293*
ρ^2	0.1528	0.1528	0.0354	0.2965

*parameter statistically significant with probability of type I error ≤ 0.05
** parameter statistically significant with probability of type I error ≤ 0.1

Exhibit 3-35 Summary of EN-EX Model Estimation Results; Dependent Variable is Expected Number of Crashes in One Direction of Freeway Travel between 2005 and 2007 (expected crashes per 3 years)

Models for EN-EN segments have the following form:

$$E(Y_i) = \exp(\text{constant} + 1.0{*}\ln(L) + b_2{*}\ln(DADT) + b_3{*}\ln(ADT_{EN\text{-}1}) + b_4{*}\ln(ADT_{EN\text{-}2}) + b_5{*}S^{-1})$$

with all variables defined above and b_i equal to estimated regression coefficients listed in Exhibit 3-36. The EN-EN model can also be expressed as:

$$E(Y_i) = L^{1.0}\, DADT^{b2}\, ADT_{EN\text{-}1}{}^{b3}\, ADT_{EN\text{-}2}{}^{b4} \exp(\text{constant} + (b_5/S))$$

For example, the model for the expected number of crashes of all types and severities (i.e., $E(Y_i)$ = Total) is expressed as:

$$E(Y_i) = \text{Total} = L^{1.0}\, DADT^{1.140}\, ADT_{EN\text{-}1}{}^{0.1730}\, ADT_{EN\text{-}2}{}^{0.0222} \exp(-11.73 + (434.3/S))$$

Variable	Total	FplusI	SingV	MultV
Constant	-8.812*	-11.08*	-3.277**	-14.55
Ln(L)	1.000	1.000	1.000	1.000
Ln(DADT)	0.8095*	0.8116*	0.3949**	1.096
$Ln(ADT_{EN-1})$	0.3387*	0.4530*	0.0805	0.5873
$Ln(ADT_{EN-2})$	0.0931	0.1332	0.0762	0.1101
S^{-1}	418.1	54.74	234.2	346.9
α	0.2770*	0.2924	0.2382*	0.2952*
ρ^2	0.1262	0.1451	0.0507	0.1669

*parameter statistically significant with probability of type I error ≤ 0.05
** parameter statistically significant with probability of type I error ≤ 0.1

Exhibit 3-36 Summary of EN-EN Model Estimation Results; Dependent Variable is Expected Number of Crashes in One Direction of Freeway Travel between 2005 and 2007 (expected crashes per 3 years)

3.4.5.1 EN-EX Model Interpretation

The signs (positive or negative) of the estimated NCHRP 3-88 model parameters, the statistical significance of the parameters, the relative parameter magnitudes across the different crash frequency models, and the relative levels of model fit were consistent with what one would expect at locations of merging, diverging, acceleration, and deceleration maneuvers associated with the EN-EX segments. The model for expected number of multiple-vehicle crashes demonstrated a combination of the largest ramp spacing effect and the best model fit.

The parameter for ramp spacing associated with the expected number of total crashes (i.e., all severities and types) was also statistically significant, a result that is expected given that a majority of these crashes involve multiple vehicles. The parameter for ramp spacing associated with the expected number of crashes resulting in a fatality or injury was positive, but not statistically significant and much smaller than the ramp parameter for crashes of all severities and types. While the results suggest an increase in the frequency of severe crashes with decreasing ramp spacing, the expected proportion of crashes resulting in a fatality or injury appears to decrease as ramp spacing decreases. The result of the NCHRP 3-88 research is consistent with published findings reported by Milton et al. (74) (see Chapter 2).

The parameter for ramp spacing associated with expected single-vehicle crashes was negative, indicating a decrease in the frequency of single-vehicle crashes as ramp spacing decreases. The finding is expected; the opportunity for single-vehicle crashes decreases as lane-change intensity increases. Single-vehicle crashes are associated with lower-volume, higher-speed conditions. Each of the findings related to the crash frequency-ramp spacing relationship are discussed in greater detail in section 3.4.6.

The 3-88 project team concluded that findings associated with other traffic and geometric variables also were generally consistent with previous safety modeling research and with expectations. The parameter for ln(ADT) was highly significant for all models, greater than 1.0 for multiple-vehicle crashes and less than 1.0 for single-vehicle crashes. The parameters indicate a smaller likelihood of a crash involving one vehicle compared to the likelihood of a crash involving more than one vehicle as traffic volumes increase. The finding is consistent with freeway safety research conducted by Bonneson and Pratt (2008) (84).

The parameter for $\ln(ADT_{EN})$ was positive and statistically significant for all crash types except single vehicle, indicating entrance volumes are associated with multiple-vehicle crashes resulting from increased merging maneuvers. The parameter value for $\ln(ADT_{EN})$ is less than 1.0 for all crash types; this finding is consistent with previous operational research indicating that the merge maneuver becomes easier as entrance volumes increase because the entering vehicles become a more dominant movement.

The amount of exiting traffic, represented by $\ln(ADT_{EX})$, did not appear to influence expected crash frequencies. The results indicate that exiting traffic directly causes a minimal, if any, safety disturbance. The result is consistent with its operational counterpart; free-flow speed adjustments are made only for interchanges with entrance ramps in the 2000 HCM freeway segment methodology.

The presence of an auxiliary lane between the entrance and exit ramps was modeled as an indicator variable (i.e., 1 = auxiliary lane present; 0 = auxiliary lane not present). Model parameters indicate that, for a given ramp spacing, fewer crashes are expected when an auxiliary lane is present. The auxiliary lane effect was largest for multiple-vehicle crashes and fatal-plus-injury crashes. Approximately 24 to 23 percent fewer multiple-vehicle crashes and fatal-plus-injury crashes, respectively are expected when an auxiliary lane is present compared to when there is not an auxiliary lane for the same ramp spacing dimension. Approximately 20 percent fewer total crashes (i.e., of all severities and types) are expected when an auxiliary lane is present; the respective regression parameter is also statistically significant. The difference was similar in magnitude for also single-vehicle crashes, but is not statistically significant.

The presence and length of a barrier adjacent to the right-side and median shoulders generally was associated with an increase in crashes, as expected (i.e., there is less room for roadside recovery before striking an object). However, the expected frequency of single-vehicle crashes decreased when a barrier was adjacent to the median shoulder (the parameter was not statistically significant). The result may indicate that crashes with a median barrier close to the traveled way may often be reported as multiple-vehicle crashes due to a redirection into the traveled way and into other vehicles after an initial barrier strike.

Results also show an increase in the expected number of fatal and injury crashes with barrier presence and length. For a barrier adjacent to the right shoulder, the increase is slightly smaller in magnitude and less statistically significant than for crashes of all severities and types, indicating a reduction in the proportion of crashes resulting in fatalities and injuries. However, a barrier adjacent to the median shoulder is associated with an increase in the proportion of crashes resulting in fatalities and injuries. Median width appears to be a key missing variable at this stage; median barriers are expected to increase crash frequency, but decrease crash severity, for narrower median widths. In addition, some detail is lost by the fact that all injury levels are currently combined into one crash outcome category.

Parameters for variables representing the vertical relationship between the freeway mainline and cross street indicate that an increased number of crashes are expected when an entrance ramp joins a freeway from a cross street that passes below the freeway. The effect was largest and statistically significant for multiple-vehicle crashes. The result is expected; vehicles are not as likely to reach freeway speeds before merging when traveling on an entrance ramp with a positive grade. Available sight distance may also be limited when joining a freeway from a lower elevation.

The same phenomena were not found for exit ramps; parameters were generally positive, but small and not statistically significant. This was also expected; the vertical relationship between mainline and cross streets for exit ramps is more likely to influence crash frequency on the ramp proper and ramp-cross street terminal. These crash types were excluded from the NCHRP 3-88 analysis. However, the positive parameters for all crashes do indicate a small safety benefit of having the cross street associated with the exit ramp pass over the freeway mainline.

Finally, the expected frequencies of all crash categories except single-vehicle were larger when only two through lanes per direction were present (compared to when three or four were present). The effect was largest and most statistically significant for multiple-vehicle crashes. For a given traffic volume, three or four lanes (compared to two) provide additional room for through moving traffic to move away from merging traffic, decreasing the probability of merging conflicts. The safety finding has an operational counterpart; the weaving intensity factor, and resulting travel speeds, decrease as the number of lanes increase in the HCM weaving analysis methodology.

3.4.5.2 EN-EN Model Interpretation

The signs (positive or negative) of the estimated NCHRP 3-88 model parameters, the statistical significance of the parameters, the relative parameter magnitudes across the different crash frequency models, and the relative levels of model fit were also consistent with what one would expect for the EN-EN models. The EN-EN model specifications were much more limited than the EN-EX models because of the small sample sizes associated with this scenario. Therefore, model interpretations must be much more general with less attention to statistical significance The model for expected number of total crashes demonstrated the largest ramp spacing effect and the model for expected number of multiple vehicle crashes demonstrated the best model fit. None of regression parameters associated with ramp spacing were statistically significant. Again, the parameter for ramp spacing associated with the expected number of crashes resulting in a fatality or injury was positive, but much smaller than the ramp parameter for crashes of all severities and types indicating the expected proportion of crashes resulting in a fatality or injury decreases as ramp spacing decreases.

The parameter for ln(ADT) was significant for all models, greater than 1.0 for multiple-vehicle crashes and less than 1.0 for single-vehicle crashes as expected (see discussion in 3.4.5.1). The parameter for $\ln(ADT_{EN-1})$ was positive and statistically significant for all crash types except single vehicle, indicating higher entrance volumes on the first (upstream) ramp of an EN-EN sequence are associated with multiple-vehicle crashes resulting from increased merging maneuvers. The parameter value for $\ln(ADT_{EN-1})$ is less than 1.0 for all crash types; this finding is consistent with previous operational research (see discussion in 3.4.5.1).

Increasing amounts of entering traffic on the second (downstream) entrance ramp, represented by $\ln(ADT_{EN-2})$, were associated with higher crash frequencies, but the effect was not as large as for $\ln(ADT_{EN-1})$. The result may indicate that crashes associated with entrance ramps occur primarily at or downstream of the merge location. The crashes associated with the volumes on the second entrance ramp are not captured by within the segment boundaries shown in Exhibit 3-30.

3.4.6 Model Validation through Comparisons of NCHRP 3-88 EN-EX Findings to a Recent Texas Study

The 3-88 project team conducted a focused safety research effort with the philosophy that a smaller sample of complete data would provide more information about ramp spacing-safety relationships than a larger, multistate sample of data with less quality control efforts and missing variables. The 3-88 project team considered data from Washington most relevant to the research objectives. Data collection efforts were focused in Washington because of the availability of key data sources (e.g., online video logs and interchange diagrams) and key data elements (e.g., ramp gore mileposts, ramp ID numbers, ramp volumes, and freeway crash-location variables).

The transferability of results to other states and geographic regions is generally the primary concern with focused, single-state efforts such as the one undertaken to date. A study by the Bonneson and Pratt of Texas Transportation Institute (TTI) that included safety modeling of freeway segments and other freeway features was published after the safety work plan of this project began (84). Where possible, the 3-88 project team compared the safety findings from analyses of Washington data to related safety findings from Texas. Similar underlying safety trends in two states as different in location, climate, topography, and freeway design as Washington and Texas would build confidence in the general transferability of the 3-88 results. The comparison efforts and conclusions are described in the remainder of this section.

A weaving accident modification factor (AMF) for a Texas freeway was reported by Bonneson and Pratt (84) and took the form:

$$AMF_{wev,FI,TX} = e^{152.9/L^*_{wev}} \text{ for } L^*_{wev} \geq 800 \text{ feet}$$

where:

$AMF_{wev,FI,TX}$ = accident modification factor for fatal and injury crashes using Texas freeway data; and,

L^*_{wev} = weaving section length (feet).

The AMF takes the value of 1.0 as the weaving length approaches infinity (i.e., a basic freeway segment). The TTI AMF was modified by the 3-88 project team to have a base condition of 2,000 feet in order to compare the results to the applicable NCHRP 3-88 AMF. The modified TTI AMF is expressed as:

$$AMF_{wev,FI,TX,2000} = e^{-0.07645+(152.9/L^*_{wev})} \text{ for } L^*_{wev} \geq 800 \text{ feet}$$

where:

$AMF_{wev,FI,TX,2000}$ = accident modification factor for fatal and injury crashes using Texas freeway data with base condition of weaving length equals 2,000 feet; and,

L^*_{wev} = weaving section length (feet).

The relationship between $AMF_{wev,TX,2000}$ and ramp spacing is plotted in Exhibit 3-37.

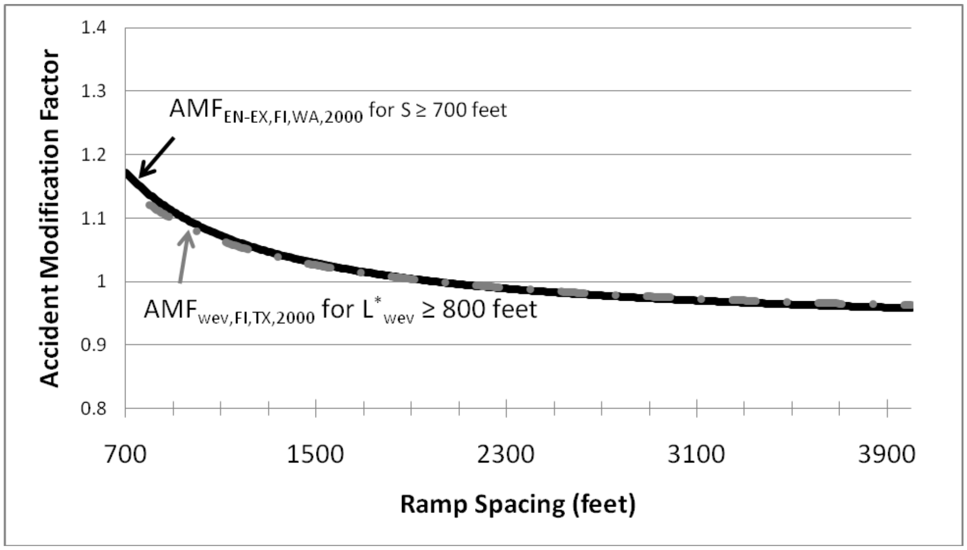


Exhibit 3-37 Comparison of Accident Modification Factors from NCHRP 3-88 and TxDOT Study 4703 for Fatal and Injury Crashes (AMF set to 1.0 for Ramp Spacing of 2,000 Feet)

The NCHRP 3-88 AMF developed with Washington data most applicable for comparison to the Texas AMF is given by:

$$AMF_{EN-EX,FI,WA,2000} = e^{-0.05995+(171.1/S)}$$

where:

$AMF_{EN-EX,FI,WA,2000}$ = accident modification factor for fatal and injury crashes using Washington freeway data with base condition of ramp spacing equals 2,000 feet; and

S = ramp spacing, defined from painted gore of entrance ramp to painted gore of exit ramp (feet).

The relationship between $AMF_{EN-EX,WA,2000}$ and ramp spacing is also plotted in Exhibit 3-37. The findings are very similar, and support the conclusion in one is likely to learn more about a *transferable*, underlying safety phenomenon associated with ramp spacing using a small sample of carefully collected data than with a larger sample of incomplete data.

Differences between the Washington and Texas studies include:

- The Texas AMF is for weaving segments only; the Washington AMF is currently applicable to both weaving segments and entrance-exit segments without an auxiliary lane.

- The Washington segments were defined from entrance gore to exit gore; the Texas freeway segments included one, more than one, or sometimes only part of a weaving segment.
- Ramp spacing in the Texas data ranged from 800 to 4,000 feet; spacing in the Washington data ranged from 700 to 27,000 feet.

3.4.7 Safety Conclusions

The primary focus of the NCHRP 3-88 research was the scenario of an entrance ramp followed by an exit ramp, a commonly occurring ramp sequence and one in which safety information is frequently needed. The 3-88 project team also explored the safety/ramp spacing relationship at locations where an entrance ramp is followed by another entrance ramp, but at less level of detail than the EN-EX scenario. The 3-88 project team used data from freeway segments in Washington State to estimate a series of negative binomial regression models. While ramp spacing was the key variable of interest, a number of other traffic and geometric variables were included in the model specification to avoid over- or under-estimating the ramp spacing-safety effect. The 3-88 project team found the signs (positive or negative) of the estimated model parameters, the statistical significance of the parameters, the relative parameter patterns across the different crash frequency models, and the relative levels of model fit were intuitive.

The 3-88 project team reduced modeling results to a set of accident modification factors (AMFs) and safety performance functions (SPFs). The AMFs can be used to estimate the expected incremental safety effect of different ramp spacing dimensions under a set of fixed traffic and roadway conditions (e.g., alternatives to upgrade existing ramps with no difference in ramp volumes between different alternatives). The SPFs can be used to estimate the expected number of crashes for scenarios where ramp spacing, ramp traffic and mainline traffic are all changing (e.g., the addition of a new interchange between two existing interchanges with expected travel pattern impacts).

NCHRP 3-88 research results show that the expected number of total crashes increases as ramp spacing decreases. The sensitivity of ramp spacing to total crashes appears highest for ramp spacing values less than 2,000 feet and becomes nearly negligible for spacings beyond 3,000 feet. The crash increase is largely a result of an increase in multiple-vehicle crashes; the expected number of single-vehicle crashes decreased as ramp spacing decreased. The finding is consistent with expectations that ramp presence and spacing is most directly associated with multiple-vehicle crashes resulting from increased numbers and densities of merging, diverging, acceleration, and deceleration maneuvers.

The expected number of severe crashes, those resulting in at least one occupant fatality or injury, also increased as ramp spacing decreased. The increase was at a much lower rate than for total crashes, indicating that much of the total crash increase is a result of an increase in less severe collisions (likely lower speed sideswipe and rear-end collisions). The increase in severe crashes appears to become relatively negligible beyond 1,000 to 1,500 feet.

The 3-88 project team established the presence of an auxiliary lane between the entrance and exit ramps as an indicator variable (i.e., 1 = auxiliary lane present; 0 = auxiliary lane not present). Model parameters indicate that, for a given ramp spacing, fewer crashes are expected when an auxiliary lane is present. The auxiliary lane effect is largest and most statistically significant for multiple-vehicle crashes and fatal-plus-injury crashes. Approximately 24 percent fewer multiple-vehicle crashes and 23 percent fewer fatal-plus-injury crashes are expected when an auxiliary lane is present compared to when there is not an auxiliary lane for the same ramp spacing dimension.

At the time of this research, no interaction between ramp spacing and weaving lane presence had been captured; however, comparisons to a Texas study indicate this interaction may be small or nonexistent. Model parameters indicate fewer crashes with an auxiliary lane present for a given ramp spacing. Ramp spacing was the primary variable of interest; however, the 3-88 project team included a number of other traffic and geometric variables to decrease unexplained variation in expected crash frequency and to try and minimize omitted variable bias. Variables representing the vertical relationship between the freeway mainline and cross street indicate that an increased number of crashes are expected when an entrance ramp joins a freeway from a cross street that passes below the freeway. The effect is largest and statistically significant for multiple-vehicle crashes and truck crashes.

The presence and length of a barrier adjacent to the right-side and median shoulders was generally associated with an increase in crashes as expected (i.e., there is less room for roadside recovery before striking an object). Capturing this variable was key to estimating the safety effect of ramp spacing. Barriers normally are present near urban areas where spacing is shorter. The effect of ramp spacing on the expected number of crashes would have been overestimated without variables for the presence and length of barriers included in the safety model.

NCHRP 3-88 research found the parameter for freeway mainline traffic was highly significant for all models, greater than 1.0 for multiple-vehicle crashes and less than 1.0 for single-vehicle crashes. The parameters indicate a smaller likelihood of a crash involving one vehicle compared to the likelihood of a crash involving more than one vehicle as traffic volumes increase and is consistent with previous research (Bonneson and Pratt, 2008) (13). The parameter for entrance ramp traffic was positive and statistically significant in the EN-EX models for all crash types except single-vehicle, indicating entrance volumes are associated with multiple-vehicle crashes resulting from increased merging maneuvers. The parameter for $\ln(ADT_{EN-1})$ was positive and statistically significant for all crash types in the EN-EN models except single vehicle, indicating higher entrance volumes on the first (upstream) ramp of an EN-EN sequence are associated with multiple-vehicle crashes resulting from increased merging maneuvers. Increasing amounts of entering traffic on the second (downstream) entrance ramp, represented by $\ln(ADT_{EN-2})$, were associated with higher crash frequencies, but the effect was not as large as for $\ln(ADT_{EN-1})$. The result may indicate that crashes associated with entrance ramps occur primarily at or downstream of the merge location.

Expected frequencies of all crash categories except single-vehicle were larger when only two through lanes per direction were present (compared to when three or four were present). The effect was largest and most statistically significant for multiple-vehicle crashes. The NCHRP 3-88 findings indicate that for a given traffic volume, three or four lanes (compared to two) provide additional room for through moving traffic to move away from merging traffic, decreasing the probability of merging conflicts.

The transferability of results to other states and geographic regions is generally the primary concern with focused, single-state efforts such as the one undertaken to date. Where possible, the 3-88 research team compared the safety findings from analyses of Washington data to related safety findings from a recent Texas study (84). The findings of AMF and SPF comparisons showed very similar safety relationships in Washington and Texas, and built confidence that the general safety trends uncovered in NCHRP 3-88 are transferable to areas with other geographic characteristics.

Chapter 4
Guidelines

Chapter 4 GUIDELINES

Two final products were produced the NCHRP 3-88 project team: this final research report, and *NCHRP Report 687: Guidelines for Ramp and Interchange Spacing (Guidelines)*. The *Guidelines* assist users as they consider the feasibility of new or rebuilt interchanges and ramps. The *Guidelines* were developed primarily for ramps and interchanges on fully-controlled access freeways, but could also be applied to ramps and interchanges on partially-controlled access highways.

The *Guidelines* are not a standard, but rather a "how to" document that is intended to be informative and present a processed for assessing spacing values. As part of this process, The *Guidelines* provide insights into the factors that influence minimum ramp and interchange spacing dimensions for various interchange forms and ramp combinations. Chapter 5 of this report discusses proposed changes to the AASHTO Green Book to create consistency between it and the *Guidelines.*

Prior to NCHRP Project 3-88, little research focused on ramp and interchange spacing had been conducted in recent decades. Rules of thumb such as one mile minimum interchange spacing in urban areas and two mile minimum interchange spacing in rural areas date from the early days of the Interstate Highway System. The minimum recommended ramp spacing values in the AASHTO's Green Book stem from publications that date from the 1970's.

The *Guidelines* present substantial background information related to freeway and interchange geometric design, traffic operations, safety, and signing. The information is drawn from major resource documents such as the AASHTO Green Book, *Highway Capacity Manual, Manual of Uniform Traffic Control Devices, Highway Safety Manual,* and *ITE Freeway and Interchange Geometric Design Handbook*; other past studies; and research conducted as part of NCHRP Project 3-88. The *Guidelines* present a framework for evaluating ramp and interchange spacing, and provide insights into the factors that influence minimum ramp and interchange spacing dimensions for various interchange forms and ramp combinations.

Chapter 1 introduces the *Guidelines* and presents their purpose, scope, and applicability. This chapter also defines and differentiates *ramp* spacing and *interchange* spacing. The *Guidelines* emphasize that ramp spacing, rather than interchange spacing, should be the primary considering when determining the adequacy of spacing.

Chapter 2 presents an overview of project development, policies relevant to ramp and interchange spacing, and major resource documents used by transportation professionals. As the project development process advances, there is both an increasing amount of information that can be used to make ramp and interchange spacing assessments and a decreasing flexibility in changing spacing values. Federal, state, and in some cases local agencies generally must approve new or substantially modified interchanges, and have policies and processes for doing so. When assessing ramp and interchange spacing and complying with relevant policies, users are likely to rely on the AASHTO Green Book, the HCM, the MUTCD, and the HSM.

Chapter 3 presents geometric design and signing considerations. A multitude of geometric features influence the design of ramps and interchanges and choices about the spacing between them. The number and type of lanes, the types and forms of interchanges, the design of ramps, and the surrounding terrain all effect choices about ramp and interchange spacing. Additionally, the AASHTO Green Book and many state-level documents provide minimum recommended ramp spacing values for both ramps and interchanges. Signing plays a role in exit ramp spacing decisions. The MUTCD recommends that a certain sequence of signs be used in advance of an interchange, but also recommends limits on the number of sign panels and message units at any one location so that drivers are not overwhelmed with information.

Chapter 4 presents traffic operations and safety considerations. Traffic operations analysis and safety analysis can be performed in the early stages of a project with planning level tools from the HCM, the ITE Freeway Handbook, and the research conducted for this project. Chapter 4 explains how to conduct such planning-level assessments, as well as complete HCM or safety analyses at later stages of a project when a complete traffic forecast is available and the level of design provides greater certainty with respect to spacing values.

Traditionally, the transportation profession has addressed safety with a nominal approach – a given design is either “safe” or “unsafe”. “Safe” designs are presumed to result from compliance with standards and guidelines. The transportation profession is shifting away this approach, and instead developing an approach where expected crash frequencies for various design alternatives will be known and used in decision-making. The *Guidelines* take this latter approach to safety.

Chapter 5 offers spacing guidance to practitioners. The chapter begins with a framework for considering ramp and interchange configurations. This framework integrates the considerations discussed in Chapters 2, 3, and 4.

Interchange spacing guidance is provided with a table containing three pairs of interchanges (with different forms). For each paring, ranges of spacing that are likely not geometrically feasible, potentially geometrically feasible, and likely geometrically feasible are identified.

Ramp spacing guidance is offered based upon geometry, traffic operations, safety, and signing.

- Based upon geometry, the *Guidelines* identified ranges of spacing that are likely not geometrically feasible, potentially geometrically feasible, and likely geometrically feasible for each of the four possible ramp combinations.

- The *Guidelines* offer traffic operations considerations for closely spaced ramp combinations based upon the HCM. The *Guidelines* offer additional traffic operations considerations for closely-spaced entry-exit and entry-entry ramps based upon the findings of this project.

- The *Guidelines* presents the relative crash risk associated with changing ramp spacing values for entry-exit and entry-entry ramp combinations.

- Based upon signing, the *Guidelines* recommends minimum values for the spacing between consecutive exit ramps and the number of exit ramps on a one-mile segment of freeway.

Chapter 6 contains five scenario-based case studies that illustrate and apply the principles of the *Guidelines*.

Appendix A contains operational analysis tools developed from the HCM and from the simulation modeling conducted as part of this research project.

Chapter 5
Resource Document Revisions

Chapter 5 RESOURCE DOCUMENT REVISIONS

For many years, transportation professionals have heavily relied upon three primary resource documents when planning and designing highway facilities: The AASHTO Green Book, the HCM, and the MUTCD. In 2010, a fourth primary resource document joined this list – the Highway Safety Manual (HSM). These documents incorporate the results of hundreds of research projects that have contributed to the knowledge base of the transportation profession.

While this research project was being conducted, an effort was underway to update (or publish for the first time) each one of these documents. By the time this project was completely, new editions of the HCM and the MUTCD had been published, the initial edition of the HSM had been published, and content for the next edition of the Green Book was finalized. As a result, it may be many years before any content from this project is incorporated into these major resource documents.

5.1 AASHTO POLICY ON GEOMETRIC DESIGN OF HIGHWAYS AND STREETS (GREEN BOOK)

At the time of NCHRP Project 3-88 research, the 2004 Green Book was being revised. It is expected to be finalized and published in 2010. A member of the NCHRP 3-88 Panel was involved with the update to Chapter 10: Grade Separations and Interchanges and coordinated with the project team. No significant changes to this chapter are anticipated in the 2010 edition, although one change will be made to the 2004 version of Exhibit 10-68 (reproduced in this report as Exhibit 2-9). Currently, Exhibit 10-68 notes that the recommended minimum ramp terminal spacing values are measured "between like points, not necessarily 'physical' gores." In the 2010 edition, this note will be changed to indicate that spacing values should be measured between painted tips. This change will make the spacing measurement definition in Exhibit 10-68 consistent with these *Guidelines* and the 2010 HCM.

Based upon the findings of NCHRP Project 3-88, more significant changes to the Green Book are proposed by the NCHRP Project 3-88 team. Changes to interchange spacing and ramp spacing guidance are outlined below in relation to the 2004 edition of the Green Book. The project team recommends that these changes be made to the next edition of the Green Book after 2010, recognizing that significant changes to the 2010 edition are not possible at this point.

5.1.1 Interchange Spacing

5.1.1.1 EXISTING

The 2004 Green Book offers the following guidance on interchange spacing:

> Interchange spacing has a pronounced effect on freeway operations. In areas of concentrated urban development, proper spacing usually is difficult to attain because of traffic demand for frequent access. Minimum spacing of arterial interchanges (distance between intersecting streets with ramps) is determined by weaving volumes, ability to sign, signal progression, and lengths of speed-change lanes. A general rule of thumb for minimum interchange spacing is 1.5 km [1 mi] in urban areas and 3.0 km [2 mi] in rural areas. In urban areas, spacing of less than 1.5 km [1 mi] may be developed by grade-separated ramps or by adding collector-distributor roads.

5.1.1.2 PROPOSED

The project team recommends the following changes to the text (changes shown in *red italics*) and the inclusion of two supporting exhibits:

> Interchange spacing has ~~a pronounced effect on freeway operations.~~ *less of an impact on freeway operations than ramp spacing. Interchange spacing is measured between crossroads as shown in Exhibit 5-1,*

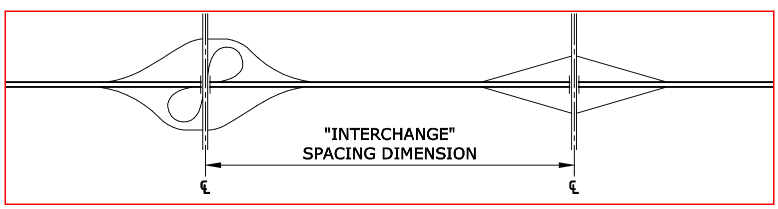
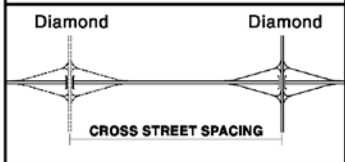
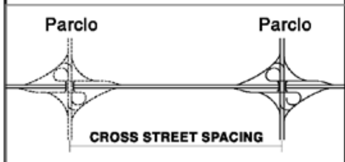
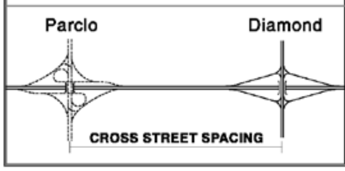


Exhibit 5-1 Definition of Interchange Spacing

> In areas of concentrated urban development, proper spacing usually is difficult to attain because of traffic demand for frequent access. Minimum spacing of arterial interchanges (distance between intersecting streets with ramps) is determined by *interchange form, lane configuration,* weaving volumes, ability to sign, signal progression, and lengths of speed-change lanes. A general rule of thumb for minimum interchange spacing is 1.5 km [1 mi] in urban areas and 3.0 km [2 mi] in rural areas. *The feasibility of interchange spacing values near 1.5 km is provided in Exhibit 5-2 for various interchange forms. Feasibility is based upon the resulting ramp spacing.*

Interchange Form	Cross Street Spacing			
	1225m – 1375m (4,000' – 4,500')	1375m – 1525m (4,500' – 5,000')	1525m – 1675m (5,000' – 5,500')	1675m – 1825m (5,500' – 6,000')
	POTENTIALLY GEOMETRICALLY FEASIBLE	POTENTIALLY GEOMETRICALLY FEASIBLE	LIKELY GEOMETRICALLY FEASIBLE	LIKELY GEOMETRICALLY FEASIBLE
	LIKELY NOT GEOMETRICALLY FEASIBLE	LIKELY NOT GEOMETRICALLY FEASIBLE	POTENTIALLY GEOMETRICALLY FEASIBLE	LIKELY GEOMETRICALLY FEASIBLE
	LIKELY NOT GEOMETRICALLY FEASIBLE	POTENTIALLY GEOMETRICALLY FEASIBLE	LIKELY GEOMETRICALLY FEASIBLE	LIKELY GEOMETRICALLY FEASIBLE

Assumes single entrance and exit design for configurations with the loop in advance or beyond the cross street.

Exhibit 5-2 Interchange Spacing Feasibility

~~In urban areas, s~~*S*pacing of less than ~~1.5 km [1 mi]~~ *the values in Exhibit 5-2* may be developed by grade-separat*ing*~~ed~~ ramps or by adding collector-distributor roads.

5.1.2 Ramp Spacing

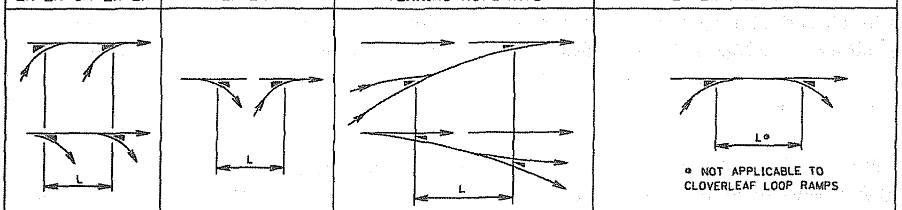
5.1.2.1 EXISTING

The 2004 Green Book offers guidance on ramp spacing:

> On urban freeways, two or more ramp terminals are often located in close succession. To provide sufficient weaving length and adequate space for signing, a reasonable distance should be provided between successive ramp terminals. Spacing between successive outer ramp terminals is dependent on the classification of the interchanges involved, the function of the ramp pairs (entrance or exit), and weaving potential.
>
> The five possible ramp-pair combinations are: (1) an entrance followed by an entrance (EN-EN), (2) an exit followed by an exit (EX-EX), (3) an exit followed by an entrance (EX-EN), (4) an entrance followed by an exit (EN-EX) (weaving), and (5) turning roadways.
>
> Exhibit 10-68 presents recommended minimum ramp terminal spacing for the various ramp-pair combinations as they are applicable to interchange classifications.
>
> Where an entrance ramp is followed by an exit ramp, the absolute minimum distance between the successive noses is governed by weaving considerations. The spacing policy for EN-EX ramp combinations is not

applicable to cloverleaf loop ramps. For these interchanges, the distance between EN-EX ramp noses is primarily dependent on loop ramp radii and roadway and median widths. A recovery lane beyond the nose of the loop ramp exit is desirable.

When the distance between the successive noses is less than 450 m [1,500 ft], the speed-change lanes should be connected to provide an auxiliary lane. This auxiliary lane improves traffic operation over relatively short sections of the freeway route and is not considered an addition to the basic number of lanes. See the section "Auxiliary Lanes" in this chapter for alternate methods of dropping these lanes.



EN-EN OR EX-EX		EX-EN		TURNING ROADWAYS		EN-EX (WEAVING)			
FULL FREEWAY	CDR OR FDR	FULL FREEWAY	CDR OR FDR	SYSTEM INTER-CHANGE	SERVICE INTER-CHANGE	SYSTEM TO SERVICE INTERCHANGE		SERVICE TO SERVICE INTERCHANGE	
						FULL FWY.	CDR OR FDR	FULL FWY.	CDR OR FDR
MINIMUM LENGTHS MEASURED BETWEEN SUCCESSIVE RAMP TERMINALS									
300 m [1000 ft]	240 m [800 ft]	150 m [500 ft]	120 m [400 ft]	240 m [800 ft]	180 m [600 ft]	600 m [2000 ft]	480 m [1600 ft]	480 m [1600 ft]	300 m [1000 ft]

NOTES: FDR - FREEWAY DISTRIBUTOR ROAD EN - ENTRANCE
CDR - COLLECTOR DISTRIBUTOR ROAD EX - EXIT

THE RECOMMENDATIONS ARE BASED ON OPERATIONAL EXPERIENCE AND NEED FOR FLEXIBILITY AND ADEQUATE SIGNING. THEY SHOULD BE CHECKED IN ACCORDANCE WITH THE PROCEDURE OUTLINED IN THE HIGHWAY CAPACITY MANUAL (4) AND THE LARGER OF THE VALUES IS SUGGESTED FOR USE. ALSO, A PROCEDURE FOR MEASURING THE LENGTH OF THE WEAVING SECTION IS GIVEN IN CHAPTER 24 OF THE 2000 HIGHWAY CAPACITY MANUAL (4).
THE "L" DISTANCES NOTED IN THE FIGURES ABOVE ARE BETWEEN LIKE POINTS, NOT NECESSARILY "PHYSICAL" GORES.
A MINIMUM DISTANCE OF 90 m [270 ft] IS RECOMMENDED BETWEEN THE END OF THE TAPER FOR THE FIRST ON RAMP AND THE THEROETICAL GORE FOR THE SUCCEDING ON RAMP FOR THE EN-EN (SIMILIAR FOR EX-EN).

Exhibit 10-68. Recommended Minimum Ramp Terminal Spacing

5.1.2.2 PROPOSED

The project team recommends replacing the current Green Book text and Exhibit 10-68 with the following (changes shown in *red italics*):

On urban freeways, two or more ramp terminals are often located in close succession. To provide sufficient weaving length and adequate space for signing, a reasonable distance should be provided between successive ramp terminals. Spacing between successive outer ramp terminals is dependent on the classification of the interchanges involved, the function of the ramp pairs (entrance or exit), and weaving potential. *Ramp spacing is measured between painted tips, as shown in Exhibit 5-3.*

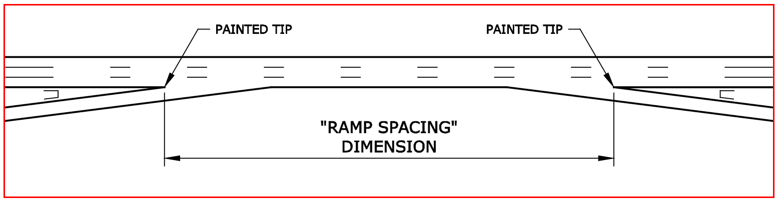


Exhibit 5-3 Definition of Ramp Spacing

The five possible ramp-pair combinations are: (1) an entrance followed by an entrance (EN-EN), (2) an exit followed by an exit (EX-EX), (3) an exit followed by an entrance (EX-EN), (4) an entrance followed by an exit (EN-EX) (weaving), and (5) turning roadways.

Minimum recommended spacing values for each of these five combinations are provided in the following sections. A range, rather than a single number, is provided in order to account for differences in convergence and divergence angles, taper and parallel designs, and other gore-area elements. Traffic operations needs must also be considered in addition to the geometric minimums presented here.

Entrance Ramp Followed by Exit Ramp (EN-EX)

Where an entrance ramp is followed by an exit ramp, the absolute minimum distance between the successive noses is governed by weaving considerations. The spacing policy for EN-EX ramp combinations is not applicable to cloverleaf loop ramps. For these interchanges, the distance between EN-EX ramp noses is primarily dependent on loop ramp radii and roadway and median widths. A recovery lane beyond the nose of the loop ramp exit is desirable.

When the distance between the successive noses is less than 450 m [1,500 ft], the speed-change lanes should be connected to provide an auxiliary lane. This auxiliary lane improves traffic operation over relatively short sections of the freeway route and is not considered an addition to the basic number of lanes. See the section "Auxiliary Lanes" in this chapter for alternate methods of dropping these lanes.

Table 5-1 Diamond Interchange Entrance-Exit Ramp Combination

Ramp Spacing Dimension	*Feasibility*
Less than 1600'	*Likely Not Geometrically Feasible*
1600' to 2600'	*Potentially Geometrically Feasible*
Greater than 2600'	*Likely Geometrically Feasible*

Table 5-2 Partial Cloverleaf Interchange Entrance-Exit Ramp Combination

Ramp Spacing Dimension	*Feasibility*
Less than 1600'	*Likely Not Geometrically Feasible*
1600' to 1800'	*Potentially Geometrically Feasible*
Greater than 1800'	*Likely Geometrically Feasible*

Assumes single entrance and exit design for configurations with the loop in advance or beyond the cross street.

Entrance Ramp Followed by Entrance Ramp (EN-EN)

Table 5-3 Entrance-Entrance Ramp Combination

Ramp Spacing Dimension	*Feasibility*
Less than 1400'	*Likely Not Geometrically Feasible*
1400' to 1800'	*Potentially Geometrically Feasible*
Greater than 1800'	*Likely Geometrically Feasible*

Exit Ramp Followed by Exit Ramp (EX-EX)

Table 5-4 Exit-Exit Ramp Combination

Ramp Spacing Dimension	*Feasibility*
Less than 900'	*Likely Not Geometrically Feasible*
900' to 1100'	*Potentially Geometrically Feasible*
Greater than 1100'	*Likely Geometrically Feasible*

Exit Ramp Followed by Entrance Ramp (EX-EN)

There are two primary scenarios of an exit-entrance combination. The shortest dimension would be that of an exit followed by the entrance for a "button hook" design where the freeway ramps are serving a local street parallel to the freeway versus a local street crossing the freeway as an over or underpass. This interchange form is not desirable and this combination is an unlikely configuration.

The second scenario would be when an exit ramp and subsequent entrance ramp are servicing grade separated ramps (ramp braids). Based on the vertical and horizontal relationships of this configuration, the spacing values in Table 5-5 are recommended. The minimum values reflect a condition where both ramp profiles are changing.

Table 5-5 Exit-Entrance Ramp Combination (Braided Ramps)

Ramp Spacing Dimension	*Feasibility*
Less than 1700'	*Likely Not Geometrically Feasible*
1700' to 2300'	*Potentially Geometrically Feasible*
Greater than 2300'	*Likely Geometrically Feasible*

Turning Roadways

A turning roadway is a configuration where the entrance and exit ramps from or to multiple origins or destinations merge or diverge prior to or after exiting a mainline segment. This is a common attribute of "single exit" designs that provide a single exit or entrance that serves multiple destinations or origins. Exhibit 5-2 depicts turning roadways.

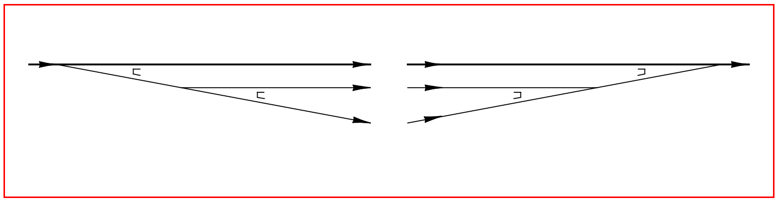


Exhibit 5-2 Turning Roadway Examples

Table 5-6 Turning Roadways

Ramp Spacing Dimension	Feasibility
Less than 600'	Likely Not Geometrically Feasible
600' to 800'	Potentially Geometrically Feasible
Greater than 800'	Likely Geometrically Feasible

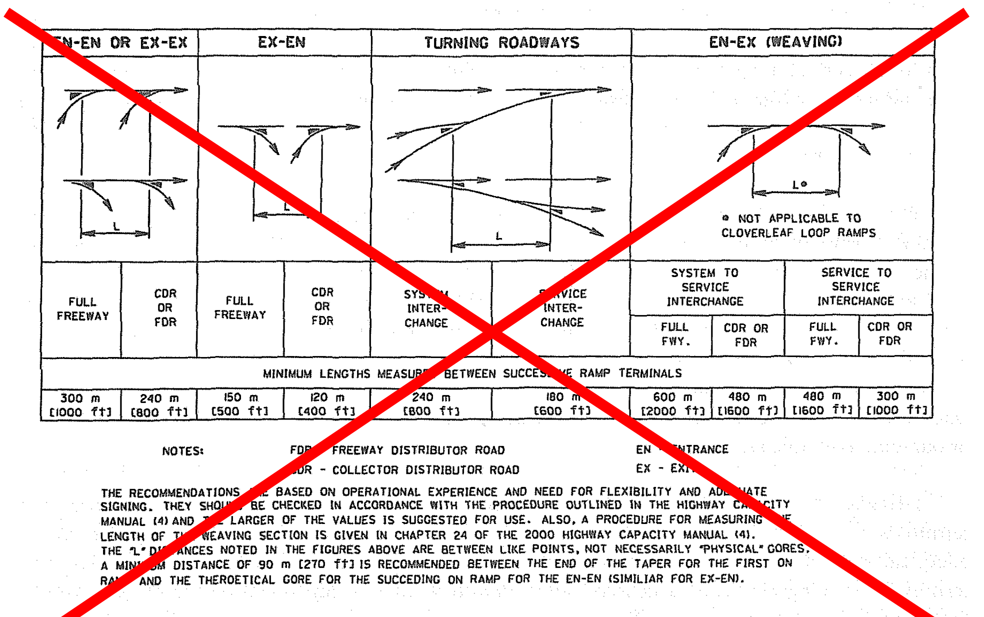


Exhibit 10-68. Recommended Minimum Ramp Terminal Spacing

5.2 HIGHWAY CAPACITY MANUAL (HCM)

After several years of preparation that occurred concurrent to this project, and update to the 2000 HCM was published in 2010. The NCHRP 3-88 project team reviewed the most recent draft chapters of the 2010 HCM to which ramp and interchange spacing are potentially relevant:

- Chapter 10: Freeway Facilities
- Chapter 11: Basic Freeway Segments
- Chapter 12: Freeway Weaving Segments
- Chapter 13: Freeway Merge and Diverge Segments

Chapter 10 provides background information on freeways and does not contain any analytical procedures. Chapter 11 contains procedures for analyzing freeway segments which are outside the immediate vicinity of ramps and interchanges. The project team does not recommend changes to these chapters.

Chapter 12 provides a procedure for analyzing weaving segments. As defined in the HCM, a weaving segment must have an auxiliary lane between the entry ramp and the exit ramp that define the segment. The HCM does not provide a procedure for analyzing a similar segment without an auxiliary lane, nor does it provide any information on the applicability of the weaving (with auxiliary lane) procedures to a non-auxiliary lane segment. Simulation modeling by the project team analyzed "weaving" segments with and without an auxiliary lane to investigate the difference in freeway speed associated with each case.

The NCHRP 3-88 project team recommends that research efforts in support of the next edition of the HCM (after 2010) consider a means of analyzing "weaving" sections without auxiliary lanes. This could be in the form of an entirely separate methodology or in the form of a factor that adjusts the weaving methodology for non-auxiliary lane designs. The findings of NCHRP 3-88 efforts could play a role in considering and developing such a methodology.

Chapter 13 provides a procedure for analyzing the "influence area" on a two-, three-, or four-lane freeway associated with a single merging ramp or a single diverging ramp. Only on three-lane freeways does the methodology take into account the presence of adjacent ramps. However, simulation models conducted for this project have identified an impact on the operating speed of a four-lane freeway due to ramp spacing.

Based upon this finding, the project team suggests this impact be more thoroughly investigated with additional field data as part of a project exclusively focused on traffic operations. The results of such a project could lead to updates to the HCM (after 2010) that could be used to quantify the impact of adjacent ramps on merges and diverges on four-lane freeways.

5.3 MANUAL OF UNIFORM TRAFFIC CONTROL DEVICES (MUTCD)

In December 2009, FHWA issued a new (2009) edition of the MUTCD. Information potentially relevant to this project is primarily found in Chapter 2E: Guide Signs – Freeways and Expressways. Chapter 2E recommends limits on the number of signs that should be located at a single point, the distance between signs, and the distance in which signs should be located prior to an exit. These guidelines effectively limit the number of exits that can be placed within a short distance of each other and still be adequately and properly signed. Human factors and other considerations that form the basis of this guidance were not explicitly investigated as part of NCHRP 3-88. The project team does not recommend any changes to the MUTCD.

5.4 HIGHWAY SAFETY MANUAL (HSM)

The first edition of the HSM was published in June 2010. The HSM contains procedures for assessing the safety performance of a number of different roadway types and components. Interchange-related information is contained within Chapter 15. That chapter presents accident modification factors (AMFs) for design elements, traffic control and operational elements, pedestrian- and bicycle-related elements, and other elements associated with interchanges.

The HSM does not yet provide quantitative information for many of the elements associated with interchanges, and there is no quantitative information regarding the effect of interchange spacing. Chapter 15 provides a general statement that decreases in interchange spacing appears to increase crashes, but the magnitude of the effect on crash frequency is uncertain. The AMFs and the safety performance functions developed in this project could form the basis of a future HSM procedure that quantifies the impact of interchange and ramp spacing on crash frequency.

Chapter 6
Suggested Research

Chapter 6 Suggested Research

Ramp and interchange spacing are topics that have received relatively little attention from the transportation research community in recent years. During this time, the knowledge base of traffic operations research has increased substantially, best practices in ramp design have evolved, and safety has become an increasingly important consideration in the planning and design process. The operations and safety research conducted as part of this project assisted the research team in developing guidelines for ramp and interchange spacing and recommendations for changes to major resource documents such as the AASHTO Green Book. The NCHRP 3-88 project team has identified other research topics (in no particular order) for future consideration:

- Research activities for this project focused on single-lane ramps, although double-lane ramps are becoming increasingly common. Double-lane ramps provide increased roadway capacity, but they can be challenging to sign and may have lane balance issues. Future research should consider these issues and provide guidance on when it is appropriate to use two-lane ramps. The research should also consider minimum ramp and interchange spacing dimensions associated with two-lane ramps, which are presumably greater than the dimensions associated with single-lane ramps.

- Historically, most ramp and interchange spacing guidance has been focused on service interchanges. Research activities for this project were focused on service interchanges and service interchange ramps as well. Additional research that examines spacing needs for system interchanges, as well as major fork and branch connections, is recommended.

- Exhibit 10-68 of the 2004 AASHTO Green Book contains separate recommended minimum ramp spacing dimensions for ramps on a “full freeway” and ramps on a “CDR or FDR” (collector distributor roadway or freeway distributor roadway). Minimum spacing dimensions provided for CDRs and FDRs are 80% or less than the full freeway dimensions. FDRs are no longer widely used, but CDRs remain an integral part of freeway and interchange design. This project investigated and is recommending changes to the full freeway recommended minimum ramp spacing values in Exhibit 10-68. Future research should investigate if different (shorter) recommended minimum ramp spacing values are still appropriate for CRDs, and, if so, what the values should be.

- Exhibit 10-68 of the 2004 AASHTO Green Book contains recommended minimum ramp spacing dimension for the four possible ramp combinations (EN-EN, EX-EX, EX-EN, and EN-EX) as well as recommended minimum spacing values between successive merges and diverges on turning roadways. This project investigated, to a varying degree, each of the four ramp combinations but not turning roadways. Future research should investigate and recommended updated minimum spacing dimensions for the various components of turning roadways.

- Exhibit 10-68 of the 2004 AASHTO Green Book considers ramp spacing as if the ramps are in isolation. However, ramps are components of interchanges, and interchange forms play an integral part in ramp spacing. Future research should consider ramps within the context of interchanges, as interchange form will influence ramp design and spacing needs.

- Ramp metering is becoming an increasing popular freeway management strategy. Because ramp meters sometimes force vehicles to stop along entry ramps, the acceleration profile of entering vehicles is fundamentally altered. Ramp meters may necessitate longer ramps and increased interchange spacing. Future research should investigate the impact of ramp meters on ramp design and spacing needs.

- The literature review and subsequent research activities conducted for this project revealed a lack of guidance on the use of auxiliary lanes. The AASHTO Green Book recommends their use when EN-EX ramp spacing is less than 1500 feet, but no volume/operational/safety-based guidance was identified by the research team. Simulation modeling by the research team identified situations when auxiliary lanes may offer operational benefits. A highway capacity-level research effort that uses more field data and examines a greater range of conditions (number of freeway lanes, traffic volume, etc) is recommended. Safety modeling by the project team identified an expected reduction in crashes associated with the presence of an auxiliary lane. The expected reduction was assumed to be the same, regardless of specific site characteristics. Future safety research that explores the interactions between traffic volumes, spacing, and auxiliary lane presence is recommended.

- This project used simulation models calibrated with limited field data as a cost-effective means of assessing the impact of ramp spacing on freeway speed. Analysis was performed for EN-EX and EN-EN ramp combinations on eight-lane freeways. Future research that studies other ramp combinations and freeways with different numbers of lanes is recommended.

- The HCM, as part of the ramp-freeway junction procedure, specifies that the "influence area" related to a ramp on a freeway extends 1500 feet upstream from a diverge and 1500 feet downstream from a merge. It is presumably desirable from an operations and safety perspective to place ramps far enough apart that the influence areas associated with them do not overlap. However, this assumption has not been investigated. Future research that verifies the length of the influence area and studies the effects of overlapping influence areas is recommended.

- The HCM contains separate procedures for the analysis of basic freeway segments, ramp-freeway junctions (i.e. merges and diverges) and weaving sections. Each of these sections is occasionally updated independently based upon new field data that reflects changes in design standards, the vehicle fleet, driver behavior, and other factors. A limitation of this approach is that inconsistencies between the methodologies are sometimes created and opportunities to better integrate the procedures with each other are minimized. For example, there have been several weaving procedures used in the HCM over the years, but there has never been a procedure for analyzing closely-spaced entrance-exit ramp combinations without auxiliary lanes (or guidance on whether or not the weaving procedure is applicable to such a situation). Likewise, the current ramp-freeway junction procedure does not account for the impacts of adjacent ramps in most cases or specify what is considered "adjacent" (for the few cases where they are taken into account). Furthermore, the basic freeway segment chapter specifies a decrease in mainline freeway performance as the number (density) of ramps increases. It is recommended that a future research project consider basic freeway segments, ramp-freeway junctions, and weaving and simultaneously update all of the methodologies in an attempt to eliminate the inconsistencies noted above.

- Two of the three HCM procedures noted in the previous recommendation (basic freeway segments and weaving) were updated for the 2010 HCM. Recognizing that an update of all three freeway-related procedures may be a number of years away, it is recommended that further research be undertaken in the interim to quantify the impact of adjacent ramps on ramp-freeway junction operation and the applicability (or lack thereof) of the weaving procedure for analysis of closely-spaced entrance-exit ramps without auxiliary lanes.

- The project team estimated safety models for EN-EX and EN-EN ramp combinations. The models are at a level of detail appropriate for project planning and preliminary design and were part of a larger effort to create guidance on ramp and interchange spacing. Additional safety-specific research efforts that build on these models, improving their accuracy and precision across a range of conditions, are recommended. Safety research that studies other ramp combinations is also needed.

- This research did not consider the interaction between ramp spacing and lengths of speed change lanes and the effects of that interaction on safety. Future safety research that explores the impact of ramp and ramp terminal designs on freeway mainline safety is recommended. Future safety models should also include variables that address the presence or lack of lane balance on safety.

- Safety models estimated by the project team express yearly or multi-year expected crash frequencies as a function of traffic and geometric variables, including ramp spacing. Measures of daily traffic volumes are used. Crash risk likely varies with hourly and sub-hourly fluctuations in traffic volumes. Research that investigates the relationship between crash risk and changes in traffic operations at an hourly or sub-hourly level is needed.

- Specific safety models for crashes involving large trucks were estimated and summarized in the *Second Interim Report* for this project. The proportion of explained variation by the truck safety model was smallest (i.e., was the weakest of all safety models estimated), indicating the model specification for truck crashes was missing key variables. Available truck-volume data were tested, but the data quality appeared suspect and were ultimately excluded from the model. Any future comprehensive model of truck crashes should include truck volumes. Future research on the relationship between ramp spacing and truck-involved crashes is recommended.

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Appendix A
Field Data Collection Sites

Appendix A Traffic Operations Work Plan - Field Data Collection Candidate Sites

Name		Loop 101: 56th to N. Scottsdale Rd		I-10 (Papago Fwy): N. Litchfield Rd to Dysart		I-275: N. Lois Ave to NW Shore Blvd
City, State, County		Phoenix, AZ		Phoenix, AZ		Tampa, FL
Ramp Combination		Entry-Exit w/o Aux Lane		Entry-Exit w/o Aux Lane		Entry-Exit w Aux Lane EB w/o Aux Lane WB
Street Names		Mainline: Loop 101		Mainline: I-10		Mainline: I-275
		Cross St: N 56th St and N. Scottsdale Rd		Cross St: N. Litchfield Rd bypass and N Dysart Rd		Cross St: NW Shore Blvd and N Lois Ave
Direction		WB	EB	WB	EB	WB
Freeway Lanes		3-lane	3-lane	2-lane	2-lane	3-lane
Lane widths (ft)		12	12	12	12	12
Shoulder Widths (ft)		14	14	6	12	10
Median Widths (ft)		45		85		20
Distances	**D1 (m)**	2.12		1		0.61
	D2 (m)	1.1	1.15	0.28	0.21	0.16
	D3 (m)	1.42	1.39	0.35	0.33	0.28
	D4 (m)	1.61	1.59	0.64	0.64	0.36
	D5 (ft)	1400	1260	880	720	695
	D6 (ft)	1250	1340	810	960	680
Terrain *		Flat		Flat		Flat
Area Type		Rural		Suburban		Urban
Speed		65 mph		65 mph		Data not obtained
Data Collection		No midpoint location identified.		No midpoint location identified.		No midpoint location identified.
Data Availability		ADOT Freeway Management System		ADOT Freeway Management System		Data available from FDOT
Site Selected?		No		No		No

	*	Terrain was estimated from Google Earth
En-Ex	D1	Interchange to Interchange
	D2	between inside edges of ramp
	D3	Distance between Markings of Gore
	D4	Distance between Gores
	D5	Distance from Interchange to start of Gore (west/south)
	D6	Distance from Interchange to start of Gore (east/north)
En-En	D1	Interchange to Interchange
	D2	between inside edges of ramp
	D2*	upstream outside edge to downstream inside edge
	D3	upstream inside edge to downstream outside edge
	D4	Distance between Gores
	D5	Distance from Interchange to start of Gore (upstream)
	D6	Distance from Interchange to start of Gore (downstream)

Appendix A

Name		I-5: Downing Ave to W 8th Ave		I-5: Downing Ave to S French Camp		SR 51 NB 20th St to Indian School Rd		SR 51 NB Bethany Home Rd to Glendale Rd
City, State, County		Stockton, CA		Stockton, CA		Phoenix, AZ		Phoenix, AZ
Ramp Combination		Entry-Exit w/o Aux Lane		Entry-Exit w/o Aux Lane		Entry-Exit w/o Aux Lane		Entry-Exit w/o Aux Lane
Street Names		Mainline: I-5		Mainline: I-5		Mainline: SR-51		Mainline: SR-51
		Cross St: Downing Ave W 8th Ave		Cross St: Downing Ave S French Camp Rd		Cross St: E Thomas Rd, E Indian School Rd		Cross St: E Bethany Home Rd, E Glendale Rd
Direction		SB	NB	SB	NB	SB	NB	NB
Freeway Lanes		3-lane	3-lane	3-lane	3-lane	3-lane	3-lane	3-lane
Lane widths (ft)		12	12	12	12	12	12	12
Shoulder Widths (ft)		10	10	10	10	10	11	9
Median Widths (ft)		60		60		35		10
Distances	D1 (m)	1		1.12		1.04		1.01
	D2 (m)	0.42	0.41	0.58	0.53	0.3	0.35	0.38
	D3 (m)	0.52	0.49	0.68	0.71	0.44	0.41	0.42
	D4 (m)	0.68	0.68	0.82	0.8	0.6	0.57	0.64
	D5 (ft)	860	850	900	830	1550	1590	940
	D6 (ft)	660	640	750	880	570	880	980
Terrain *		Flat		Flat		Flat		Flat
Area Type		Suburban		Suburban		Urban		Suburban
Speed		Data not obtained		Data not obtained		55 mph		55 mph
Data Collection		No midpoint location identified.		No midpiont location identified.		No midpiont location identified.		No midpiont location identified.
Data Availability		Data available from Caltrans		Data available from Caltrans		ADOT Freeway Management System		ADOT Freeway Management System
Site Selected?		No		No		No		No

Appendix A

Name		SR 51 Glendale Rd to Northern Ave	SR 51 SB Union Hills to Bell Rd	I-10 from Orange Grove Rd to Ina Rd		SR 51 SB N 32nd St to E Northern Ave
City, State, County		Phoenix, AZ	Phoenix, AZ	Tucson, AZ		Phoenix, AZ
Ramp Combination		Entry-Exit w/o Aux Lane SB w Aux NB	Entry-Exit w/o Aux Lane SB	Entry-Exit w/o Aux Lane		Entry-Entry w Aux Lane
Street Names		Mainline: SR-51	Mainline: SR-51	Mainline: I-10		Mainline: SR 51
		Cross St: E Glendale Rd, E Northern Ave	Cross St: E Glendale Rd, E Northern Ave	Cross St: Orange Grove Rd, Ina Rd		Cross St: E 32nd St, E Northern Ave
Direction		SB	SB	SB	NB	SB
Freeway Lanes		3-lane	4-lane	3-lane	3-lane	3-5 lane
Lane widths (ft)		12	12	12	12	12
Shoulder Widths (ft)		8	7	10	10	10
Median Widths (ft)		45	45	60		22
Distances	D1 (m)	1.4	1	1.32		2
	D2 (m)	0.71	0.3	0.52	0.45	0.57 (0.67*)
	D3 (m)	0.81	0.38	0.61	0.53	0.65
	D4 (m)	1.07	0.6	0.79	0.75	0.68
	D5 (ft)	800	980	1500	1150	1150
	D6 (ft)	1010	1090	1280	1790	5775
Terrain *		Slope	Flat	Flat		Slope
Area Type		Suburban	Suburban	Surburban		Suburban
Speed		65 mph	65 mph	65 mph		65 mph
Data Collection		No midpiont location identified.	Pedestrian overpass at midpoint	No midpiont location identified.		Pedestrian overpass at midpoint
Data Availability		ADOT Freeway Management System	ADOT Freeway Management System	ADOT Freeway Management System		ADOT Freeway Management System
Site Selected?		No	**Yes**	No		No

Appendix A

Name		SR 202 Priest Dr to N Center Pkwy
City, State, County		Phoenix, AZ
Ramp Combination		Entry-Entry
Street Names		Mainline: SR 202
		Cross St: N Priest Dr, N Center Pkwy
Direction		EB
Freeway Lanes		4-lane
Lane widths (ft)		12
Shoulder Widths (ft)		9
Median Widths (ft)		22
Distances	D1 (m)	0.64
	D2 (m)	0.36 (0.38*)
	D3 (m)	0.51
	D4 (m)	0.49
	D5 (ft)	1820
	D6 (ft)	850
Terrain *		Slope
Area Type		Suburban
Speed		65 mph
Data Collection		Bridge over-crossing at midpoint
Data Availability		ADOT Freeway Management System
Site Selected?		**Yes**

Appendix B
Findings From Other NCHRP Datasets

NCHRP Project 3-37 – Merge Data Collection Sites

The following plots contain data in averaged in 15 minute bins collected at merge sites as part of NCHRP Project 3-37. The data is presented in three different ways:

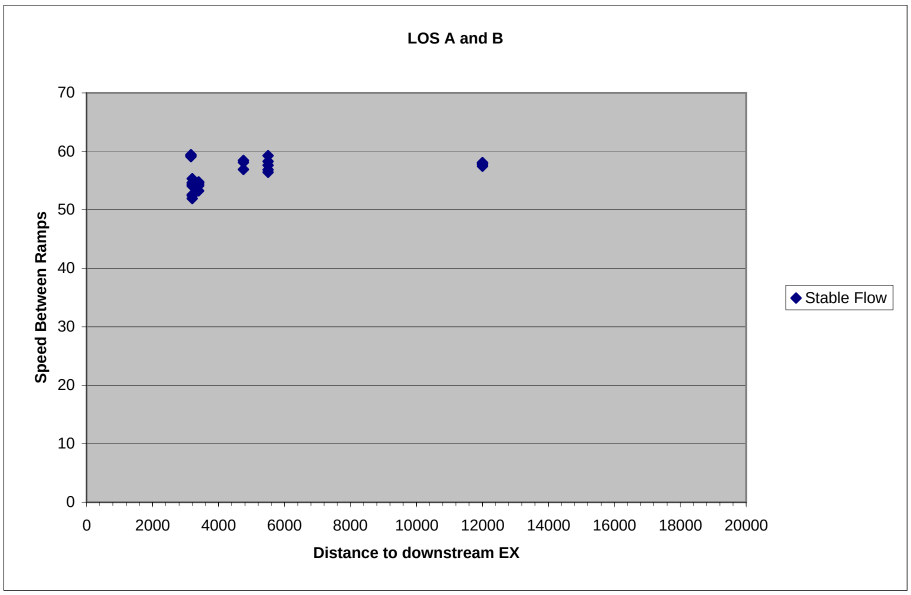
- Each 15-minute period classified as stable or unstable flow
- Each 15-minute period classified as being on a 2-, 3-, or 4-lane (one-way) freeway
- Each 15-minute period classified as having a low, moderate, or high entry ramp volume.

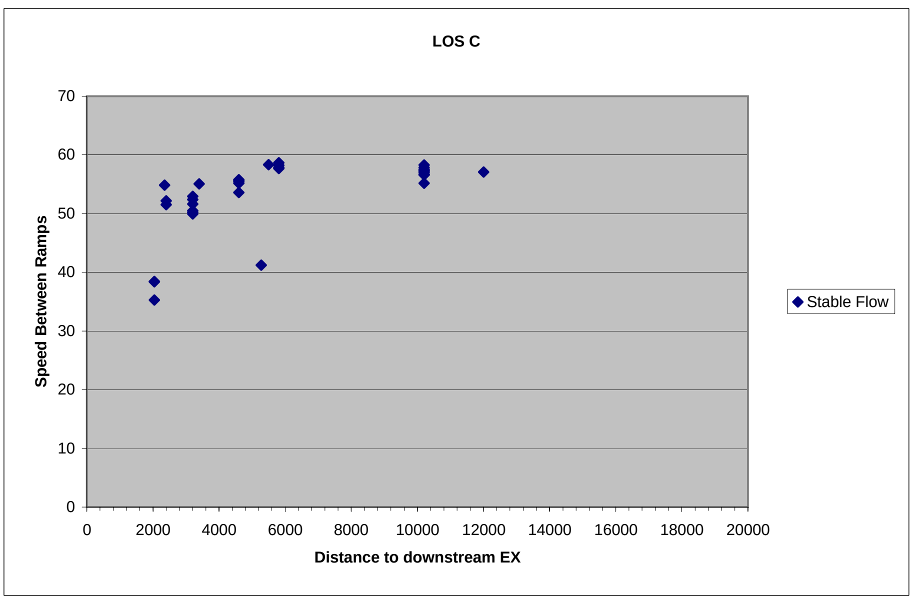
Within each of these classifications, separate charts are provided for data in each LOS.

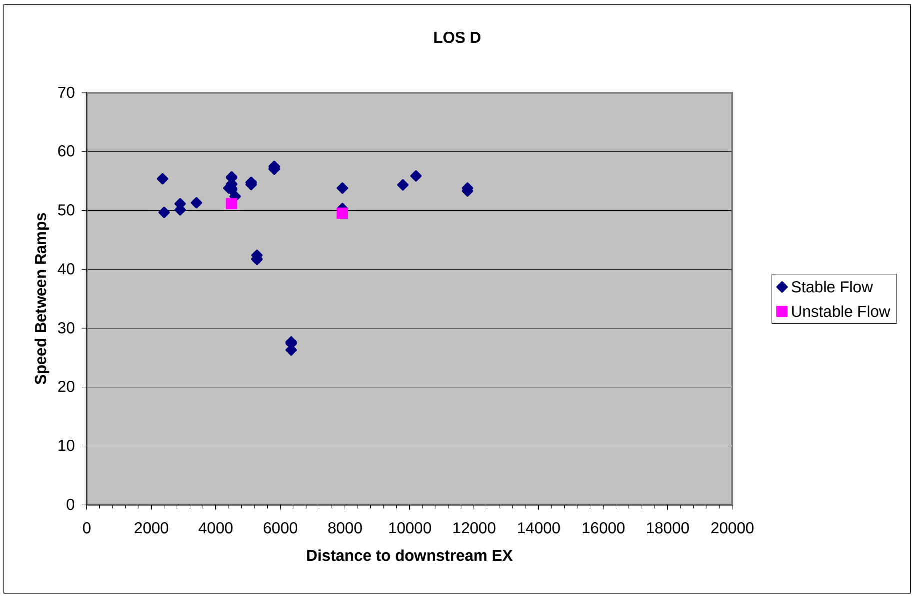
Notes on the charts:

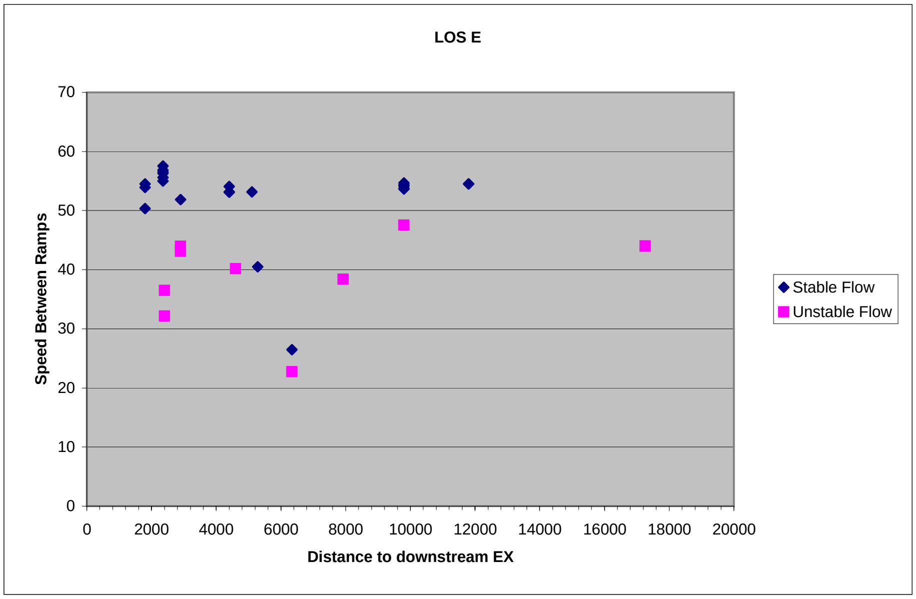
- LOS was measured upstream of the merge ramp and determined by the Project 3-37 researchers
- “Speed between ramps” is the minimum average speed measured by detectors located downstream of the merging ramp

Sorted By:
Stable or Unstable Flow






LOS D
70
60
50
40
30
20
10
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Speed Between Ramps
Distance to downstream EX
Stable Flow
Unstable Flow


LOS E
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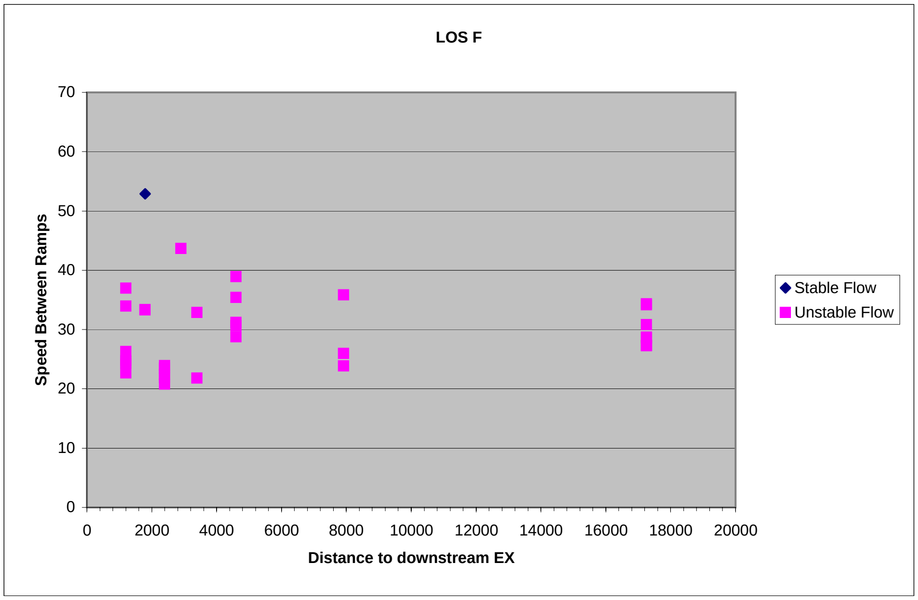
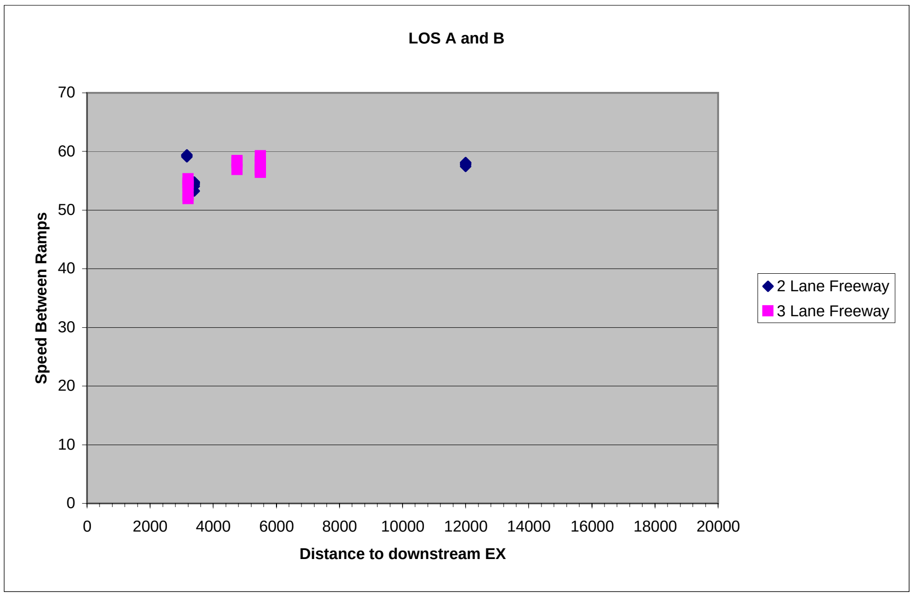
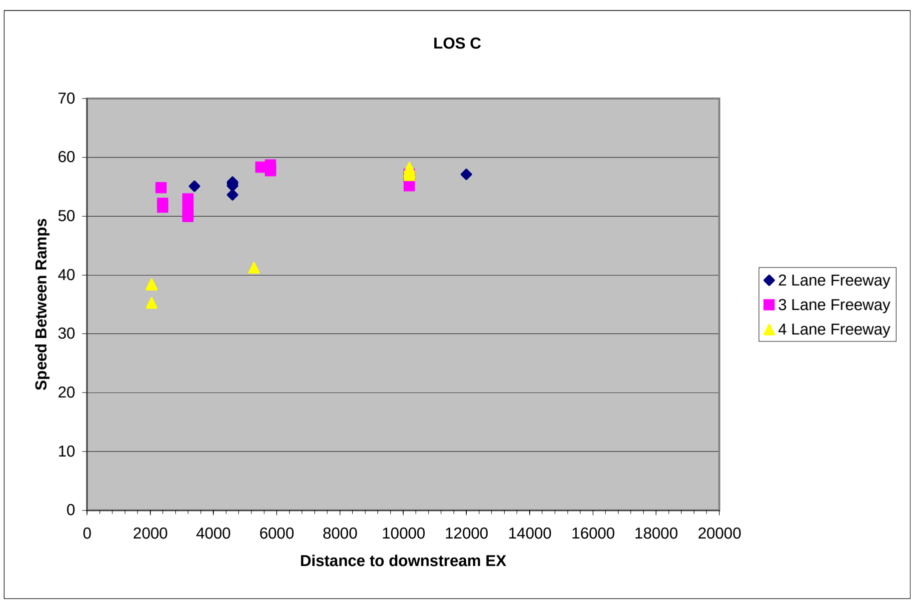
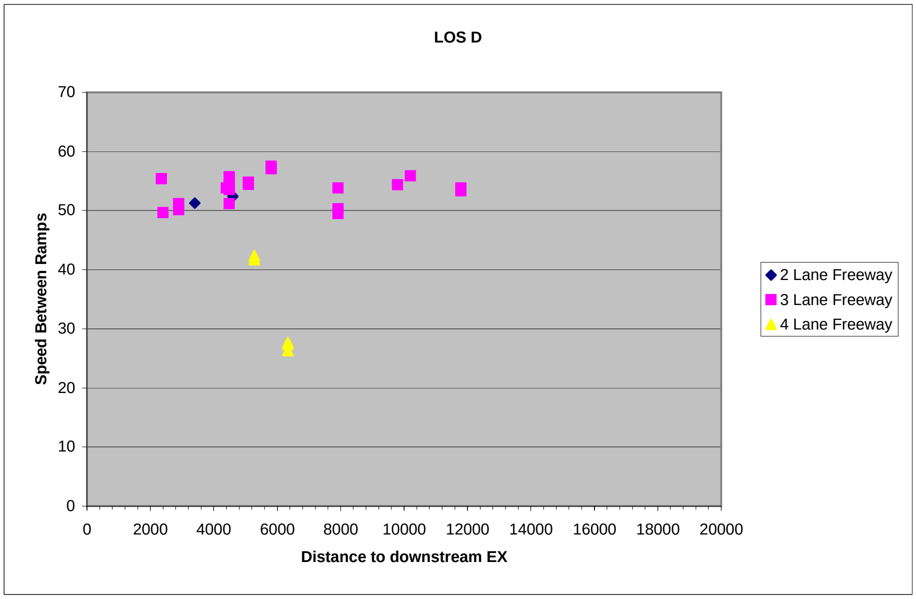
20000
Speed Between Ramps
Distance to downstream EX
Stable Flow
Unstable Flow

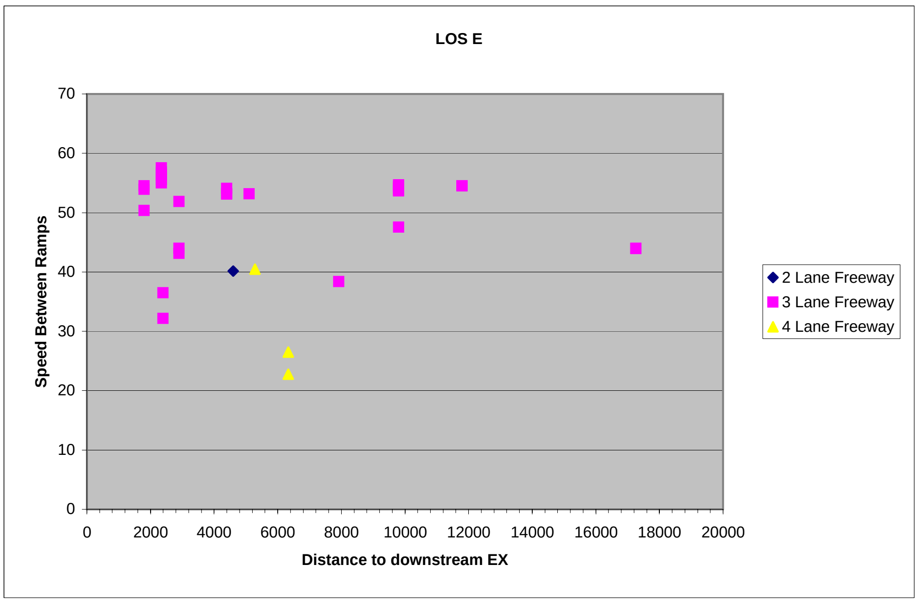

LOS F
70
60
50
40
30
20
10
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Speed Between Ramps
Distance to downstream EX
Stable Flow
Unstable Flow

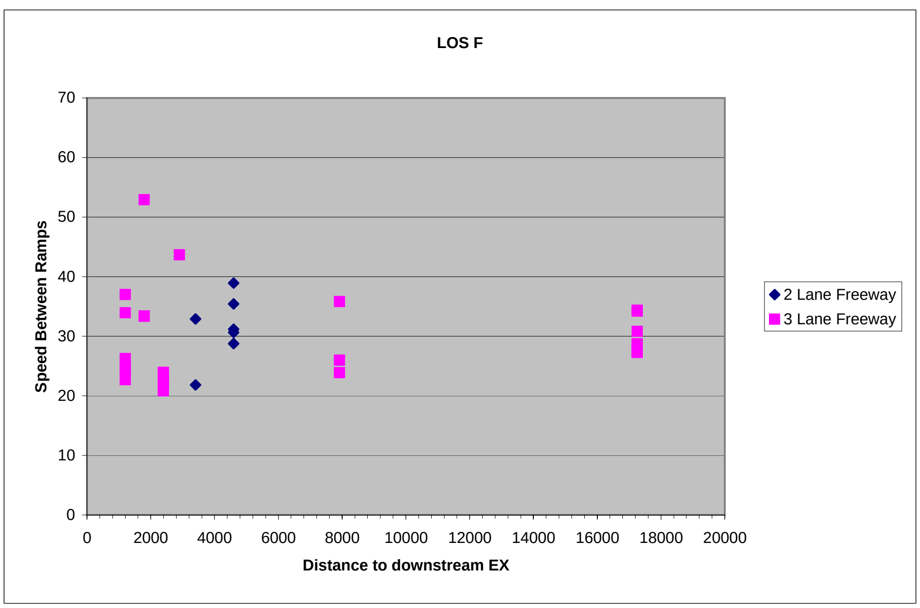
Sorted By:
Number of Freeway Lanes



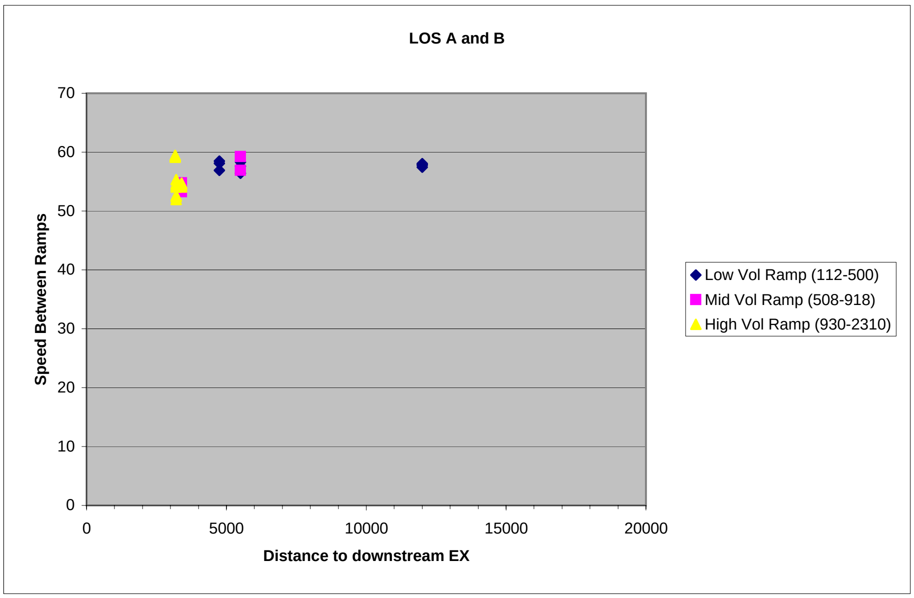


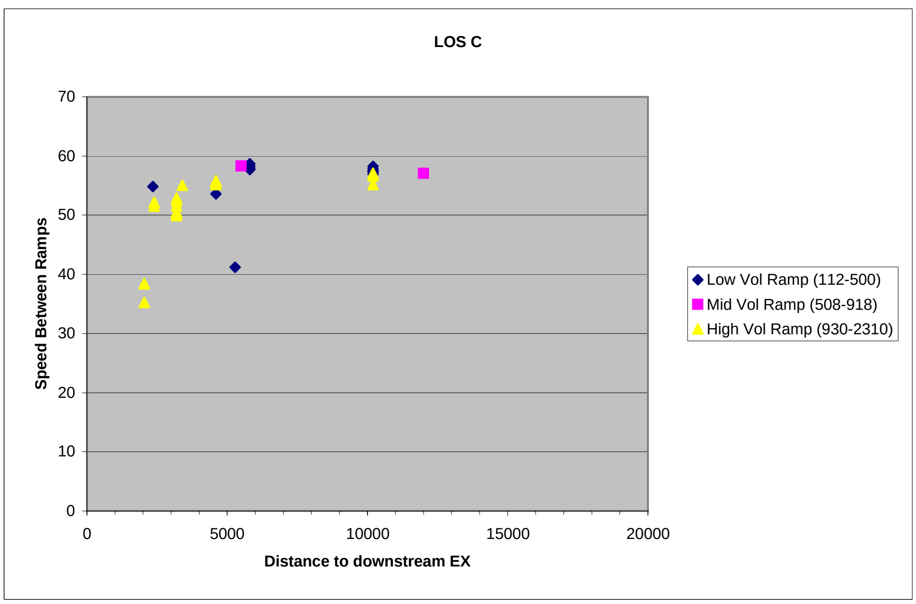

LOS D
Speed Between Ramps
Distance to downstream EX
2 Lane Freeway
3 Lane Freeway
4 Lane Freeway

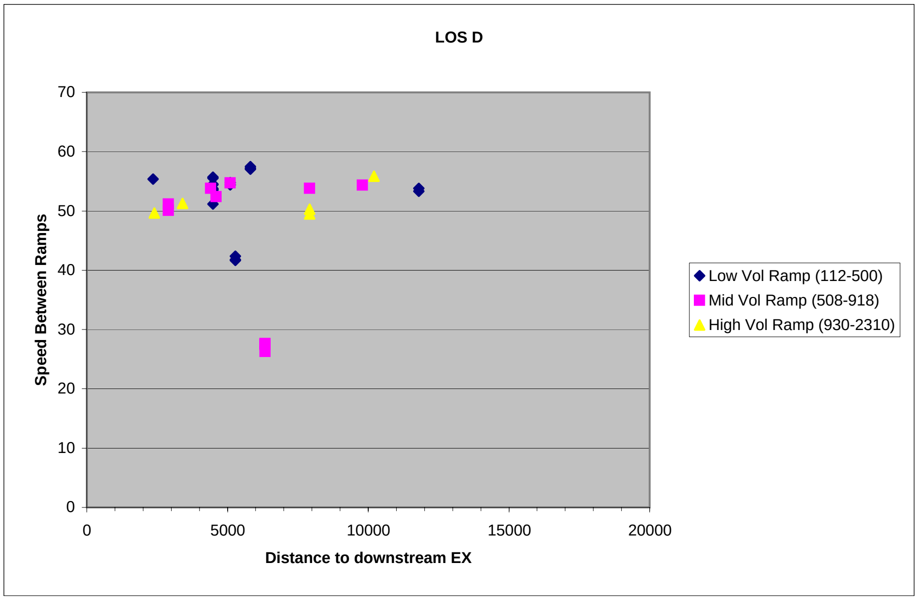

LOS E
Speed Between Ramps
Distance to downstream EX
2 Lane Freeway
3 Lane Freeway
4 Lane Freeway

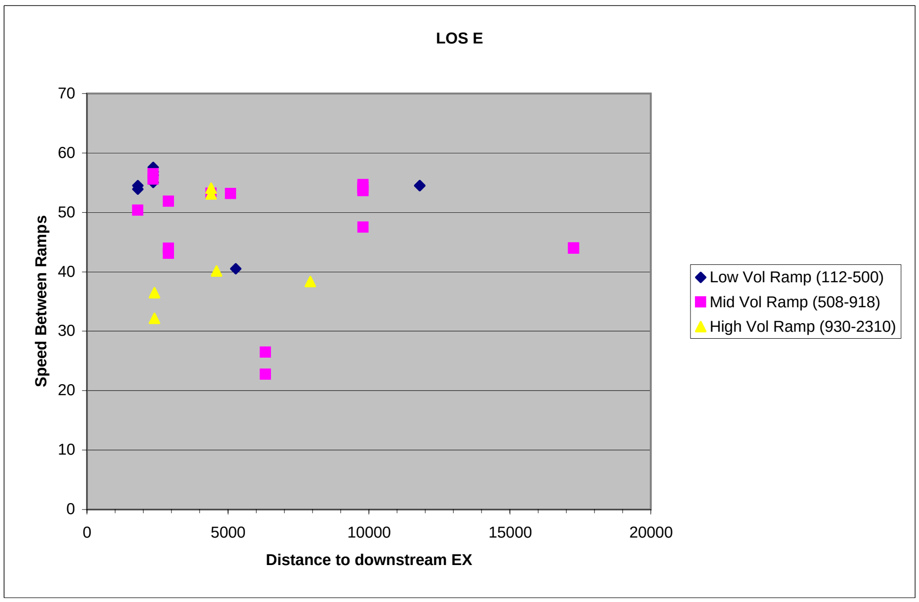

LOS F
Speed Between Ramps
Distance to downstream EX
2 Lane Freeway
3 Lane Freeway

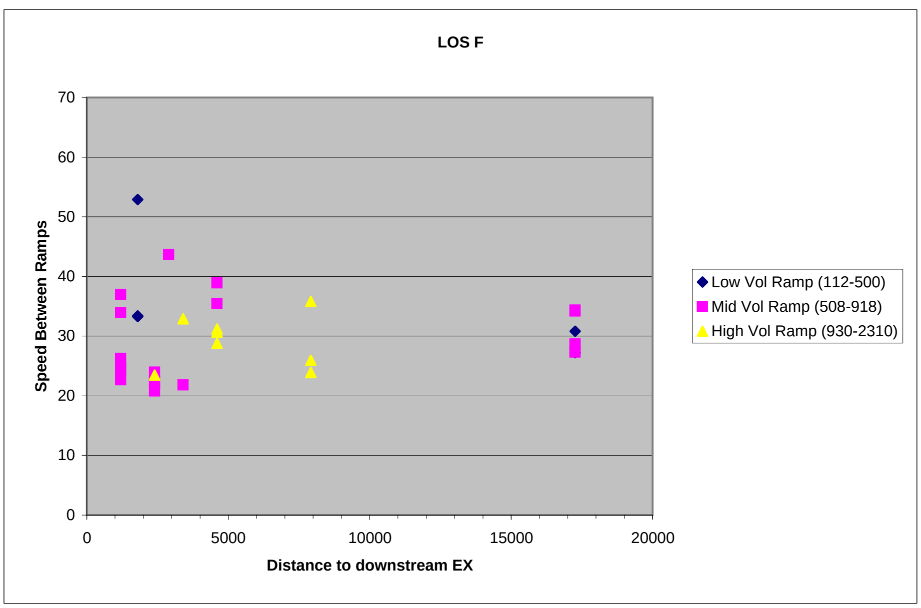
Sorted By:
Ramp Volume






LOS D
Speed Between Ramps
Distance to downstream EX
0
5000
10000
15000
20000
0
10
20
30
40
50
60
70
Low Vol Ramp (112-500)
Mid Vol Ramp (508-918)
High Vol Ramp (930-2310)


LOS E
Speed Between Ramps
Distance to downstream EX
0
5000
10000
15000
20000
0
10
20
30
40
50
60
70
Low Vol Ramp (112-500)
Mid Vol Ramp (508-918)
High Vol Ramp (930-2310)


LOS F
Speed Between Ramps
Distance to downstream EX
0
5000
10000
15000
20000
0
10
20
30
40
50
60
70
Low Vol Ramp (112-500)
Mid Vol Ramp (508-918)
High Vol Ramp (930-2310)

NCHRP Project 3-37 – Diverge Data Collection Sites

The following plots contain data in averaged in 15 minute bins collected at diverge sites as part of NCHRP Project 3-37. The data is presented in three different ways:

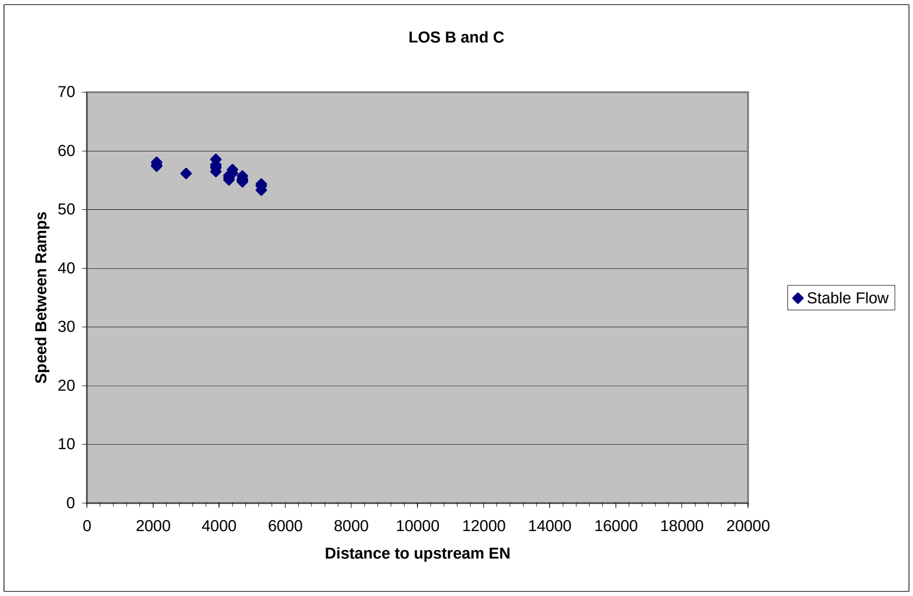
- Each 15-minute period classified as stable or unstable flow
- Each 15-minute period classified as being on a 2-, 3-, or 4-lane (one-way) freeway
- Each 15-minute period classified as having a low, moderate, or high exit ramp volume.

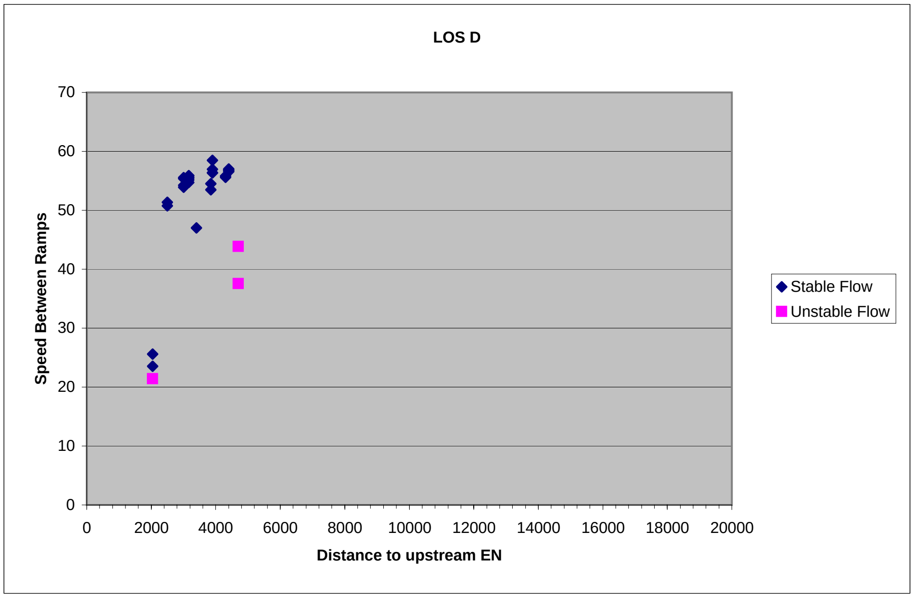
Within each of these classifications, separate charts are provided for data in each LOS.

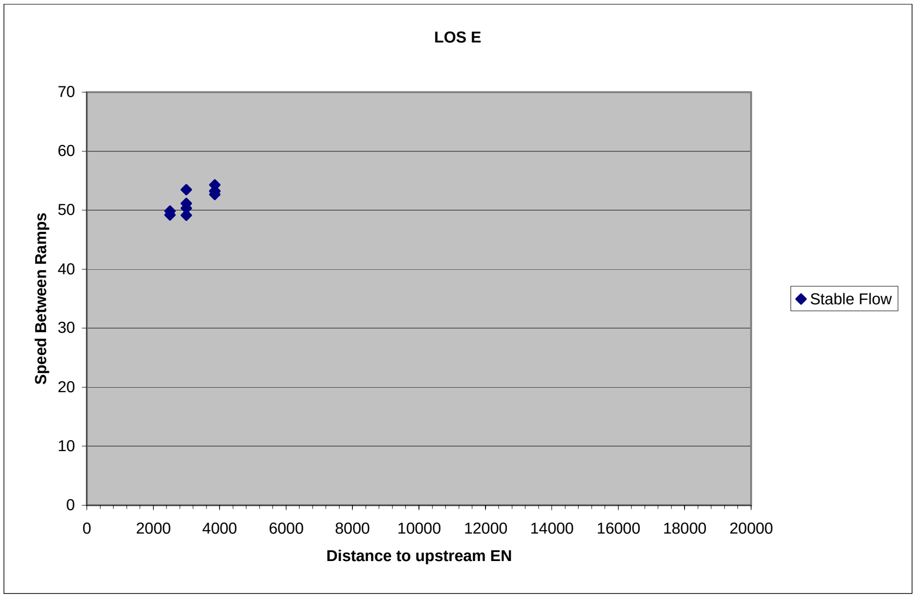
Notes on the charts:

- LOS was measured upstream of the diverge ramp (between the merge and diverge ramps) and determined by the Project 3-37 researchers
- "Speed between ramps" is the minimum average speed measured by detectors located downstream of the merging ramp

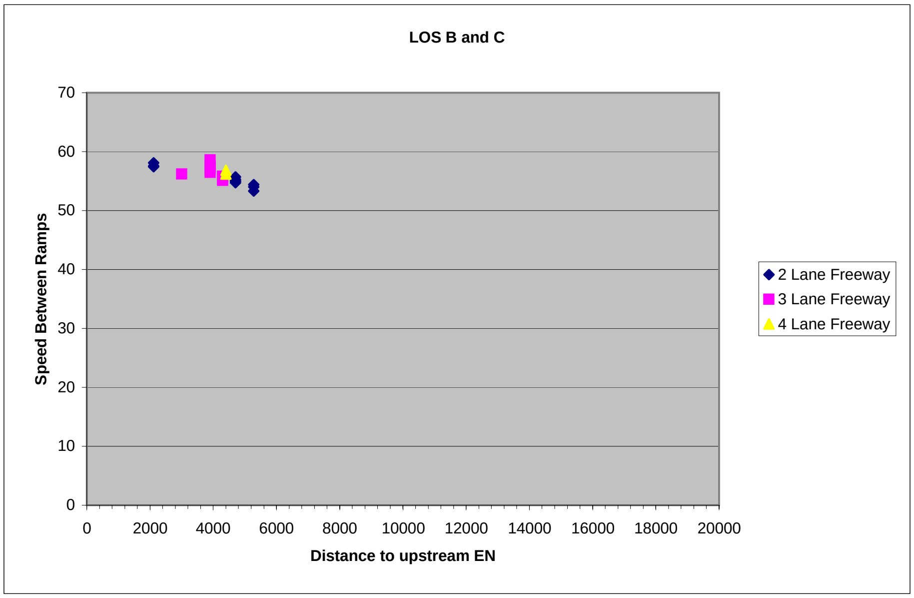
Sorted by:
Stable or Unstable Flow

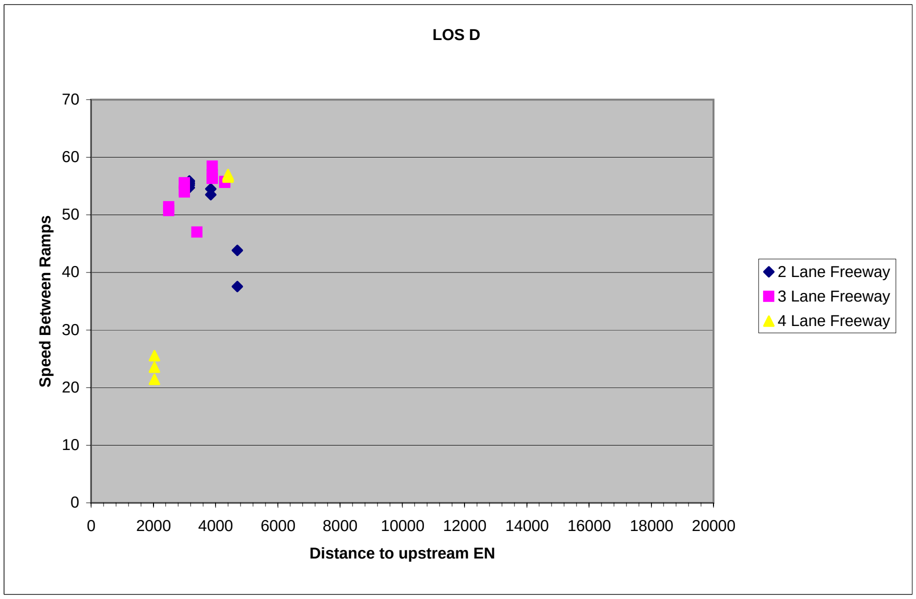


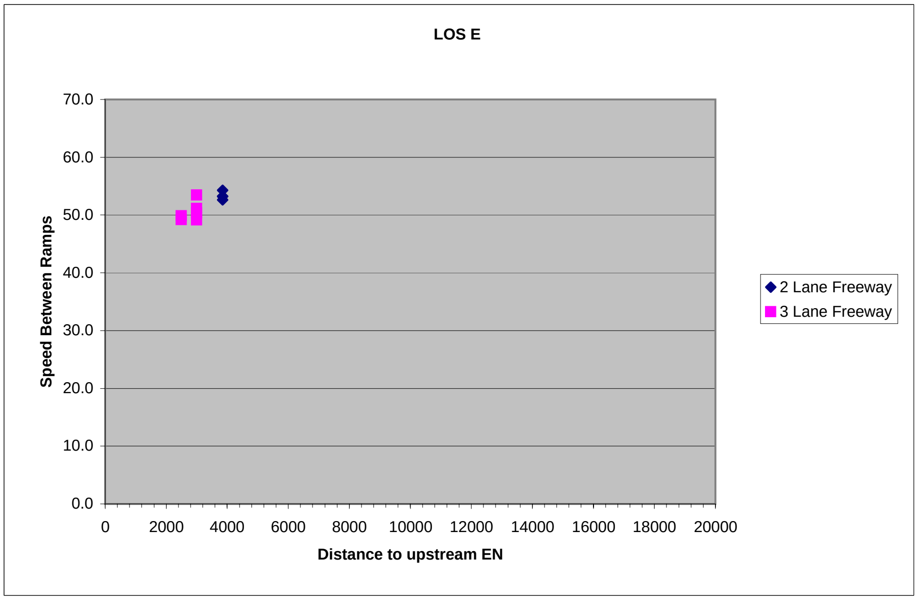




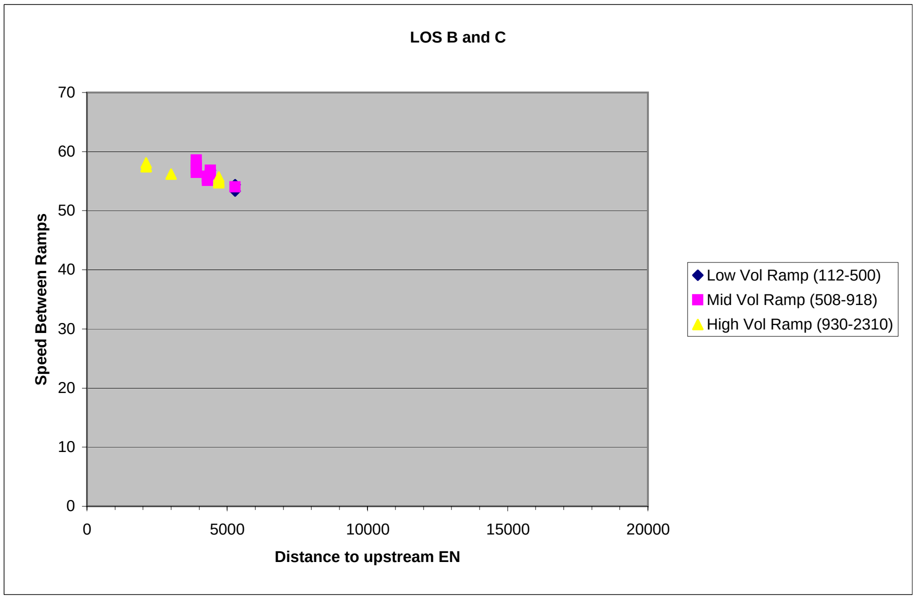
Sorted by:
Number of Freeway Lanes

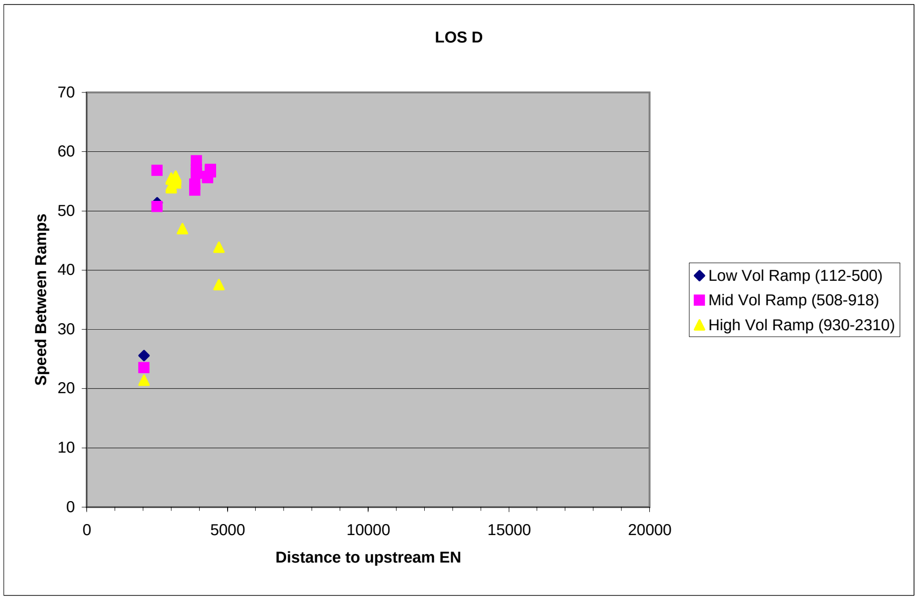


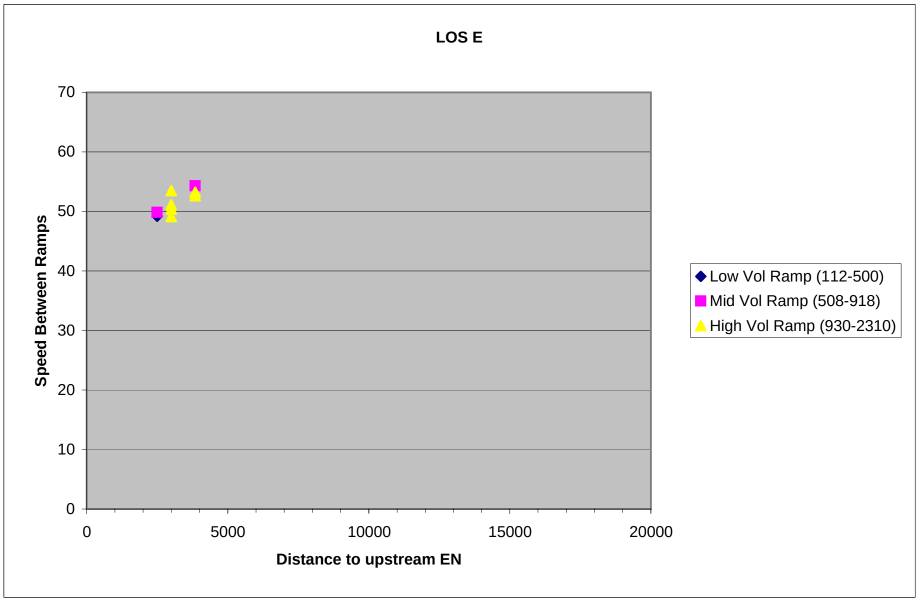




Sorted by: Ramp Volume

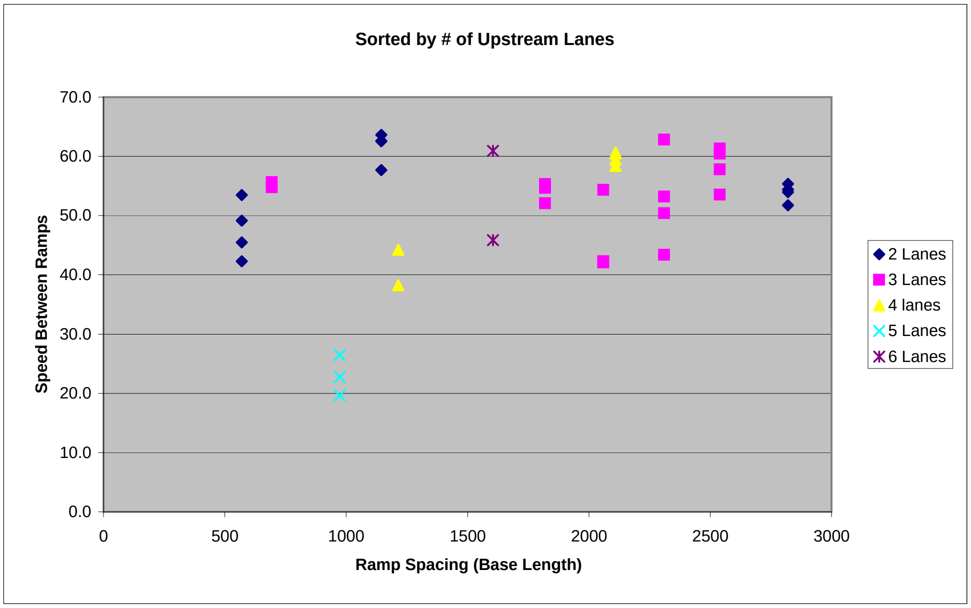


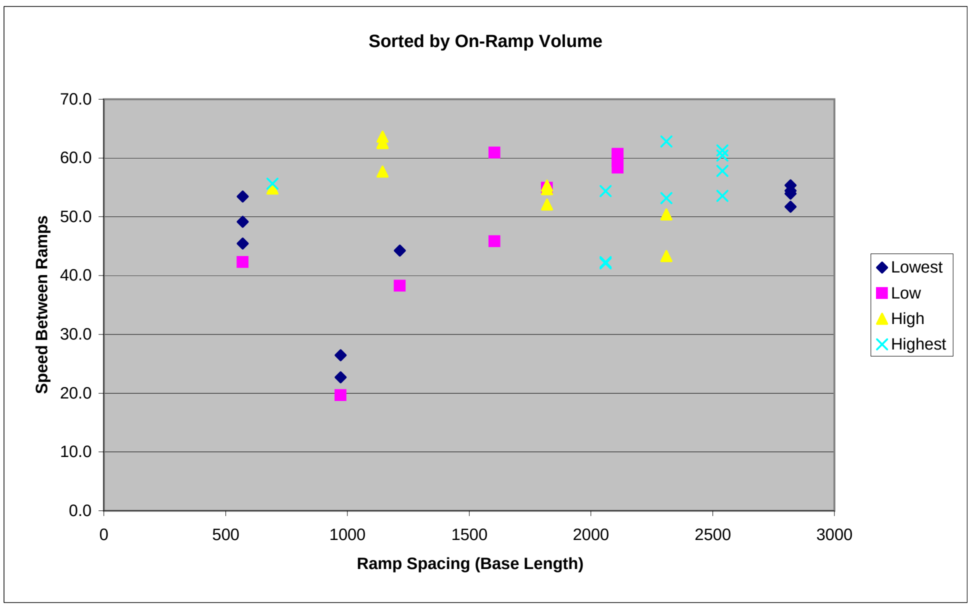


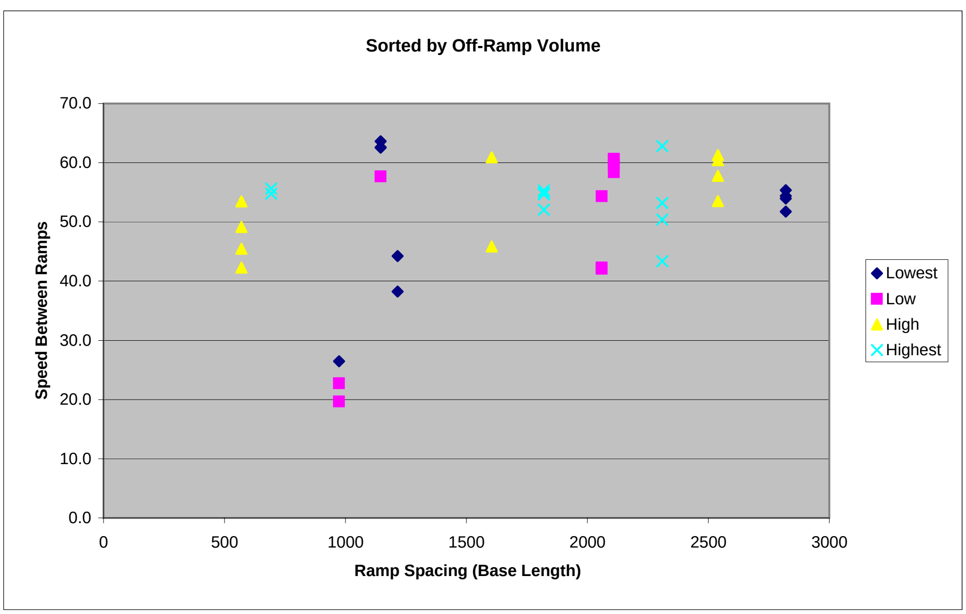


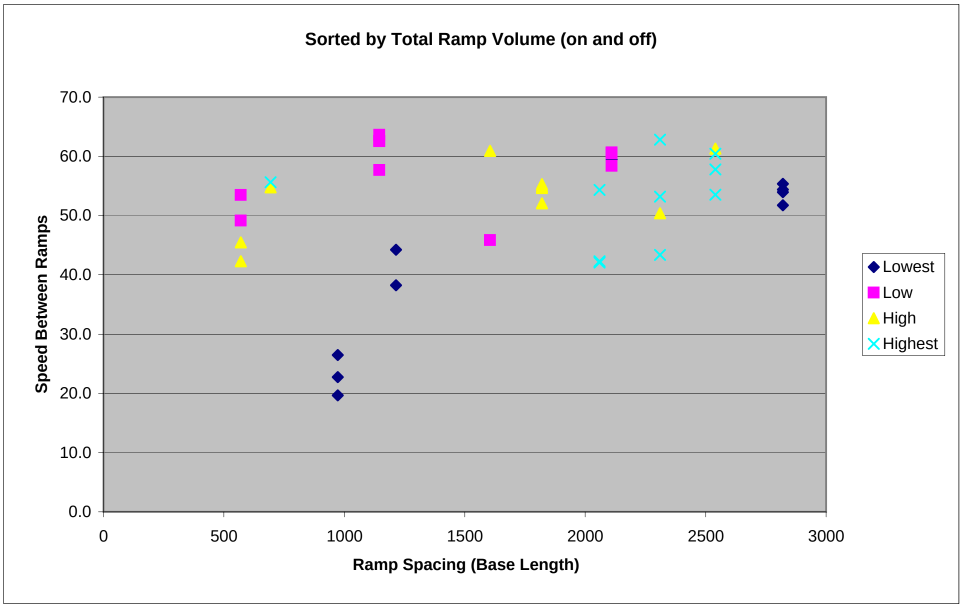
NCHRP Project 3-75 – Speed of all vehicles in weaving section (between ramps)

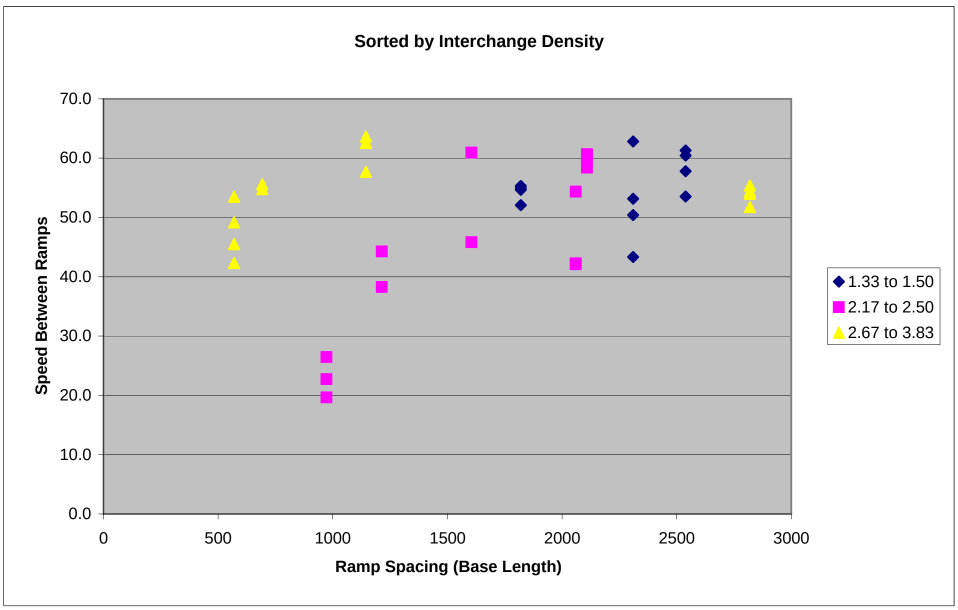
The following plots contain data in averaged in 15 minute bins collected at as part of NCHRP Project 3-75. Each graph contains the complete set of data collected by the Project 3-75 researchers.

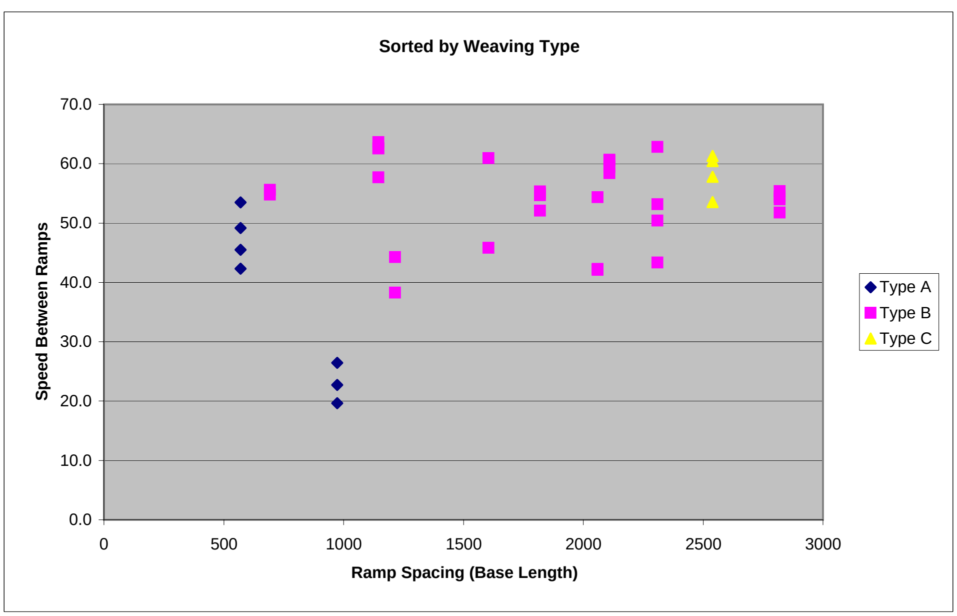

Sorted by # of Upstream Lanes
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Speed Between Ramps
0
500
1000
1500
2000
2500
3000
Ramp Spacing (Base Length)
2 Lanes
3 Lanes
4 lanes
5 Lanes
6 Lanes

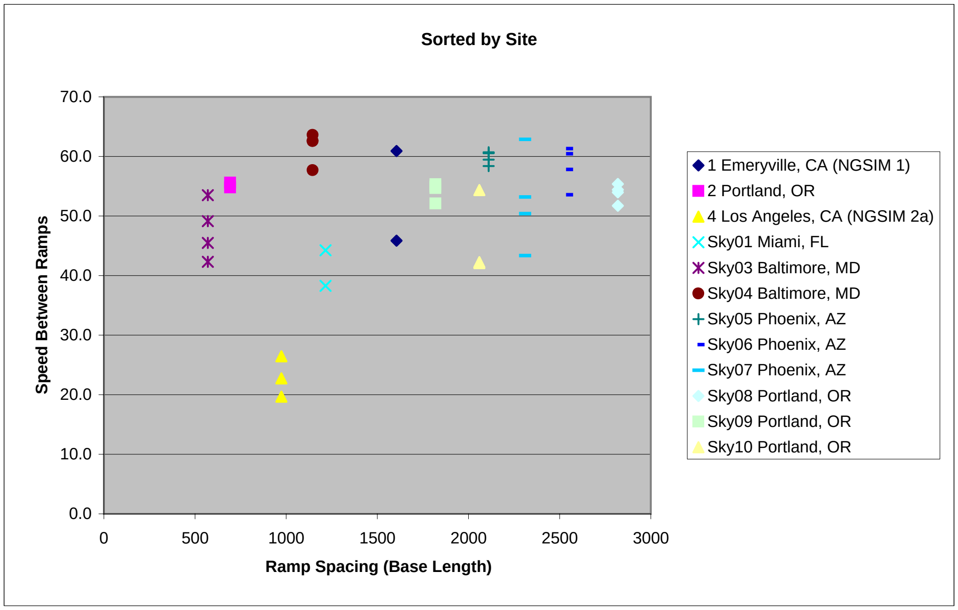

Sorted by On-Ramp Volume
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Speed Between Ramps
0
500
1000
1500
2000
2500
3000
Ramp Spacing (Base Length)
Lowest
Low
High
Highest


Sorted by Off-Ramp Volume
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Speed Between Ramps
0
500
1000
1500
2000
2500
3000
Ramp Spacing (Base Length)
Lowest
Low
High
Highest

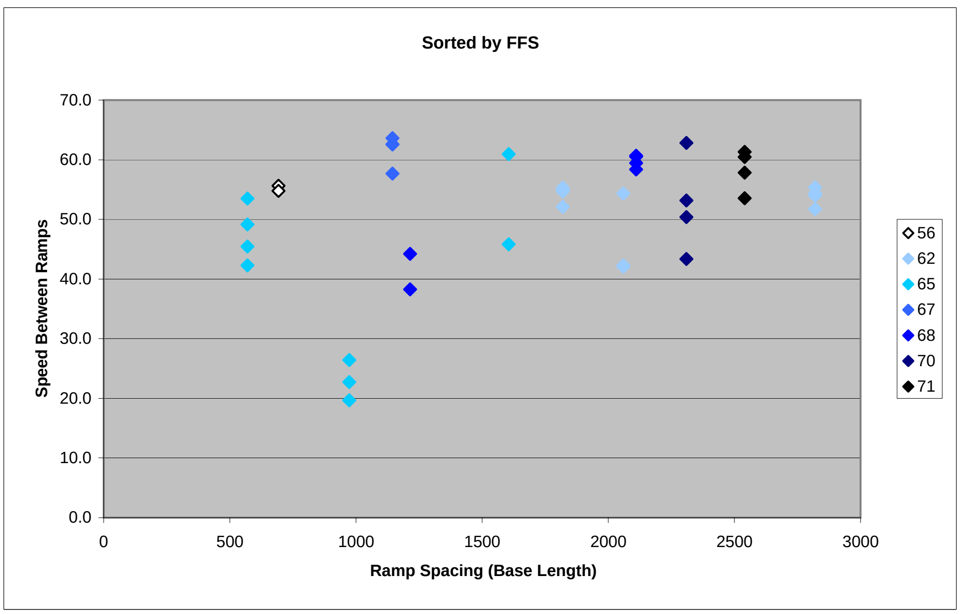

Sorted by Total Ramp Volume (on and off)
Speed Between Ramps
Ramp Spacing (Base Length)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
0
500
1000
1500
2000
2500
3000
Lowest
Low
High
Highest


Sorted by Interchange Density
Speed Between Ramps
Ramp Spacing (Base Length)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
0
500
1000
1500
2000
2500
3000
1.33 to 1.50
2.17 to 2.50
2.67 to 3.83

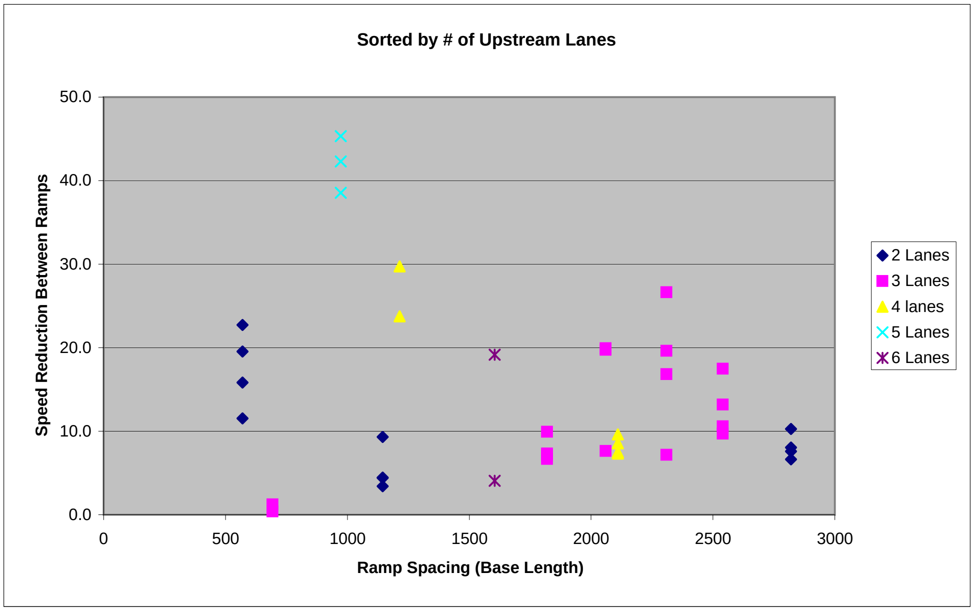

Sorted by Weaving Type
Speed Between Ramps
Ramp Spacing (Base Length)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
0
500
1000
1500
2000
2500
3000
Type A
Type B
Type C



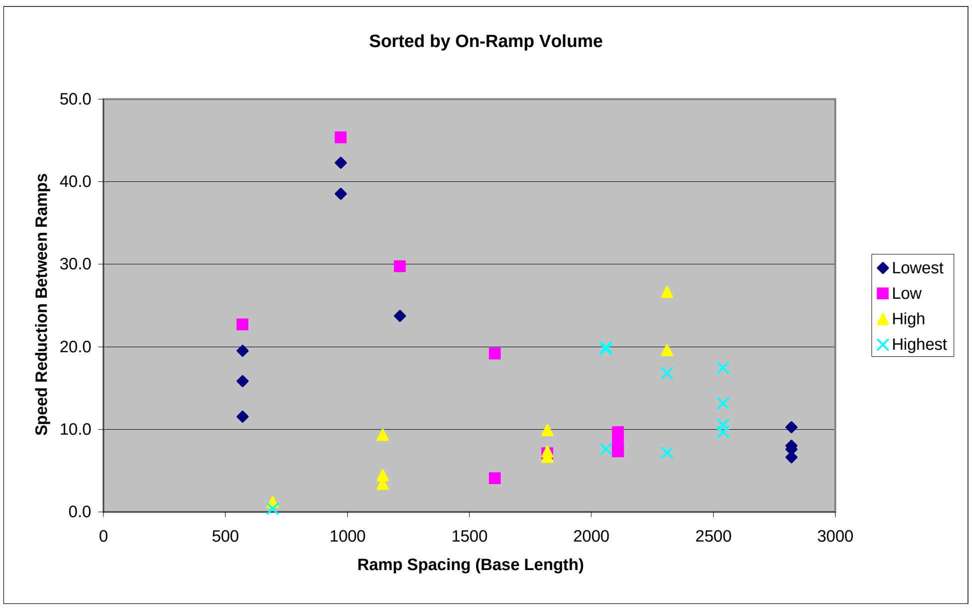
Site Notes 2 - 2 lane exit
Sky03 - cloverleaf
Sky06 - 2 lane entry
Sky09 - 2 lane exit
Sky10 - 2 lane entry and 2 lane exit



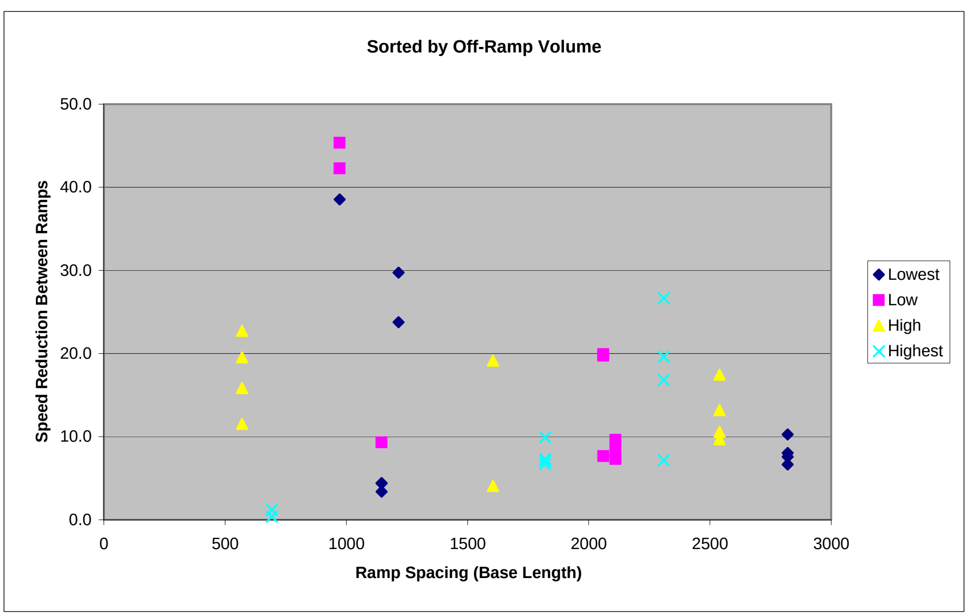
NCHRP Project 3-75 – Reduction in free-flow speed of all vehicles in weaving section (between ramps)



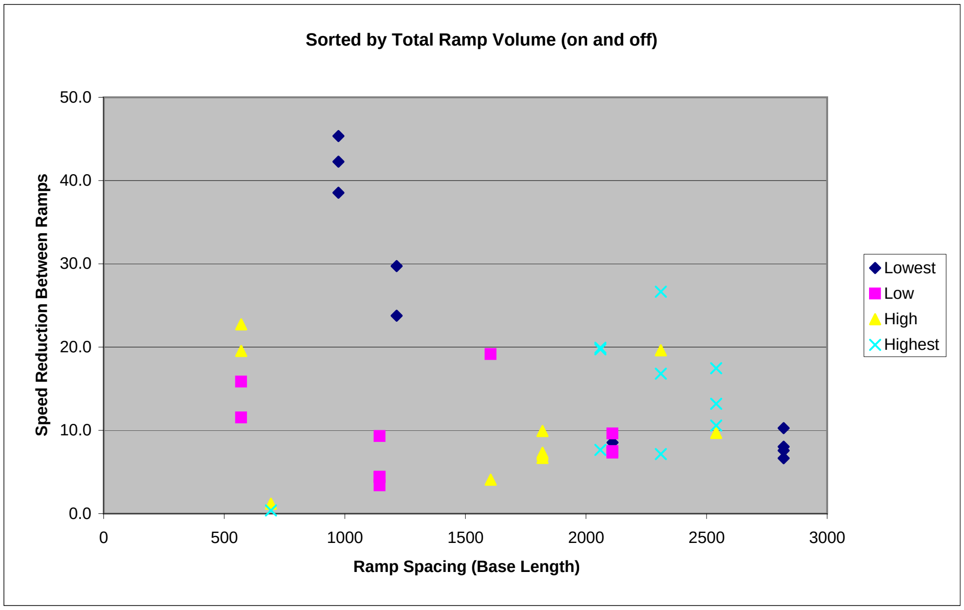
Sorted by # of Upstream Lanes
Speed Reduction Between Ramps
50.0
40.0
30.0
20.0
10.0
0.0
0
500
1000
1500
2000
2500
3000
Ramp Spacing (Base Length)
2 Lanes
3 Lanes
4 lanes
5 Lanes
6 Lanes

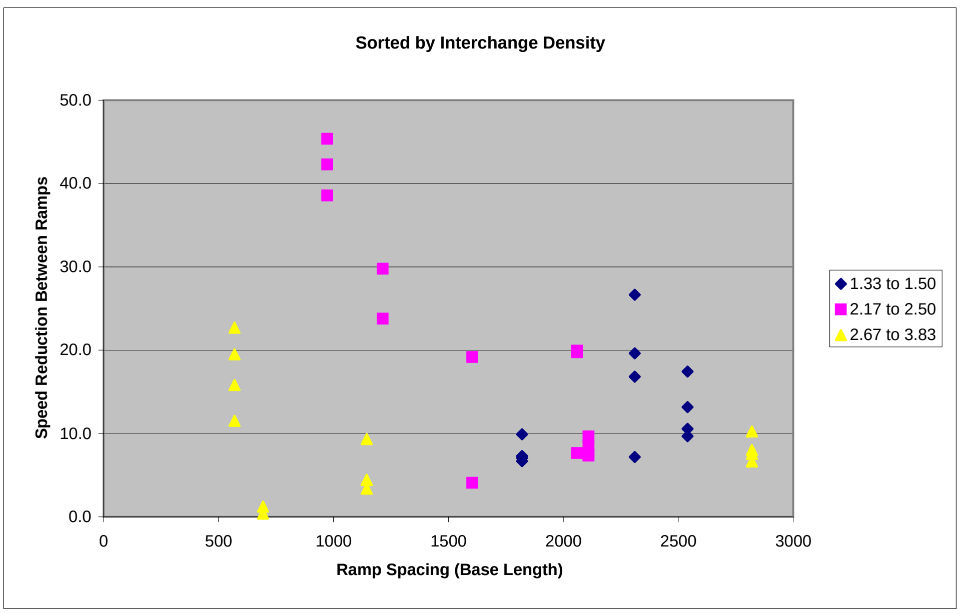


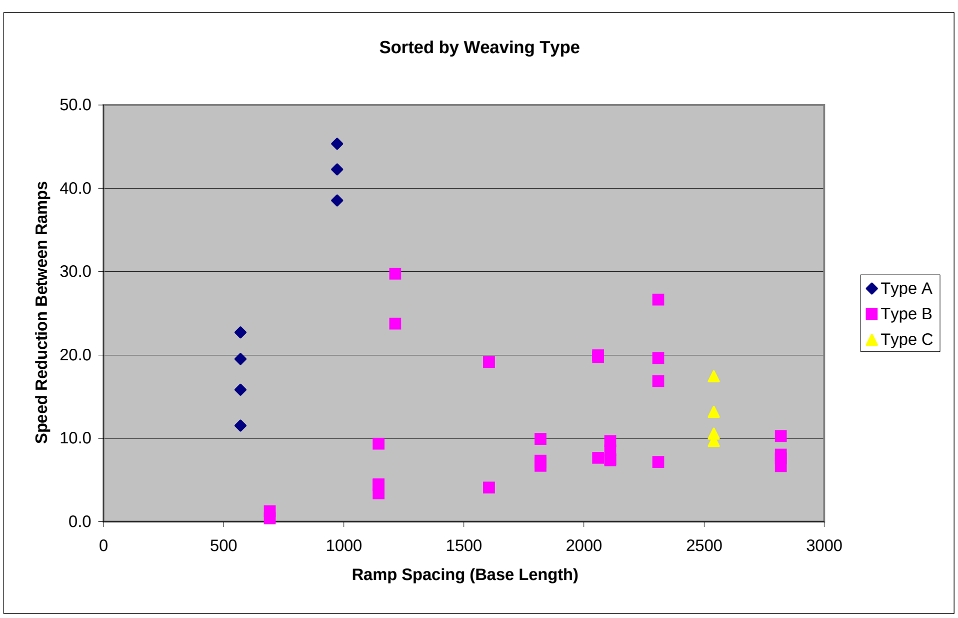
Sorted by On-Ramp Volume
Speed Reduction Between Ramps
50.0
40.0
30.0
20.0
10.0
0.0
0
500
1000
1500
2000
2500
3000
Ramp Spacing (Base Length)
Lowest
Low
High
Highest

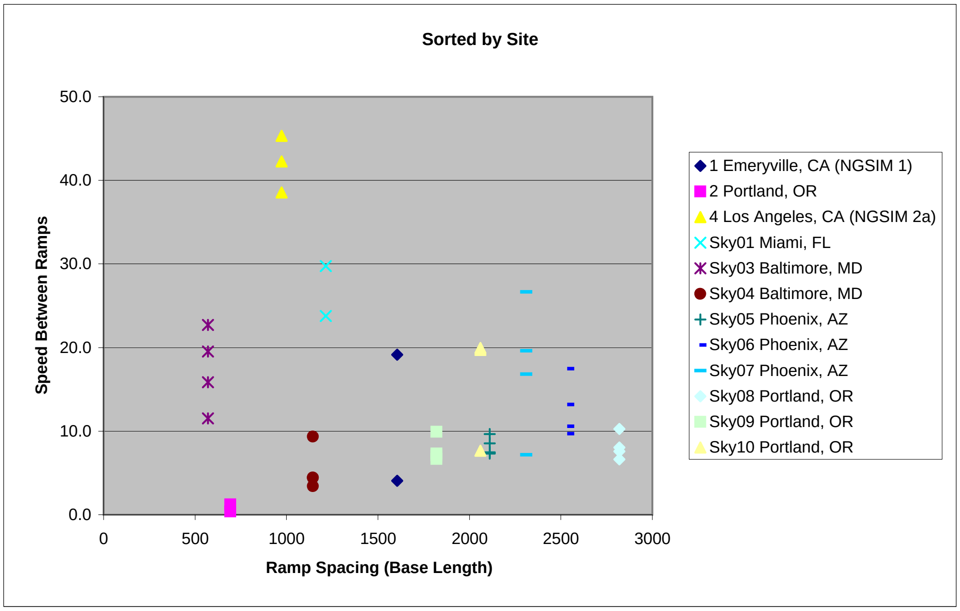


Sorted by Off-Ramp Volume
Speed Reduction Between Ramps
50.0
40.0
30.0
20.0
10.0
0.0
0
500
1000
1500
2000
2500
3000
Ramp Spacing (Base Length)
Lowest
Low
High
Highest

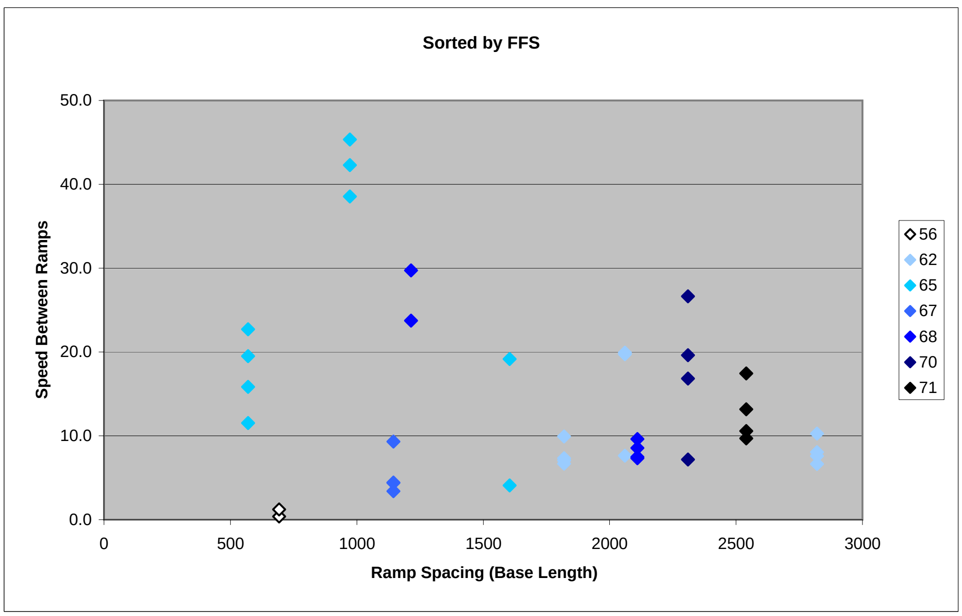

Sorted by Total Ramp Volume (on and off)
Speed Reduction Between Ramps
Ramp Spacing (Base Length)
50.0
40.0
30.0
20.0
10.0
0.0
0
500
1000
1500
2000
2500
3000
Lowest
Low
High
Highest


Sorted by Interchange Density
Speed Reduction Between Ramps
Ramp Spacing (Base Length)
50.0
40.0
30.0
20.0
10.0
0.0
0
500
1000
1500
2000
2500
3000
1.33 to 1.50
2.17 to 2.50
2.67 to 3.83


Sorted by Weaving Type
Speed Reduction Between Ramps
Ramp Spacing (Base Length)
50.0
40.0
30.0
20.0
10.0
0.0
0
500
1000
1500
2000
2500
3000
Type A
Type B
Type C



Site Notes 2 - 2 lane exit
Sky03 - cloverleaf
Sky06 - 2 lane entry
Sky09 - 2 lane exit
Sky10 - 2 lane entry and 2 lane exit



Appendix C
Field Data

Entry-Exit Site Data

Traffic Research and Analysis, Inc.

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Site ID	File Name	Route	Location	Direction	Count Type	Count Dur	Start Date	Start Time	Avg Vol	AM PkHr	AM PkVol	AM PHF	PM PkHr	PM PkVol	PM PHF	Dir Split	pctSU	pctCB	Avg Spd	Latitude	Longitude
1	0901148	SR 51	S of UNION HILLS DR & PRIOR TO ON-RAMP MERGE	SB	RADAR	24	4/14/2009	0:00	42303	7:45	3410	0.9743	17:15	3164	0.8654		2.7%	0.4%	68.6	33.6530	-112.0006
2	0901149	SR 51	Btwn UNION HILLS DR ON-RAMP & BELL RD OFF-RAMP	SB	RADAR	24	4/14/2009	0:00	51754	7:15	4606	0.9750	17:15	3736	0.8811		4.4%	0.4%	68.0	33.6489	-112.0011
3	0901150	SR 51	N of BELL RD & AFTER OFF-RAMP	SB	RADAR	24	4/14/2009	0:00	46080	7:15	4292	0.9719	17:15	3277	0.8886		3.4%	0.4%	68.3	33.6436	-112.0022
4	0901151	SR 51 ON-RAMP	S of UNION HILLS DR	SB	VOL	24	4/14/2009	0:00	9657	6:45	1235	0.7978	14:15	617	0.8429					33.6520	-112.0006
5	0901152	SR 51 OFF-RAMP	To BELL RD	SB	SPD	24	4/14/2009	0:00	5835	8:15	378	0.7875	16:45	489	0.7149		0.9%	0.3%	59.9	33.6436	-112.0022

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Site ID	File Name	Route	Location	Direction	Comments
1	0901148	SR 51	S of UNION HILLS DR & PRIOR TO ON-RAMP MERGE	SB	
2	0901149	SR 51	Btwn UNION HILLS DR ON-RAMP & BELL RD OFF-RAMP	SB	
3	0901150	SR 51	N of BELL RD & AFTER OFF-RAMP	SB	
4	0901151	SR 51 ON-RAMP	S of UNION HILLS DR	SB	FACTOR = 1.0136
5	0901152	SR 51 OFF-RAMP	To BELL RD	SB	

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: **Kittelson**
File Number: **901148**
Route: **SR 51**
Location: **S of UNION HILLS DR PRIOR TO ON-RAMP MERGE**

Site Ref: **1**
Direction: **SB**
Latitude: **33.65298**
Longitude: **-112.00058**

Count Date	Total Volume	Avg Speed	Len 0-25	Len 26-55	Len 56-75	Len 76+	Volume by Lane								Average Speed by Lane				
							SB 1	SB 2	SB 3	SB 4	SB HOV				SB 1	SB 2	SB 3	SB 4	HOV
4/14/2009	52	66.3	47	3	1	1	12	17	16	3	4				66.3	63.8	67.0	66.7	73.8
4/14/2009 0:15	60	65.7	58	0	2	0	8	31	12	7	2				63.5	64.0	68.7	69.3	70.9
4/14/2009 0:30	49	63.0	48	1	0	0	6	24	11	5	3				56.8	63.5	63.9	63.3	67.8
4/14/2009 0:45	35	62.6	35	0	0	0	5	20	10	0	0				62.1	63.0	62.0	63.3	67.8
4/14/2009 1:00	29	61.5	28	1	0	0	6	11	7	3	2				61.0	60.4	60.0	68.3	64.4
4/14/2009 1:15	13	61.3	13	0	0	0	1	7	5	0	0				60.8	58.4	65.5	68.3	64.4
4/14/2009 1:30	24	60.8	24	0	0	0	2	9	8	3	2				55.4	60.4	58.4	67.3	68.1
4/14/2009 1:45	31	57.0	30	1	0	0	4	12	10	5	0				12.6	60.1	66.3	66.4	68.1
4/14/2009 2:00	27	66.2	26	1	0	0	5	8	11	3	0				65.2	64.7	66.6	70.3	68.1
4/14/2009 2:15	17	67.3	17	0	0	0	1	7	7	1	1				55.9	68.2	67.2	73.3	67.9
4/14/2009 2:30	14	64.2	13	1	0	0	2	6	6	0	0				65.4	64.4	63.7	73.3	67.9
4/14/2009 2:45	23	68.5	21	2	0	0	5	8	6	2	2				67.1	65.9	68.5	80.5	70.7
4/14/2009 3:00	22	66.7	21	1	0	0	4	7	8	2	1				65.8	64.5	68.4	67.1	71.1
4/14/2009 3:15	23	65.2	21	1	1	0	4	8	9	2	0				73.0	61.9	64.6	65.9	71.1
4/14/2009 3:30	32	65.2	24	7	1	0	2	11	15	4	0				63.8	63.3	66.1	67.9	71.1
4/14/2009 3:45	39	66.5	38	1	0	0	3	16	17	2	1				68.5	66.4	66.6	64.1	63.6
4/14/2009 4:00	54	66.7	52	2	0	0	9	21	13	4	7				65.4	66.5	66.0	69.6	68.8
4/14/2009 4:15	53	67.1	51	1	1	0	4	17	23	4	5				67.8	65.0	68.0	67.6	69.6
4/14/2009 4:30	115	66.3	112	3	0	0	9	42	48	9	7				68.7	63.7	67.1	72.0	66.5
4/14/2009 4:45	132	68.0	129	2	1	0	15	37	49	14	17				70.3	67.0	66.9	70.3	69.4
4/14/2009 5:00	180	68.3	178	2	0	0	19	62	63	26	10				67.0	66.7	68.9	70.5	70.9
4/14/2009 5:15	220	67.9	220	0	0	0	20	75	76	34	15				67.6	66.1	67.2	71.4	72.9
4/14/2009 5:30	371	68.3	360	9	2	0	27	104	132	67	41				67.7	66.6	67.9	69.8	71.7
4/14/2009 5:45	500	68.8	488	10	2	0	44	136	165	106	49				68.7	66.2	67.9	72.1	72.2
4/14/2009 6:00	511	69.0	502	8	1	0	60	147	165	99	40				70.0	66.3	68.8	71.5	72.3
4/14/2009 6:15	582	68.3	566	15	1	0	45	155	218	140	24				69.8	66.2	67.5	70.9	71.9
4/14/2009 6:30	730	68.7	713	17	0	0	75	204	236	179	36				69.7	66.0	68.2	71.5	71.1
4/14/2009 6:45	745	68.8	726	15	4	0	58	165	274	217	31				69.8	66.7	68.1	70.6	71.7
4/14/2009 7:00	732	69.2	717	14	1	0	67	163	244	212	46				68.9	67.3	68.0	71.7	71.9
4/14/2009 7:15	807	69.1	788	17	2	0	72	191	240	244	60				69.9	66.7	67.9	71.4	71.7
4/14/2009 7:30	860	69.1	845	12	3	0	63	219	259	256	63				69.9	66.7	67.7	71.5	72.3
4/14/2009 7:45	875	69.2	858	15	2	0	66	211	277	248	73				69.4	66.9	68.2	71.3	72.3
4/14/2009 8:00	860	69.5	842	15	2	1	83	228	270	227	52				69.3	67.1	68.9	72.1	72.2
4/14/2009 8:15	801	69.1	777	17	7	0	85	199	234	224	59				68.2	66.0	68.5	72.0	71.6
4/14/2009 8:30	874	68.8	851	17	5	1	96	227	275	229	47				69.6	66.6	68.0	71.3	71.1
4/14/2009 8:45	807	68.9	781	21	5	0	87	230	245	200	45				68.9	66.6	68.3	71.5	71.7
4/14/2009 9:00	833	68.7	805	23	5	0	98	239	235	213	48				70.7	66.1	68.1	70.6	72.2
4/14/2009 9:15	766	68.4	746	19	1	0	102	217	209	158	80				67.6	66.1	68.1	70.3	72.8
4/14/2009 9:30	781	68.4	757	18	6	0	105	238	229	144	65				68.1	66.1	68.2	70.8	72.1
4/14/2009 9:45	666	68.7	636	26	3	1	92	198	193	122	61				69.0	66.1	68.2	71.3	72.7
4/14/2009 10:00	664	68.6	641	20	3	0	86	221	191	127	39				69.6	66.6	68.4	71.1	71.3
4/14/2009 10:15	629	68.6	603	21	4	1	77	210	181	116	45				69.8	66.6	68.0	71.0	71.6
4/14/2009 10:30	591	68.5	570	18	3	0	85	186	176	110	34				69.6	66.0	67.9	71.9	71.3
4/14/2009 10:45	605	69.3	583	16	3	3	69	199	195	105	37				69.3	67.1	69.7	71.1	73.7
4/14/2009 11:00	574	68.7	549	22	3	0	81	196	173	90	34				67.7	67.2	68.4	71.2	73.8
4/14/2009 11:15	574	68.6	547	25	2	0	81	184	166	100	43				69.3	65.9	68.3	71.3	73.2
4/14/2009 11:30	602	68.7	580	18	4	0	93	192	181	94	42				68.5	66.6	68.6	71.7	72.3
4/14/2009 11:45	560	70.1	536	21	3	0	75	192	171	85	37				70.6	68.1	69.7	73.2	73.7
4/14/2009 12:00	582	69.4	555	24	3	0	86	191	168	101	36				69.8	67.6	69.4	71.5	72.1
4/14/2009 12:15	533	68.3	518	13	2	0	84	176	157	83	33				67.7	66.8	68.4	70.7	72.0
4/14/2009 12:30	587	69.7	561	25	0	1	95	188	165	100	39				69.2	67.9	69.4	72.0	74.4
4/14/2009 12:45	596	68.6	560	32	3	1	85	197	181	96	37				68.5	66.9	68.8	70.9	71.5
4/14/2009 13:00	613	68.1	589	19	4	1	98	193	184	93	45				67.3	66.2	68.7	69.8	72.4
4/14/2009 13:15	583	69.2	554	20	8	1	95	184	164	104	36				69.9	67.1	68.9	71.5	72.2
4/14/2009 13:30	634	68.9	605	25	4	0	103	195	184	101	51				67.7	67.0	69.0	72.1	72.3
4/14/2009 13:45	642	68.6	606	33	3	0	94	203	199	106	40				67.5	66.6	68.6	71.6	73.6
4/14/2009 14:00	653	68.5	622	27	3	1	88	216	193	110	46				67.1	66.3	68.8	71.1	74.2
4/14/2009 14:15	633	69.0	599	31	3	0	114	211	167	98	43				68.6	67.3	68.6	72.0	73.2
4/14/2009 14:30	719	68.9	695	23	1	0	103	232	209	126	49				69.4	66.6	69.1	70.7	73.0
4/14/2009 14:45	707	69.5	672	33	1	1	104	202	206	138	57				69.8	68.0	68.3	71.9	72.5
4/14/2009 15:00	760	69.2	733	25	1	1	109	241	216	136	58				69.3	67.1	68.9	71.8	73.4
4/14/2009 15:15	659	69.3	636	22	1	0	87	210	210	122	30				68.8	67.8	69.3	71.2	72.6
4/14/2009 15:30	693	68.9	664	28	1	0	119	224	208	115	27				67.9	67.2	69.5	71.7	71.7
4/14/2009 15:45	707	69.1	682	23	2	0	116	224	191	147	29				68.6	67.7	68.7	71.8	71.7
4/14/2009 16:00	735	69.2	704	31	0	0	117	249	207	128	34				69.3	67.6	69.4	71.4	71.6
4/14/2009 16:15	640	69.3	619	19	2	0	87	216	197	112	28				68.6	67.5	69.4	72.0	73.2
4/14/2009 16:30	717	69.1	694	22	1	0	123	237	189	138	30				69.3	66.8	69.3	71.9	72.6
4/14/2009 16:45	721	70.1	708	11	2	0	104	227	202	152	36				70.4	68.1	69.7	72.7	72.9
4/14/2009 17:00	718	69.3	705	13	0	0	114	227	207	124	46				68.9	67.3	69.0	72.9	71.9
4/14/2009 17:15	768	68.3	746	21	1	0	127	238	225	145	33				67.9	66.1	69.0	70.7	71.2
4/14/2009 17:30	914	68.9	898	14	2	0	130	265	266	195	58				68.9	67.0	68.7	70.9	71.8
4/14/2009 17:45	760	69.0	748	11	0	1	110	241	219	151	39				69.5	66.6	69.1	71.6	72.0
4/14/2009 18:00	722	69.4	706	15	1	0	101	222	208	148	43				69.2	67.2	69.1	72.3	72.1
4/14/2009 18:15	647	69.3	635	12	0	0	102	195	183	113	54				69.5	67.7	68.9	71.7	71.0
4/14/2009 18:30	577	68.9	566	11	0	0	82	183	177	107	28				69.7	66.7	69.1	70.9	71.3
4/14/2009 18:45	528	69.1	514	13	1	0	77	178	154	94	25				70.5	67.3	69.1	71.2	70.1
4/14/2009 19:00	448	69.3	441	6	1	0	73	146	143	71	15				69.9	67.0	68.9	73.6	71.5
4/14/2009 19:15	382	67.3	375	6	1	0	69	131	106	56	20				68.6	65.7	66.8	69.0	70.9
4/14/2009 19:30	328	67.0	322	6	0	0	52	110	100	44	22				67.4	65.1	66.6	69.6	72.1
4/14/2009 19:45	321	66.3	317	4	0	0	57	98	104	45	17				66.7	64.9	66.0	68.2	70.7
4/14/2009 20:00	272	66.5	268	4	0	0	41	88	90	34	19				66.8	65.1	66.1	69.2	69.9
4/14/2009 20:15	208	66.1	205	2	1	0	38	86	64	15	5				66.3	64.9	67.3	66.7	68.9
4/14/2009 20:30	263	66.6	260	3	0	0	48	96	70	33	16				66.7	65.6	66.1	68.3	71.1
4/14/2009 20:45	247	66.0	246	0	1	0	37	80	82	33	15				65.2	64.5	66.0	68.7	69.3
4/14/2009 21:00	243	65.2	243	0	0	0	38	80	84	36	5				62.8	64.9	65.4	67.7	67.9
4/14/2009 21:15	212	65.6	209	3	0	0	24	77	73	28	10				66.4	64.7	65.0	68.1	67.4
4/14/2009 21:30	222	65.9	219	2	1	0	48	63	65	35	11				66.2	63.6	66.4	67.6	69.7
4/14/2009 21:45	203	66.6	199	3	1	0	47	61	57	25	13				66.3	66.1	67.3	66.8	67.3
4/14/2009 22:00	200	65.6	197	3	0	0	35	68	62	23	12				65.0	64.5	64.9	67.7	73.8
4/14/2009 22:15	180	66.2	179	0	1	0	29	65	53	22	11				69.2	64.2	65.9	67.4	68.9
4/14/2009 22:30	148	65.5	146	1	1	0	22	56	43	22	5				66.6	64.5	65.0	66.8	70.3
4/14/2009 22:45	151	64.9	148	3	0	0	21	57	52	18	3				69.3	64.1	63.5	65.7	67.0
4/14/2009 23:00	140	65.9	139	1	0	0	29	47	44	15	5				66.2	64.3	66.1	69.1	66.5
4/14/2009 23:15	100	64.7	98	2	0	0	15	35	32	16	2				65.9	64.6	63.1	66.1	70.6
4/14/2009 23:30	84	64.9	83	1	0	0	18	33	21	8	4				64.6	63.8	64.2	70.7	67.6
4/14/2009 23:45	59	64.8	58	0	1	0	11	24	15	5	4				65.5	63.4	64.9	65.9	69.7
Day Totals	**42303**	**68.6**	**41019**	**1125**	**143**	**16**	**5724**	**12973**	**12760**	**8212**	**2634**	**0**	**0**	**0**	**68.6**	**66.6**	**68.3**	**71.2**	**72.0**

AM Peak Hr	**7:45**
AM Peak Vol	**3410**
AM PHF	**0.9743**
PM Peak Hr	**17:15**
PM Peak Vol	**3164**
PM PHF	**0.8654**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client:	**Kittelson**
File Number:	**901148**
Route:	**SR 51**
Location:	**S of UNION HILLS [**

Count Date	Total Volume	Avg Speed		Small Vehcles 0-25' by Lane								Medium Vehicles 26-55' by Lane							
				SB 1	SB 2	SB 3	SB 4	HOV				SB 1	SB 2	SB 3	SB 4	HOV			
4/14/2009	52	66.3		10	16	14	3	4				2	0	1	0	0			
4/14/2009 0:15	60	65.7		8	30	11	7	2				0	0	0	0	0			
4/14/2009 0:30	49	63.0		5	24	11	5	3				1	0	0	0	0			
4/14/2009 0:45	35	62.6		5	20	10	0	0				0	0	0	0	0			
4/14/2009 1:00	29	61.5		5	11	7	3	2				1	0	0	0	0			
4/14/2009 1:15	13	61.3		1	7	5	0	0				0	0	0	0	0			
4/14/2009 1:30	24	60.8		2	9	8	3	2				0	0	0	0	0			
4/14/2009 1:45	31	57.0		3	12	10	5	0				1	0	0	0	0			
4/14/2009 2:00	27	66.2		5	7	11	3	0				0	1	0	0	0			
4/14/2009 2:15	17	67.3		1	7	7	1	1				0	0	0	0	0			
4/14/2009 2:30	14	64.2		2	5	6	0	0				0	1	0	0	0			
4/14/2009 2:45	23	68.5		5	7	5	2	2				0	1	1	0	0			
4/14/2009 3:00	22	66.7		4	6	8	2	1				0	1	0	0	0			
4/14/2009 3:15	23	65.2		4	7	8	2	0				0	0	1	0	0			
4/14/2009 3:30	32	65.2		1	8	12	3	0				1	3	2	1	0			
4/14/2009 3:45	39	66.5		3	16	16	2	1				0	0	1	0	0			
4/14/2009 4:00	54	66.7		8	20	13	4	7				1	1	0	0	0			
4/14/2009 4:15	53	67.1		4	17	22	3	5				0	0	1	0	0			
4/14/2009 4:30	115	66.3		9	40	47	9	7				0	2	1	0	0			
4/14/2009 4:45	132	68.0		15	36	47	14	17				0	1	1	0	0			
4/14/2009 5:00	180	68.3		18	61	63	26	10				1	1	0	0	0			
4/14/2009 5:15	220	67.9		20	75	76	34	15				0	0	0	0	0			
4/14/2009 5:30	371	68.3		27	96	130	67	40				0	7	1	0	1			
4/14/2009 5:45	500	68.8		42	133	161	105	47				2	3	2	1	2			
4/14/2009 6:00	511	69.0		59	142	165	96	40				1	4	0	3	0			
4/14/2009 6:15	582	68.3		44	148	215	135	24				1	6	3	5	0			
4/14/2009 6:30	730	68.7		71	195	233	178	36				4	9	3	1	0			
4/14/2009 6:45	745	68.8		58	151	272	215	30				0	11	1	2	1			
4/14/2009 7:00	732	69.2		65	158	240	209	45				1	5	4	3	1			
4/14/2009 7:15	807	69.1		72	178	236	242	60				0	12	3	2	0			
4/14/2009 7:30	860	69.1		62	211	254	255	63				1	5	5	1	0			
4/14/2009 7:45	875	69.2		63	201	275	246	73				3	8	2	2	0			
4/14/2009 8:00	860	69.5		81	219	266	225	51				1	8	3	2	1			
4/14/2009 8:15	801	69.1		84	190	225	221	57				0	8	5	2	2			
4/14/2009 8:30	874	68.8		94	213	273	225	46				0	12	1	3	1			
4/14/2009 8:45	807	68.9		82	222	234	198	45				5	6	9	1	0			
4/14/2009 9:00	833	68.7		95	227	226	210	47				2	12	5	3	1			
4/14/2009 9:15	766	68.4		98	206	207	155	80				4	11	1	3	0			
4/14/2009 9:30	781	68.4		103	224	222	143	65				2	10	5	1	0			
4/14/2009 9:45	666	68.7		86	181	186	122	61				6	14	6	0	0			
4/14/2009 10:00	664	68.6		82	211	183	126	39				4	9	6	1	0			
4/14/2009 10:15	629	68.6		74	197	175	113	44				1	11	6	2	1			
4/14/2009 10:30	591	68.5		83	175	168	110	34				2	10	6	0	0			
4/14/2009 10:45	605	69.3		65	189	188	104	37				3	7	5	1	0			
4/14/2009 11:00	574	68.7		76	188	166	87	32				5	6	6	3	2			
4/14/2009 11:15	574	68.6		78	167	162	97	43				3	15	4	3	0			
4/14/2009 11:30	602	68.7		92	185	168	93	42				1	6	10	1	0			
4/14/2009 11:45	560	70.1		71	179	166	83	37				4	12	3	2	0			
4/14/2009 12:00	582	69.4		82	179	161	97	36				4	11	6	3	0			
4/14/2009 12:15	533	68.3		80	172	152	83	31				4	3	4	0	2			
4/14/2009 12:30	587	69.7		91	180	156	96	38				4	8	8	4	1			
4/14/2009 12:45	596	68.6		81	177	174	93	35				4	17	6	3	2			
4/14/2009 13:00	613	68.1		93	188	176	87	45				4	5	5	5	0			
4/14/2009 13:15	583	69.2		89	172	158	99	36				5	5	6	4	0			
4/14/2009 13:30	634	68.9		96	186	173	99	51				7	8	9	1	0			
4/14/2009 13:45	642	68.6		85	189	190	102	40				9	12	9	3	0			
4/14/2009 14:00	653	68.5		82	203	185	107	45				5	12	6	3	1			
4/14/2009 14:15	633	69.0		107	195	159	95	43				7	14	7	3	0			
4/14/2009 14:30	719	68.9		98	225	203	120	49				5	7	5	6	0			
4/14/2009 14:45	707	69.5		100	190	193	136	53				4	11	12	2	4			
4/14/2009 15:00	760	69.2		106	233	205	133	56				3	6	11	3	2			
4/14/2009 15:15	659	69.3		83	201	206	120	26				4	8	4	2	4			
4/14/2009 15:30	693	68.9		109	217	201	110	27				10	7	7	4	0			
4/14/2009 15:45	707	69.1		110	213	186	144	29				6	11	4	2	0			
4/14/2009 16:00	735	69.2		111	237	197	127	32				6	12	10	1	2			
4/14/2009 16:15	640	69.3		86	208	190	107	28				1	8	7	3	0			
4/14/2009 16:30	717	69.1		118	231	179	136	30				5	6	9	2	0			
4/14/2009 16:45	721	70.1		102	220	199	151	36				2	5	3	1	0			
4/14/2009 17:00	718	69.3		111	224	202	123	45				3	3	5	1	1			
4/14/2009 17:15	768	68.3		122	232	219	142	31				5	5	6	3	2			
4/14/2009 17:30	914	68.9		126	261	260	193	58				4	3	6	1	0			
4/14/2009 17:45	760	69.0		109	234	216	150	39				1	6	3	1	0			
4/14/2009 18:00	722	69.4		98	217	203	146	42				3	5	4	2	1			
4/14/2009 18:15	647	69.3		99	193	178	112	53				3	2	5	1	1			
4/14/2009 18:30	577	68.9		81	183	169	105	28				1	0	8	2	0			
4/14/2009 18:45	528	69.1		73	175	151	91	24				4	3	3	2	1			
4/14/2009 19:00	448	69.3		73	141	141	71	15				0	4	2	0	0			
4/14/2009 19:15	382	67.3		67	130	105	53	20				1	1	1	3	0			
4/14/2009 19:30	328	67.0		52	109	97	43	21				0	1	3	1	1			
4/14/2009 19:45	321	66.3		56	97	104	44	16				1	1	0	1	1			
4/14/2009 20:00	272	66.5		40	85	90	34	19				1	3	0	0	0			
4/14/2009 20:15	208	66.1		38	84	63	15	5				0	2	0	0	0			
4/14/2009 20:30	263	66.6		48	93	70	33	16				0	3	0	0	0			
4/14/2009 20:45	247	66.0		37	79	82	33	15				0	0	0	0	0			
4/14/2009 21:00	243	65.2		38	80	84	36	5				0	0	0	0	0			
4/14/2009 21:15	212	65.6		23	77	72	28	9				1	0	1	0	1			
4/14/2009 21:30	222	65.9		46	62	65	35	11				2	0	0	0	0			
4/14/2009 21:45	203	66.6		46	58	57	25	13				1	2	0	0	0			
4/14/2009 22:00	200	65.6		35	67	62	21	12				0	1	0	2	0			
4/14/2009 22:15	180	66.2		29	64	53	22	11				0	0	0	0	0			
4/14/2009 22:30	148	65.5		21	55	43	22	5				0	1	0	0	0			
4/14/2009 22:45	151	64.9		20	56	51	18	3				1	1	1	0	0			
4/14/2009 23:00	140	65.9		29	47	43	15	5				0	0	1	0	0			
4/14/2009 23:15	100	64.7		15	34	32	15	2				0	1	0	1	0			
4/14/2009 23:30	84	64.9		18	33	21	7	4				0	0	0	1	0			
4/14/2009 23:45	59	64.8		11	23	15	5	4				0	0	0	0	0			
Day Totals	**42303**	**68.6**		**5515**	**12436**	**12404**	**8070**	**2594**	**0**	**0**	**0**	**195**	**463**	**301**	**126**	**40**	**0**	**0**	**0**

AM Peak Hr	**7:45**
AM Peak Vol	**3410**
AM PHF	**0.9743**
PM Peak Hr	**17:15**
PM Peak Vol	**3164**
PM PHF	**0.8654**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client:	**Kittelson**	Site Ref:	**1**
File Number:	**901148**	Direction:	**SB**
Route:	**SR 51**	Latitude:	**33.65298**
Location:	**S of UNION HILLS [**	Longitude:	**-112.00058**

			Large Vehicles 56-75' by Lane								Combination Vehicles76'+ by Lane							
Count Date	**Total Volume**	**Avg Speed**	**SB 1**	**SB 2**	**SB 3**	**SB 4**	**HOV**				**SB 1**	**SB 2**	**SB 3**	**SB 4**	**HOV**			
4/14/2009	52	66.3	0	1	0	0	0				0	0	1	0	0			
4/14/2009 0:15	60	65.7	0	1	1	0	0				0	0	0	0	0			
4/14/2009 0:30	49	63.0	0	0	0	0	0				0	0	0	0	0			
4/14/2009 0:45	35	62.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 1:00	29	61.5	0	0	0	0	0				0	0	0	0	0			
4/14/2009 1:15	13	61.3	0	0	0	0	0				0	0	0	0	0			
4/14/2009 1:30	24	60.8	0	0	0	0	0				0	0	0	0	0			
4/14/2009 1:45	31	57.0	0	0	0	0	0				0	0	0	0	0			
4/14/2009 2:00	27	66.2	0	0	0	0	0				0	0	0	0	0			
4/14/2009 2:15	17	67.3	0	0	0	0	0				0	0	0	0	0			
4/14/2009 2:30	14	64.2	0	0	0	0	0				0	0	0	0	0			
4/14/2009 2:45	23	68.5	0	0	0	0	0				0	0	0	0	0			
4/14/2009 3:00	22	66.7	0	0	0	0	0				0	0	0	0	0			
4/14/2009 3:15	23	65.2	0	1	0	0	0				0	0	0	0	0			
4/14/2009 3:30	32	65.2	0	0	1	0	0				0	0	0	0	0			
4/14/2009 3:45	39	66.5	0	0	0	0	0				0	0	0	0	0			
4/14/2009 4:00	54	66.7	0	0	0	0	0				0	0	0	0	0			
4/14/2009 4:15	53	67.1	0	0	0	1	0				0	0	0	0	0			
4/14/2009 4:30	115	66.3	0	0	0	0	0				0	0	0	0	0			
4/14/2009 4:45	132	68.0	0	0	1	0	0				0	0	0	0	0			
4/14/2009 5:00	180	68.3	0	0	0	0	0				0	0	0	0	0			
4/14/2009 5:15	220	67.9	0	0	0	0	0				0	0	0	0	0			
4/14/2009 5:30	371	68.3	0	1	1	0	0				0	0	0	0	0			
4/14/2009 5:45	500	68.8	0	0	2	0	0				0	0	0	0	0			
4/14/2009 6:00	511	69.0	0	1	0	0	0				0	0	0	0	0			
4/14/2009 6:15	582	68.3	0	1	0	0	0				0	0	0	0	0			
4/14/2009 6:30	730	68.7	0	0	0	0	0				0	0	0	0	0			
4/14/2009 6:45	745	68.8	0	3	1	0	0				0	0	0	0	0			
4/14/2009 7:00	732	69.2	1	0	0	0	0				0	0	0	0	0			
4/14/2009 7:15	807	69.1	0	1	1	0	0				0	0	0	0	0			
4/14/2009 7:30	860	69.1	0	3	0	0	0				0	0	0	0	0			
4/14/2009 7:45	875	69.2	0	2	0	0	0				0	0	0	0	0			
4/14/2009 8:00	860	69.5	1	0	1	0	0				0	1	0	0	0			
4/14/2009 8:15	801	69.1	1	1	4	1	0				0	0	0	0	0			
4/14/2009 8:30	874	68.8	1	2	1	1	0				1	0	0	0	0			
4/14/2009 8:45	807	68.9	0	2	2	1	0				0	0	0	0	0			
4/14/2009 9:00	833	68.7	1	0	4	0	0				0	0	0	0	0			
4/14/2009 9:15	766	68.4	0	0	1	0	0				0	0	0	0	0			
4/14/2009 9:30	781	68.4	0	4	2	0	0				0	0	0	0	0			
4/14/2009 9:45	666	68.7	0	2	1	0	0				0	1	0	0	0			
4/14/2009 10:00	664	68.6	0	1	2	0	0				0	0	0	0	0			
4/14/2009 10:15	629	68.6	1	2	0	1	0				1	0	0	0	0			
4/14/2009 10:30	591	68.5	0	1	2	0	0				0	0	0	0	0			
4/14/2009 10:45	605	69.3	1	2	0	0	0				0	1	2	0	0			
4/14/2009 11:00	574	68.7	0	2	1	0	0				0	0	0	0	0			
4/14/2009 11:15	574	68.6	0	2	0	0	0				0	0	0	0	0			
4/14/2009 11:30	602	68.7	0	1	3	0	0				0	0	0	0	0			
4/14/2009 11:45	560	70.1	0	1	2	0	0				0	0	0	0	0			
4/14/2009 12:00	582	69.4	0	1	1	1	0				0	0	0	0	0			
4/14/2009 12:15	533	68.3	0	1	1	0	0				0	0	0	0	0			
4/14/2009 12:30	587	69.7	0	0	0	0	0				0	0	1	0	0			
4/14/2009 12:45	596	68.6	0	2	1	0	0				0	1	0	0	0			
4/14/2009 13:00	613	68.1	1	0	2	1	0				0	0	1	0	0			
4/14/2009 13:15	583	69.2	1	6	0	1	0				0	1	0	0	0			
4/14/2009 13:30	634	68.9	0	1	2	1	0				0	0	0	0	0			
4/14/2009 13:45	642	68.6	0	2	0	1	0				0	0	0	0	0			
4/14/2009 14:00	653	68.5	1	1	1	0	0				0	0	1	0	0			
4/14/2009 14:15	633	69.0	0	2	1	0	0				0	0	0	0	0			
4/14/2009 14:30	719	68.9	0	0	1	0	0				0	0	0	0	0			
4/14/2009 14:45	707	69.5	0	1	0	0	0				0	0	1	0	0			
4/14/2009 15:00	760	69.2	0	1	0	0	0				0	1	0	0	0			
4/14/2009 15:15	659	69.3	0	1	0	0	0				0	0	0	0	0			
4/14/2009 15:30	693	68.9	0	0	0	1	0				0	0	0	0	0			
4/14/2009 15:45	707	69.1	0	0	1	1	0				0	0	0	0	0			
4/14/2009 16:00	735	69.2	0	0	0	0	0				0	0	0	0	0			
4/14/2009 16:15	640	69.3	0	0	0	2	0				0	0	0	0	0			
4/14/2009 16:30	717	69.1	0	0	1	0	0				0	0	0	0	0			
4/14/2009 16:45	721	70.1	0	2	0	0	0				0	0	0	0	0			
4/14/2009 17:00	718	69.3	0	0	0	0	0				0	0	0	0	0			
4/14/2009 17:15	768	68.3	0	1	0	0	0				0	0	0	0	0			
4/14/2009 17:30	914	68.9	0	1	0	1	0				0	0	0	0	0			
4/14/2009 17:45	760	69.0	0	0	0	0	0				0	1	0	0	0			
4/14/2009 18:00	722	69.4	0	0	1	0	0				0	0	0	0	0			
4/14/2009 18:15	647	69.3	0	0	0	0	0				0	0	0	0	0			
4/14/2009 18:30	577	68.9	0	0	0	0	0				0	0	0	0	0			
4/14/2009 18:45	528	69.1	0	0	0	1	0				0	0	0	0	0			
4/14/2009 19:00	448	69.3	0	1	0	0	0				0	0	0	0	0			
4/14/2009 19:15	382	67.3	1	0	0	0	0				0	0	0	0	0			
4/14/2009 19:30	328	67.0	0	0	0	0	0				0	0	0	0	0			
4/14/2009 19:45	321	66.3	0	0	0	0	0				0	0	0	0	0			
4/14/2009 20:00	272	66.5	0	0	0	0	0				0	0	0	0	0			
4/14/2009 20:15	208	66.1	0	0	1	0	0				0	0	0	0	0			
4/14/2009 20:30	263	66.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 20:45	247	66.0	0	1	0	0	0				0	0	0	0	0			
4/14/2009 21:00	243	65.2	0	0	0	0	0				0	0	0	0	0			
4/14/2009 21:15	212	65.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 21:30	222	65.9	0	1	0	0	0				0	0	0	0	0			
4/14/2009 21:45	203	66.6	0	1	0	0	0				0	0	0	0	0			
4/14/2009 22:00	200	65.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 22:15	180	66.2	0	1	0	0	0				0	0	0	0	0			
4/14/2009 22:30	148	65.5	1	0	0	0	0				0	0	0	0	0			
4/14/2009 22:45	151	64.9	0	0	0	0	0				0	0	0	0	0			
4/14/2009 23:00	140	65.9	0	0	0	0	0				0	0	0	0	0			
4/14/2009 23:15	100	64.7	0	0	0	0	0				0	0	0	0	0			
4/14/2009 23:30	84	64.9	0	0	0	0	0				0	0	0	0	0			
4/14/2009 23:45	59	64.8	0	1	0	0	0				0	0	0	0	0			
Day Totals	**42303**	**68.6**	**12**	**67**	**48**	**16**	**0**	**0**	**0**	**0**	**2**	**7**	**7**	**0**	**0**	**0**	**0**	**0**

AM Peak Hr	**7:45**
AM Peak Vol	**3410**
AM PHF	**0.9743**
PM Peak Hr	**17:15**
PM Peak Vol	**3164**
PM PHF	**0.8654**

Traffic Research and Analysis, Inc.
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Phoenix, AZ 85018
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Client: **Kittelson** | Site Ref: **2**
File Number: **901149** | Direction: **SB**
Route: **SR 51** | Latitude: **33.64891**
Location: **Btwn UNION HILLS DR ON-RAMP BELL RD OFF-RAMP** | Longitude: **-112.00106**

							Volume by Lane								Average Speed by Lane				
Count Date	Total Volume	Avg Speed	Len 0-25	Len 26-55	Len 56-75	Len 76+	SB 1	SB 2	SB 3	SB 4	SB HOV				SB 1	SB 2	SB 3	SB 4	HOV
4/14/2009	64	65.8	61	1	2	0	25	18	14	3	4				64.3	66.4	64.9	67.9	73.7
4/14/2009 0:15	68	67.4	66	0	2	0	20	30	11	4	3				62.3	67.8	72.5	69.5	75.5
4/14/2009 0:30	58	66.0	57	1	0	0	18	22	10	5	3				63.0	66.3	68.7	68.8	68.1
4/14/2009 0:45	43	64.9	39	4	0	0	14	18	10	1	0				64.3	65.1	64.8	68.8	68.1
4/14/2009 1:00	33	65.6	31	2	0	0	12	9	6	4	2				63.9	66.0	63.8	71.1	67.7
4/14/2009 1:15	21	64.7	21	0	0	0	12	5	4	0	0				64.1	66.5	64.3	71.1	67.7
4/14/2009 1:30	29	63.6	28	1	0	0	9	8	7	3	2				60.7	63.1	61.2	72.7	73.8
4/14/2009 1:45	36	64.0	36	0	0	0	6	16	9	5	0				55.7	63.2	68.0	69.1	73.8
4/14/2009 2:00	33	65.1	32	1	0	0	13	7	11	2	0				60.1	66.2	68.3	75.4	73.8
4/14/2009 2:15	24	66.4	24	0	0	0	6	6	8	3	1				61.1	69.7	67.3	67.7	67.8
4/14/2009 2:30	19	64.1	17	0	2	0	5	8	6	0	0				62.0	65.6	63.8	67.7	67.8
4/14/2009 2:45	30	67.0	28	2	0	0	11	9	7	1	2				63.2	64.4	73.7	75.3	72.4
4/14/2009 3:00	29	66.5	29	0	0	0	8	9	10	1	1				60.2	66.9	70.8	64.5	71.1
4/14/2009 3:15	28	65.4	26	1	1	0	6	10	10	2	0				66.2	65.0	66.2	61.2	71.1
4/14/2009 3:30	41	65.3	32	8	1	0	10	13	14	4	0				62.3	64.8	67.1	68.6	71.1
4/14/2009 3:45	58	66.5	56	2	0	0	21	15	18	4	0				65.0	65.0	68.4	71.1	71.1
4/14/2009 4:00	64	67.0	62	2	0	0	17	24	15	2	6				64.7	66.3	69.8	63.4	70.7
4/14/2009 4:15	68	68.0	66	1	1	0	15	22	23	3	5				69.4	65.8	67.8	72.7	71.4
4/14/2009 4:30	127	67.8	124	3	0	0	18	42	52	9	6				67.2	65.5	68.6	73.5	70.0
4/14/2009 4:45	164	68.9	160	3	1	0	40	44	49	11	20				65.6	69.0	69.2	71.5	73.5
4/14/2009 5:00	225	69.0	223	2	0	0	55	66	63	29	12				66.5	68.1	70.1	72.5	72.0
4/14/2009 5:15	278	68.6	273	5	0	0	60	79	92	30	17				65.8	66.7	69.7	72.4	74.5
4/14/2009 5:30	436	68.7	414	19	3	0	81	112	131	67	45				65.3	67.1	68.9	71.9	73.3
4/14/2009 5:45	619	69.4	592	24	2	1	130	157	166	107	59				65.4	67.0	69.8	74.2	74.7
4/14/2009 6:00	623	69.7	599	23	1	0	155	154	171	100	43				67.3	67.1	70.5	73.9	74.8
4/14/2009 6:15	745	68.8	710	33	2	0	166	180	216	152	31				66.1	67.0	68.8	72.8	73.5
4/14/2009 6:30	932	69.1	879	50	3	0	223	237	244	195	33				65.8	67.2	69.7	73.8	72.5
4/14/2009 6:45	996	69.1	953	38	2	3	222	210	300	229	35				66.5	66.7	69.7	72.4	73.0
4/14/2009 7:00	996	69.2	955	40	1	0	269	212	252	216	47				66.4	67.5	69.5	73.2	73.3
4/14/2009 7:15	1129	68.6	1077	49	3	0	311	250	258	243	67				65.4	67.1	68.9	72.9	72.5
4/14/2009 7:30	1179	68.6	1137	38	4	0	302	283	261	266	67				65.9	66.6	68.9	72.3	73.0
4/14/2009 7:45	1181	68.4	1128	50	2	1	269	287	293	256	76				64.2	66.6	69.0	72.4	73.6
4/14/2009 8:00	1117	68.5	1069	45	2	1	277	277	286	223	54				64.8	66.4	69.7	73.2	73.1
4/14/2009 8:15	1042	68.2	994	39	8	1	253	248	255	221	65				64.8	65.9	68.8	72.8	72.9
4/14/2009 8:30	1111	68.0	1058	45	7	1	276	265	276	245	49				64.7	66.2	68.2	72.5	72.4
4/14/2009 8:45	1069	67.8	1006	56	7	0	274	266	264	212	53				64.0	66.2	68.7	72.2	73.4
4/14/2009 9:00	1032	68.1	980	46	5	1	252	264	251	217	48				65.4	66.2	68.8	71.6	73.1
4/14/2009 9:15	960	67.9	916	41	3	0	258	242	213	166	81				63.7	65.9	69.3	72.2	74.2
4/14/2009 9:30	899	68.1	844	48	5	2	207	243	222	155	72				64.6	66.6	69.0	71.4	73.4
4/14/2009 9:45	785	67.9	736	44	4	1	193	214	191	127	60				64.7	65.9	69.0	72.1	73.4
4/14/2009 10:00	799	68.0	752	43	3	1	192	242	191	130	44				64.8	66.6	69.0	72.1	72.4
4/14/2009 10:15	732	68.4	694	31	4	3	181	209	189	106	47				65.6	66.7	69.2	72.6	73.3
4/14/2009 10:30	706	67.9	667	35	3	1	187	193	173	117	36				64.7	65.7	69.1	72.6	74.5
4/14/2009 10:45	710	68.5	672	31	6	1	176	200	193	103	38				65.4	66.9	70.1	71.7	74.1
4/14/2009 11:00	689	67.8	648	38	3	0	185	199	175	95	35				64.7	66.5	69.3	71.6	74.3
4/14/2009 11:15	680	68.0	638	40	2	0	168	193	179	95	45				64.8	66.2	69.1	72.6	74.0
4/14/2009 11:30	727	68.0	686	36	4	1	190	199	190	100	48				65.3	66.6	68.6	72.5	72.8
4/14/2009 11:45	658	68.9	618	35	4	1	162	202	167	94	33				66.1	67.7	69.6	73.1	73.9
4/14/2009 12:00	720	68.5	672	45	2	1	194	206	177	105	38				66.1	66.9	69.7	72.1	74.4
4/14/2009 12:15	629	67.8	601	26	2	0	168	180	161	82	38				64.8	66.7	68.8	71.7	73.0
4/14/2009 12:30	677	68.2	640	36	0	1	176	196	160	100	45				65.1	66.8	69.2	71.9	74.2
4/14/2009 12:45	691	67.4	643	45	2	1	184	199	177	94	37				64.3	66.2	68.9	71.6	71.9
4/14/2009 13:00	704	67.9	665	33	6	0	163	217	180	97	47				64.8	66.8	69.2	70.9	73.0
4/14/2009 13:15	701	68.4	641	50	8	2	202	194	171	96	38				66.2	66.2	69.6	72.8	74.5
4/14/2009 13:30	768	67.9	712	51	5	0	214	217	175	109	53				64.6	66.4	69.3	72.8	72.9
4/14/2009 13:45	751	66.9	693	54	3	1	185	227	179	117	43				62.9	65.3	68.4	71.8	72.6
4/14/2009 14:00	769	66.7	712	52	4	1	201	216	197	111	44				63.1	65.0	67.9	72.0	72.9
4/14/2009 14:15	741	67.7	685	52	3	1	214	211	168	104	44				64.8	66.5	68.9	72.0	73.3
4/14/2009 14:30	872	67.2	824	46	1	1	245	231	201	145	50				63.6	66.2	68.8	70.8	73.3
4/14/2009 14:45	862	68.1	800	59	2	1	231	226	207	145	53				65.5	66.6	68.6	72.3	72.7
4/14/2009 15:00	916	67.9	868	44	3	1	267	230	218	134	67				64.7	66.2	69.2	72.0	73.7
4/14/2009 15:15	802	68.6	761	39	2	0	224	219	211	111	37				66.1	67.4	69.7	72.4	72.3
4/14/2009 15:30	817	68.1	772	44	1	0	227	236	206	121	27				65.1	67.0	69.5	72.6	72.7
4/14/2009 15:45	827	68.2	789	36	2	0	240	210	199	148	30				64.7	67.5	69.7	72.2	72.6
4/14/2009 16:00	865	68.1	817	48	0	0	237	261	204	128	35				65.9	66.6	69.3	72.4	71.7
4/14/2009 16:15	777	67.9	735	39	3	0	206	230	198	117	26				65.1	67.0	68.7	72.4	72.9
4/14/2009 16:30	840	68.3	800	35	2	3	238	233	205	131	33				65.4	67.1	69.4	72.5	73.8
4/14/2009 16:45	855	68.8	821	32	2	0	227	243	204	145	36				66.1	67.1	69.9	73.5	72.9
4/14/2009 17:00	839	67.9	805	30	4	0	239	229	200	124	47				65.0	66.7	69.0	72.6	72.3
4/14/2009 17:15	920	68.0	885	34	1	0	252	254	237	143	34				65.6	66.2	69.3	72.3	72.3
4/14/2009 17:30	1060	68.2	1018	40	2	0	261	268	262	211	58				64.9	66.5	68.9	72.3	72.6
4/14/2009 17:45	884	67.8	859	24	0	1	245	229	222	148	40				64.8	66.3	69.3	71.8	72.0
4/14/2009 18:00	872	68.6	849	22	1	0	236	231	217	145	43				65.9	66.7	69.7	73.0	72.7
4/14/2009 18:15	774	68.6	749	25	0	0	213	207	187	107	60				66.4	67.4	69.1	72.8	71.9
4/14/2009 18:30	705	68.4	684	21	0	0	193	193	184	106	29				66.6	66.7	69.4	71.8	72.8
4/14/2009 18:45	618	68.6	590	26	2	0	169	176	158	88	27				66.4	67.2	69.8	72.5	72.2
4/14/2009 19:00	559	67.8	544	13	2	0	169	159	146	68	17				64.6	66.6	69.2	73.7	74.1
4/14/2009 19:15	445	66.8	434	11	0	0	136	131	106	50	22				64.8	65.9	68.2	69.3	71.4
4/14/2009 19:30	407	66.6	394	12	1	0	120	113	110	39	25				64.5	65.0	67.8	71.1	71.3
4/14/2009 19:45	383	66.5	374	9	0	0	109	111	98	48	17				64.6	65.3	67.4	69.6	72.1
4/14/2009 20:00	338	66.3	329	9	0	0	102	97	84	34	21				63.7	65.8	66.8	71.1	70.7
4/14/2009 20:15	264	66.1	259	4	1	0	96	85	65	13	5				64.9	65.8	67.7	67.6	72.0
4/14/2009 20:30	322	66.2	314	8	0	0	103	92	80	31	16				64.3	65.3	67.4	69.6	71.9
4/14/2009 20:45	296	66.0	292	3	1	0	85	84	78	33	16				64.6	64.2	66.7	70.1	70.4
4/14/2009 21:00	319	65.5	313	6	0	0	106	87	86	32	8				62.7	65.8	66.5	69.8	70.9
4/14/2009 21:15	271	65.6	263	8	0	0	80	83	73	25	10				63.2	65.3	66.8	68.3	71.1
4/14/2009 21:30	286	65.9	282	3	1	0	99	73	65	37	12				63.2	65.0	67.9	69.9	70.0
4/14/2009 21:45	261	66.0	253	7	1	0	97	69	60	21	14				63.6	66.6	67.8	68.6	68.5
4/14/2009 22:00	234	65.7	230	3	1	0	71	70	60	23	10				63.6	64.8	65.9	70.6	73.3
4/14/2009 22:15	226	65.9	223	3	0	0	75	65	55	20	11				64.1	64.5	67.6	69.0	71.6
4/14/2009 22:30	182	65.1	179	2	1	0	61	55	41	20	5				61.6	65.5	67.1	68.8	72.3
4/14/2009 22:45	173	65.4	171	2	0	0	43	62	51	13	4				65.2	65.0	65.0	68.7	69.4
4/14/2009 23:00	156	66.0	153	3	0	0	45	51	39	16	5				64.8	65.2	66.4	71.0	66.4
4/14/2009 23:15	120	64.8	118	2	0	0	34	36	34	14	2				61.9	65.4	65.3	68.3	71.7
4/14/2009 23:30	93	65.7	92	1	0	0	33	30	20	6	4				63.9	65.7	66.6	70.9	68.5
4/14/2009 23:45	71	66.0	68	2	1	0	20	26	15	6	4				64.8	64.5	68.0	67.4	72.9
Day Totals	**51754**	**68.0**	**49288**	**2255**	**176**	**35**	**13695**	**13966**	**12987**	**8324**	**2782**	**0**	**0**	**0**	**65.0**	**66.5**	**69.0**	**72.3**	**73.0**

AM Peak Hr	**7:15**
AM Peak Vol	**4606**
AM PHF	**0.9750**
PM Peak Hr	**17:15**
PM Peak Vol	**3736**
PM PHF	**0.8811**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: **Kittelson**
File Number: **901149**
Route: **SR 51**
Location: **Btwn UNION HILLS**

Count Date	Total Volume	Avg Speed	Small Vehcles 0-25' by Lane								Medium Vehicles 26-55' by Lane							
			SB 1	SB 2	SB 3	SB 4	HOV				SB 1	SB 2	SB 3	SB 4	HOV			
4/14/2009	64	65.8	24	17	13	3	4				1	0	0	0	0			
4/14/2009 0:15	68	67.4	20	29	10	4	3				0	0	0	0	0			
4/14/2009 0:30	58	66.0	17	22	10	5	3				1	0	0	0	0			
4/14/2009 0:45	43	64.9	12	17	10	0	0				2	1	0	1	0			
4/14/2009 1:00	33	65.6	11	9	6	3	2				1	0	0	1	0			
4/14/2009 1:15	21	64.7	12	5	4	0	0				0	0	0	0	0			
4/14/2009 1:30	29	63.6	8	8	7	3	2				1	0	0	0	0			
4/14/2009 1:45	36	64.0	6	16	9	5	0				0	0	0	0	0			
4/14/2009 2:00	33	65.1	13	6	11	2	0				0	1	0	0	0			
4/14/2009 2:15	24	66.4	6	6	8	3	1				0	0	0	0	0			
4/14/2009 2:30	19	64.1	5	6	6	0	0				0	0	0	0	0			
4/14/2009 2:45	30	67.0	11	8	6	1	2				0	1	1	0	0			
4/14/2009 3:00	29	66.5	8	9	10	1	1				0	0	0	0	0			
4/14/2009 3:15	28	65.4	6	9	9	2	0				0	0	1	0	0			
4/14/2009 3:30	41	65.3	8	10	11	3	0				2	3	2	1	0			
4/14/2009 3:45	58	66.5	20	15	17	4	0				1	0	1	0	0			
4/14/2009 4:00	64	67.0	16	23	15	2	6				1	1	0	0	0			
4/14/2009 4:15	68	68.0	15	22	22	2	5				0	0	1	0	0			
4/14/2009 4:30	127	67.8	18	40	51	9	6				0	2	1	0	0			
4/14/2009 4:45	164	68.9	40	43	46	11	20				0	1	2	0	0			
4/14/2009 5:00	225	69.0	54	65	63	29	12				1	1	0	0	0			
4/14/2009 5:15	278	68.6	59	77	91	29	17				1	2	1	1	0			
4/14/2009 5:30	436	68.7	77	103	126	64	44				3	8	4	3	1			
4/14/2009 5:45	619	69.4	127	150	155	103	57				3	6	9	4	2			
4/14/2009 6:00	623	69.7	151	144	165	96	43				4	9	6	4	0			
4/14/2009 6:15	745	68.8	161	169	209	140	31				5	10	7	11	0			
4/14/2009 6:30	932	69.1	210	226	225	188	30				12	10	18	7	3			
4/14/2009 6:45	996	69.1	217	190	291	221	34				5	17	8	7	1			
4/14/2009 7:00	996	69.2	266	203	243	199	44				3	8	9	17	3			
4/14/2009 7:15	1129	68.6	305	236	239	232	65				6	13	18	10	2			
4/14/2009 7:30	1179	68.6	298	270	247	257	65				4	11	12	9	2			
4/14/2009 7:45	1181	68.4	265	263	279	247	74				3	22	14	9	2			
4/14/2009 8:00	1117	68.5	273	260	268	215	53				3	16	17	8	1			
4/14/2009 8:15	1042	68.2	246	235	242	211	60				5	10	10	9	5			
4/14/2009 8:30	1111	68.0	271	250	255	233	49				2	13	19	11	0			
4/14/2009 8:45	1069	67.8	269	247	241	200	49				4	16	21	11	4			
4/14/2009 9:00	1032	68.1	247	246	234	207	46				4	18	13	9	2			
4/14/2009 9:15	960	67.9	249	226	202	159	80				9	15	9	7	1			
4/14/2009 9:30	899	68.1	198	227	205	144	70				8	12	15	11	2			
4/14/2009 9:45	785	67.9	182	196	184	115	59				10	16	6	11	1			
4/14/2009 10:00	799	68.0	185	228	176	121	42				7	12	13	9	2			
4/14/2009 10:15	732	68.4	176	191	181	102	44				4	15	7	3	2			
4/14/2009 10:30	706	67.9	185	179	155	113	35				2	13	15	4	1			
4/14/2009 10:45	710	68.5	170	182	183	99	38				6	13	9	3	0			
4/14/2009 11:00	689	67.8	181	185	161	86	35				4	12	13	9	0			
4/14/2009 11:15	680	68.0	158	176	171	88	45				10	15	8	7	0			
4/14/2009 11:30	727	68.0	185	188	170	95	48				5	9	17	5	0			
4/14/2009 11:45	658	68.9	152	183	162	89	32				9	18	2	5	1			
4/14/2009 12:00	720	68.5	186	191	162	95	38				8	14	14	9	0			
4/14/2009 12:15	629	67.8	163	175	148	80	35				5	4	12	2	3			
4/14/2009 12:30	677	68.2	170	188	148	93	41				6	8	11	7	4			
4/14/2009 12:45	691	67.4	179	177	165	88	34				5	20	11	6	3			
4/14/2009 13:00	704	67.9	157	209	165	90	44				5	8	12	6	2			
4/14/2009 13:15	701	68.4	187	178	154	86	36				14	10	17	8	1			
4/14/2009 13:30	768	67.9	203	201	156	100	52				11	15	16	8	1			
4/14/2009 13:45	751	66.9	171	204	167	109	42				12	22	12	7	1			
4/14/2009 14:00	769	66.7	184	198	180	107	43				17	15	15	4	1			
4/14/2009 14:15	741	67.7	206	192	148	97	42				8	17	19	6	2			
4/14/2009 14:30	872	67.2	232	222	188	133	49				13	8	12	12	1			
4/14/2009 14:45	862	68.1	223	215	185	129	48				8	10	21	15	5			
4/14/2009 15:00	916	67.9	260	220	199	124	65				6	8	19	9	2			
4/14/2009 15:15	802	68.6	217	208	199	104	33				7	9	12	7	4			
4/14/2009 15:30	817	68.1	215	223	193	114	27				12	13	13	6	0			
4/14/2009 15:45	827	68.2	235	200	188	140	26				5	10	10	7	4			
4/14/2009 16:00	865	68.1	229	250	183	123	32				8	11	21	5	3			
4/14/2009 16:15	777	67.9	200	220	179	110	26				6	9	19	5	0			
4/14/2009 16:30	840	68.3	230	224	190	124	32				8	9	12	5	1			
4/14/2009 16:45	855	68.8	222	231	194	138	36				5	10	10	7	0			
4/14/2009 17:00	839	67.9	233	223	188	116	45				5	5	11	7	2			
4/14/2009 17:15	920	68.0	245	249	225	135	31				7	4	12	8	3			
4/14/2009 17:30	1060	68.2	256	258	246	202	56				5	9	16	8	2			
4/14/2009 17:45	884	67.8	241	217	217	144	40				4	11	5	4	0			
4/14/2009 18:00	872	68.6	232	224	209	142	42				4	7	7	3	1			
4/14/2009 18:15	774	68.6	205	204	177	104	59				8	3	10	3	1			
4/14/2009 18:30	705	68.4	190	189	174	102	29				3	4	10	4	0			
4/14/2009 18:45	618	68.6	161	169	147	87	26				8	6	10	1	1			
4/14/2009 19:00	559	67.8	168	151	141	67	17				1	6	5	1	0			
4/14/2009 19:15	445	66.8	135	128	103	47	21				1	3	3	3	1			
4/14/2009 19:30	407	66.6	118	111	104	39	22				1	2	6	0	3			
4/14/2009 19:45	383	66.5	108	108	97	45	16				1	3	1	3	1			
4/14/2009 20:00	338	66.3	101	91	83	33	21				1	6	1	1	0			
4/14/2009 20:15	264	66.1	96	82	63	13	5				0	3	1	0	0			
4/14/2009 20:30	322	66.2	102	89	77	31	15				1	3	3	0	1			
4/14/2009 20:45	296	66.0	85	82	77	32	16				0	1	1	1	0			
4/14/2009 21:00	319	65.5	105	85	84	31	8				1	2	2	1	0			
4/14/2009 21:15	271	65.6	78	82	69	25	9				2	1	4	0	1			
4/14/2009 21:30	286	65.9	96	72	65	37	12				3	0	0	0	0			
4/14/2009 21:45	261	66.0	95	66	58	20	14				2	2	2	1	0			
4/14/2009 22:00	234	65.7	71	69	60	20	10				0	1	0	2	0			
4/14/2009 22:15	226	65.9	75	63	54	20	11				0	2	1	0	0			
4/14/2009 22:30	182	65.1	60	54	40	20	5				0	1	1	0	0			
4/14/2009 22:45	173	65.4	43	61	50	13	4				0	1	1	0	0			
4/14/2009 23:00	156	66.0	43	51	38	16	5				2	0	1	0	0			
4/14/2009 23:15	120	64.8	34	35	34	13	2				0	1	0	1	0			
4/14/2009 23:30	93	65.7	33	30	19	6	4				0	0	1	0	0			
4/14/2009 23:45	71	66.0	19	25	14	6	4				1	0	1	0	0			
Day Totals	**51754**	**68.0**	**13290**	**13209**	**12208**	**7895**	**2686**	**0**	**0**	**0**	**382**	**667**	**713**	**400**	**93**	**0**	**0**	**0**

AM Peak Hr	**7:15**
AM Peak Vol	**4606**
AM PHF	**0.9750**
PM Peak Hr	**17:15**
PM Peak Vol	**3736**
PM PHF	**0.8811**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: **Kittelson**
File Number: **901149**
Route: **SR 51**
Location: **Btwn UNION HILLS**

Site Ref: **2**
Direction: **SB**
Latitude: **33.64891**
Longitude: **-112.00106**

			Large Vehicles 56-75' by Lane								Combination Vehicles76'+ by Lane							
Count Date	**Total Volume**	**Avg Speed**	**SB 1**	**SB 2**	**SB 3**	**SB 4**	**HOV**				**SB 1**	**SB 2**	**SB 3**	**SB 4**	**HOV**			
4/14/2009	64	65.8	0	1	1	0	0				0	0	0	0	0			
4/14/2009 0:15	68	67.4	0	1	1	0	0				0	0	0	0	0			
4/14/2009 0:30	58	66.0	0	0	0	0	0				0	0	0	0	0			
4/14/2009 0:45	43	64.9	0	0	0	0	0				0	0	0	0	0			
4/14/2009 1:00	33	65.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 1:15	21	64.7	0	0	0	0	0				0	0	0	0	0			
4/14/2009 1:30	29	63.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 1:45	36	64.0	0	0	0	0	0				0	0	0	0	0			
4/14/2009 2:00	33	65.1	0	0	0	0	0				0	0	0	0	0			
4/14/2009 2:15	24	66.4	0	0	0	0	0				0	0	0	0	0			
4/14/2009 2:30	19	64.1	0	2	0	0	0				0	0	0	0	0			
4/14/2009 2:45	30	67.0	0	0	0	0	0				0	0	0	0	0			
4/14/2009 3:00	29	66.5	0	0	0	0	0				0	0	0	0	0			
4/14/2009 3:15	28	65.4	0	1	0	0	0				0	0	0	0	0			
4/14/2009 3:30	41	65.3	0	0	1	0	0				0	0	0	0	0			
4/14/2009 3:45	58	66.5	0	0	0	0	0				0	0	0	0	0			
4/14/2009 4:00	64	67.0	0	0	0	0	0				0	0	0	0	0			
4/14/2009 4:15	68	68.0	0	0	0	1	0				0	0	0	0	0			
4/14/2009 4:30	127	67.8	0	0	0	0	0				0	0	0	0	0			
4/14/2009 4:45	164	68.9	0	0	1	0	0				0	0	0	0	0			
4/14/2009 5:00	225	69.0	0	0	0	0	0				0	0	0	0	0			
4/14/2009 5:15	278	68.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 5:30	436	68.7	1	1	1	0	0				0	0	0	0	0			
4/14/2009 5:45	619	69.4	0	1	1	0	0				0	0	1	0	0			
4/14/2009 6:00	623	69.7	0	1	0	0	0				0	0	0	0	0			
4/14/2009 6:15	745	68.8	0	1	0	1	0				0	0	0	0	0			
4/14/2009 6:30	932	69.1	1	1	1	0	0				0	0	0	0	0			
4/14/2009 6:45	996	69.1	0	1	1	0	0				0	2	0	1	0			
4/14/2009 7:00	996	69.2	0	1	0	0	0				0	0	0	0	0			
4/14/2009 7:15	1129	68.6	0	1	1	1	0				0	0	0	0	0			
4/14/2009 7:30	1179	68.6	0	2	2	0	0				0	0	0	0	0			
4/14/2009 7:45	1181	68.4	1	1	0	0	0				0	1	0	0	0			
4/14/2009 8:00	1117	68.5	1	0	1	0	0				0	1	0	0	0			
4/14/2009 8:15	1042	68.2	1	3	3	1	0				1	0	0	0	0			
4/14/2009 8:30	1111	68.0	2	2	2	1	0				1	0	0	0	0			
4/14/2009 8:45	1069	67.8	1	3	2	1	0				0	0	0	0	0			
4/14/2009 9:00	1032	68.1	1	0	4	0	0				0	0	0	1	0			
4/14/2009 9:15	960	67.9	0	1	2	0	0				0	0	0	0	0			
4/14/2009 9:30	899	68.1	0	3	2	0	0				1	1	0	0	0			
4/14/2009 9:45	785	67.9	1	1	1	1	0				0	1	0	0	0			
4/14/2009 10:00	799	68.0	0	2	1	0	0				0	0	1	0	0			
4/14/2009 10:15	732	68.4	1	2	0	1	0				0	1	1	0	1			
4/14/2009 10:30	706	67.9	0	1	2	0	0				0	0	1	0	0			
4/14/2009 10:45	710	68.5	0	5	1	0	0				0	0	0	1	0			
4/14/2009 11:00	689	67.8	0	2	1	0	0				0	0	0	0	0			
4/14/2009 11:15	680	68.0	0	2	0	0	0				0	0	0	0	0			
4/14/2009 11:30	727	68.0	0	1	3	0	0				0	1	0	0	0			
4/14/2009 11:45	658	68.9	1	0	3	0	0				0	1	0	0	0			
4/14/2009 12:00	720	68.5	0	1	1	0	0				0	0	0	1	0			
4/14/2009 12:15	629	67.8	0	1	1	0	0				0	0	0	0	0			
4/14/2009 12:30	677	68.2	0	0	0	0	0				0	0	1	0	0			
4/14/2009 12:45	691	67.4	0	1	1	0	0				0	1	0	0	0			
4/14/2009 13:00	704	67.9	1	0	3	1	1				0	0	0	0	0			
4/14/2009 13:15	701	68.4	0	6	0	1	1				1	0	0	1	0			
4/14/2009 13:30	768	67.9	0	1	3	1	0				0	0	0	0	0			
4/14/2009 13:45	751	66.9	1	1	0	1	0				1	0	0	0	0			
4/14/2009 14:00	769	66.7	0	3	1	0	0				0	0	1	0	0			
4/14/2009 14:15	741	67.7	0	1	1	1	0				0	1	0	0	0			
4/14/2009 14:30	872	67.2	0	1	0	0	0				0	0	1	0	0			
4/14/2009 14:45	862	68.1	0	1	0	1	0				0	0	1	0	0			
4/14/2009 15:00	916	67.9	1	1	0	1	0				0	1	0	0	0			
4/14/2009 15:15	802	68.6	0	2	0	0	0				0	0	0	0	0			
4/14/2009 15:30	817	68.1	0	0	0	1	0				0	0	0	0	0			
4/14/2009 15:45	827	68.2	0	0	1	1	0				0	0	0	0	0			
4/14/2009 16:00	865	68.1	0	0	0	0	0				0	0	0	0	0			
4/14/2009 16:15	777	67.9	0	1	0	2	0				0	0	0	0	0			
4/14/2009 16:30	840	68.3	0	0	1	1	0				0	0	2	1	0			
4/14/2009 16:45	855	68.8	0	2	0	0	0				0	0	0	0	0			
4/14/2009 17:00	839	67.9	1	1	1	1	0				0	0	0	0	0			
4/14/2009 17:15	920	68.0	0	1	0	0	0				0	0	0	0	0			
4/14/2009 17:30	1060	68.2	0	1	0	1	0				0	0	0	0	0			
4/14/2009 17:45	884	67.8	0	0	0	0	0				0	1	0	0	0			
4/14/2009 18:00	872	68.6	0	0	1	0	0				0	0	0	0	0			
4/14/2009 18:15	774	68.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 18:30	705	68.4	0	0	0	0	0				0	0	0	0	0			
4/14/2009 18:45	618	68.6	0	1	1	0	0				0	0	0	0	0			
4/14/2009 19:00	559	67.8	0	2	0	0	0				0	0	0	0	0			
4/14/2009 19:15	445	66.8	0	0	0	0	0				0	0	0	0	0			
4/14/2009 19:30	407	66.6	1	0	0	0	0				0	0	0	0	0			
4/14/2009 19:45	383	66.5	0	0	0	0	0				0	0	0	0	0			
4/14/2009 20:00	338	66.3	0	0	0	0	0				0	0	0	0	0			
4/14/2009 20:15	264	66.1	0	0	1	0	0				0	0	0	0	0			
4/14/2009 20:30	322	66.2	0	0	0	0	0				0	0	0	0	0			
4/14/2009 20:45	296	66.0	0	1	0	0	0				0	0	0	0	0			
4/14/2009 21:00	319	65.5	0	0	0	0	0				0	0	0	0	0			
4/14/2009 21:15	271	65.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 21:30	286	65.9	0	1	0	0	0				0	0	0	0	0			
4/14/2009 21:45	261	66.0	0	1	0	0	0				0	0	0	0	0			
4/14/2009 22:00	234	65.7	0	0	0	1	0				0	0	0	0	0			
4/14/2009 22:15	226	65.9	0	0	0	0	0				0	0	0	0	0			
4/14/2009 22:30	182	65.1	1	0	0	0	0				0	0	0	0	0			
4/14/2009 22:45	173	65.4	0	0	0	0	0				0	0	0	0	0			
4/14/2009 23:00	156	66.0	0	0	0	0	0				0	0	0	0	0			
4/14/2009 23:15	120	64.8	0	0	0	0	0				0	0	0	0	0			
4/14/2009 23:30	93	65.7	0	0	0	0	0				0	0	0	0	0			
4/14/2009 23:45	71	66.0	0	1	0	0	0				0	0	0	0	0			
Day Totals	**51754**	**68.0**	**18**	**77**	**56**	**23**	**2**	**0**	**0**	**0**	**5**	**13**	**10**	**6**	**1**	**0**	**0**	**0**	

AM Peak Hr	**7:15**
AM Peak Vol	**4606**
AM PHF	**0.9750**
PM Peak Hr	**17:15**
PM Peak Vol	**3736**
PM PHF	**0.8811**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client:	**Kittelson**	Site Ref:	**3**
File Number:	**901150**	Direction:	**SB**
Route:	**SR 51**	Latitude:	**33.64358**
Location:	**N of BELL RD AFTER OFF-RAMP**	Longitude:	**-112.00218**

Count Date	Total Volume	Avg Speed	Len 0-25	Len 26-55	Len 56-75	Len 76+	Volume by Lane SB 1	SB 2	SB 3	SB 4	SB HOV				Average Speed by Lane SB 1	SB 2	SB 3	SB 4	HOV
4/14/2009	51	65.7	48	1	1	1	10	21	14	2	4				65.0	65.7	64.5	62.9	73.3
4/14/2009 0:15	59	67.6	57	0	2	0	6	34	10	5	4				60.9	66.0	73.0	70.4	73.7
4/14/2009 0:30	48	66.6	47	1	0	0	5	24	11	5	3				65.7	65.6	67.4	68.2	70.6
4/14/2009 0:45	39	64.7	37	2	0	0	8	20	8	2	1				62.7	65.2	65.3	64.3	67.0
4/14/2009 1:00	28	64.6	27	1	0	0	6	10	7	3	2				61.1	62.9	66.7	71.4	65.7
4/14/2009 1:15	15	65.1	15	0	0	0	4	6	5	0	0				58.2	68.0	67.1	71.4	65.7
4/14/2009 1:30	24	64.7	23	1	0	0	2	10	7	3	2				56.1	63.3	64.6	70.5	72.0
4/14/2009 1:45	33	64.7	33	0	0	0	3	14	11	5	0				56.1	62.2	68.4	68.9	72.0
4/14/2009 2:00	27	65.3	26	1	0	0	4	12	9	2	0				65.5	63.9	65.8	70.8	72.0
4/14/2009 2:15	22	67.9	21	1	0	0	1	8	9	2	2				68.2	68.0	67.9	72.9	62.5
4/14/2009 2:30	17	64.9	15	1	1	0	3	6	7	1	0				60.4	64.5	66.9	66.8	62.5
4/14/2009 2:45	25	65.9	23	2	0	0	4	11	7	1	2				60.8	64.8	68.7	69.8	70.8
4/14/2009 3:00	28	66.8	27	1	0	0	4	11	11	1	1				61.4	65.6	70.1	63.6	68.6
4/14/2009 3:15	27	65.3	24	2	1	0	3	9	13	2	0				70.8	63.8	65.6	61.5	68.6
4/14/2009 3:30	39	66.8	30	8	1	0	4	15	18	2	0				61.6	67.3	67.2	70.2	68.6
4/14/2009 3:45	55	67.1	53	2	0	0	7	21	22	5	0				64.5	65.3	68.8	70.6	68.6
4/14/2009 4:00	59	66.8	58	1	0	0	8	26	17	2	6				66.2	65.5	68.5	63.2	69.2
4/14/2009 4:15	63	67.2	61	1	1	0	3	27	24	4	5				63.8	65.4	68.2	69.0	72.4
4/14/2009 4:30	122	66.9	118	4	0	0	3	51	48	14	6				59.9	65.4	67.9	70.0	67.4
4/14/2009 4:45	149	68.5	146	2	1	0	8	46	58	14	23				63.9	65.7	69.1	70.6	72.6
4/14/2009 5:00	204	68.6	200	4	0	0	18	67	74	30	15				66.5	65.7	70.2	70.6	72.6
4/14/2009 5:15	260	68.2	259	1	0	0	11	91	102	39	17				63.1	65.1	69.9	69.9	74.7
4/14/2009 5:30	423	68.3	406	14	3	0	24	120	151	85	43				64.4	65.5	68.8	70.5	72.6
4/14/2009 5:45	588	69.4	568	17	3	0	24	186	189	130	59				66.5	66.0	69.9	72.3	73.5
4/14/2009 6:00	575	69.8	554	20	1	0	41	169	197	127	41				65.5	66.5	70.5	73.1	74.0
4/14/2009 6:15	701	68.8	676	24	1	0	38	219	244	168	32				65.5	66.1	69.0	71.6	74.1
4/14/2009 6:30	890	69.5	860	28	2	0	60	248	297	242	43				65.7	66.2	70.1	72.0	74.9
4/14/2009 6:45	948	69.1	909	34	5	0	61	218	340	282	47				66.0	66.1	69.4	71.0	73.8
4/14/2009 7:00	927	70.1	904	21	1	1	63	238	318	254	54				65.6	66.9	70.6	72.7	75.1
4/14/2009 7:15	1073	69.8	1042	29	2	0	59	293	343	291	87				67.3	66.7	70.0	72.2	73.2
4/14/2009 7:30	1074	69.5	1045	26	3	0	80	302	317	300	75				67.0	66.4	70.2	71.4	74.7
4/14/2009 7:45	1104	69.1	1075	27	1	1	84	307	344	280	89				64.6	65.2	70.0	71.7	74.8
4/14/2009 8:00	1041	69.4	1005	33	2	1	81	302	326	269	63				65.5	66.4	70.4	71.7	73.6
4/14/2009 8:15	969	69.4	929	31	9	0	80	266	288	261	74				66.4	66.1	70.0	71.8	73.1
4/14/2009 8:30	1017	68.6	977	34	5	1	84	308	306	263	56				65.1	65.7	69.0	71.8	72.2
4/14/2009 8:45	965	68.6	934	25	6	0	79	288	295	243	60				64.0	65.9	69.1	71.3	73.5
4/14/2009 9:00	948	68.7	910	31	7	0	90	279	292	234	53				65.0	65.7	69.7	71.2	73.4
4/14/2009 9:15	849	68.3	821	27	1	0	72	277	242	176	82				64.3	65.3	69.0	71.2	73.9
4/14/2009 9:30	823	67.9	786	30	7	0	69	268	227	174	85				64.7	65.0	68.3	70.7	73.0
4/14/2009 9:45	688	67.9	656	29	3	0	66	218	196	147	61				64.2	65.5	68.4	70.6	72.9
4/14/2009 10:00	720	68.6	688	28	3	1	60	241	226	143	50				65.4	65.8	69.8	71.3	73.0
4/14/2009 10:15	653	68.7	618	30	4	1	53	232	207	110	51				64.9	66.4	69.3	71.9	73.2
4/14/2009 10:30	633	67.8	610	20	3	0	60	226	183	122	42				65.9	65.0	68.7	70.8	73.4
4/14/2009 10:45	645	68.4	612	26	5	2	47	228	207	118	45				65.1	65.7	69.6	70.9	72.9
4/14/2009 11:00	590	67.8	564	23	3	0	70	206	187	92	35				63.8	65.5	69.0	71.0	74.6
4/14/2009 11:15	609	68.3	574	32	3	0	48	220	188	105	48				64.8	64.9	69.8	71.6	74.3
4/14/2009 11:30	647	68.4	614	28	4	1	66	218	192	119	52				64.9	65.8	69.0	72.1	72.8
4/14/2009 11:45	587	69.4	557	26	4	0	48	225	174	105	35				64.9	67.1	70.6	72.5	74.3
4/14/2009 12:00	634	68.7	601	30	2	1	66	232	182	111	43				65.3	66.4	69.7	71.7	73.8
4/14/2009 12:15	544	68.3	522	20	2	0	45	203	166	92	38				65.2	66.7	68.9	70.5	72.5
4/14/2009 12:30	574	68.8	544	29	0	1	50	208	166	101	49				65.3	66.3	69.6	71.4	74.9
4/14/2009 12:45	604	68.4	562	38	2	2	45	238	190	96	35				64.5	66.1	69.4	71.9	73.7
4/14/2009 13:00	611	68.7	588	19	4	0	48	229	179	106	49				65.5	66.3	69.8	70.8	74.4
4/14/2009 13:15	598	68.4	553	38	5	2	56	217	165	121	39				66.3	65.6	69.0	71.7	73.6
4/14/2009 13:30	669	68.8	626	39	4	0	72	230	199	116	52				65.1	66.2	69.9	72.2	73.9
4/14/2009 13:45	650	67.6	606	40	1	3	52	241	198	111	48				62.9	65.1	68.8	70.8	73.2
4/14/2009 14:00	671	67.2	634	32	4	1	55	238	213	114	51				62.9	64.9	67.6	70.4	73.2
4/14/2009 14:15	633	68.5	591	39	3	0	70	221	190	107	45				64.6	66.5	69.4	71.3	73.7
4/14/2009 14:30	739	67.9	710	28	0	1	65	261	219	137	57				64.2	65.5	68.7	70.3	73.8
4/14/2009 14:45	763	68.2	722	39	1	1	79	258	228	144	54				65.3	66.2	68.4	71.0	74.2
4/14/2009 15:00	797	68.8	757	38	1	1	83	270	239	146	59				66.2	66.2	69.3	72.1	73.9
4/14/2009 15:15	697	68.7	669	26	2	0	69	235	223	133	37				67.3	66.5	68.8	71.8	73.8
4/14/2009 15:30	712	68.8	680	31	1	0	78	249	233	121	31				66.3	66.5	69.5	73.0	72.7
4/14/2009 15:45	717	68.8	689	26	2	0	70	248	219	148	32				64.7	66.8	70.0	71.6	73.2
4/14/2009 16:00	731	68.3	702	29	0	0	67	273	223	130	38				65.5	66.0	69.5	71.7	71.9
4/14/2009 16:15	683	68.6	654	27	2	0	62	254	216	121	30				64.8	66.2	69.6	72.6	73.7
4/14/2009 16:30	725	68.5	697	27	1	0	73	257	211	151	33				64.4	66.1	69.4	72.0	74.5
4/14/2009 16:45	762	68.9	743	16	2	1	88	276	218	142	38				65.9	66.8	69.8	72.3	73.4
4/14/2009 17:00	715	68.6	693	21	1	0	73	245	221	128	48				64.6	66.1	69.8	71.9	73.1
4/14/2009 17:15	805	68.5	776	28	1	0	77	294	243	157	34				65.3	65.8	69.6	72.2	73.5
4/14/2009 17:30	922	68.0	905	15	2	0	83	307	266	210	56				64.5	65.9	68.5	70.8	71.6
4/14/2009 17:45	780	67.6	761	18	0	1	79	259	240	156	46				63.0	64.9	69.1	70.6	72.7
4/14/2009 18:00	770	68.4	755	15	0	0	83	270	214	158	45				64.2	65.9	69.6	71.5	74.7
4/14/2009 18:15	673	68.5	657	15	1	0	63	231	188	130	61				66.0	66.4	68.7	71.4	72.7
4/14/2009 18:30	619	67.9	604	15	0	0	69	211	195	112	32				64.6	65.4	69.3	71.4	71.5
4/14/2009 18:45	550	67.8	533	14	3	0	56	202	170	97	25				64.3	65.6	69.0	71.4	71.8
4/14/2009 19:00	482	67.8	468	13	1	0	61	192	132	79	18				64.8	66.0	68.2	72.1	74.5
4/14/2009 19:15	385	66.4	380	5	0	0	43	156	112	50	24				62.9	64.4	68.4	69.0	70.9
4/14/2009 19:30	352	65.9	343	8	1	0	24	147	110	43	28				63.4	63.1	67.3	69.6	71.5
4/14/2009 19:45	324	66.1	321	3	0	0	26	132	100	50	16				61.6	63.7	67.7	69.6	72.1
4/14/2009 20:00	293	66.3	289	4	0	0	25	127	88	32	21				62.7	64.8	67.9	67.6	70.9
4/14/2009 20:15	220	65.5	216	3	1	0	28	105	63	16	8				62.5	63.9	68.8	66.5	69.2
4/14/2009 20:30	275	65.5	269	6	0	0	37	105	82	32	19				61.7	64.1	66.8	67.6	71.0
4/14/2009 20:45	258	65.8	255	2	1	0	18	110	77	36	17				63.3	63.7	67.0	68.1	71.2
4/14/2009 21:00	278	65.6	276	2	0	0	36	107	95	32	8				61.8	64.3	67.4	68.0	69.5
4/14/2009 21:15	242	65.3	237	5	0	0	25	101	74	30	12				62.5	64.1	66.3	67.6	69.4
4/14/2009 21:30	254	65.8	246	7	0	1	43	90	69	42	10				63.1	63.7	67.9	68.4	71.0
4/14/2009 21:45	214	66.4	208	5	1	0	23	88	71	18	14				61.5	65.6	68.1	68.0	68.3
4/14/2009 22:00	208	65.6	203	5	0	0	23	75	74	25	11				62.1	64.1	66.6	67.7	71.8
4/14/2009 22:15	195	65.2	193	2	0	0	35	69	57	21	13				62.3	63.0	68.0	67.0	70.1
4/14/2009 22:30	155	65.4	154	1	0	0	13	70	47	17	8				62.7	64.4	66.4	66.2	70.0
4/14/2009 22:45	145	64.3	143	1	1	0	15	67	48	11	4				63.3	62.7	65.8	66.5	71.1
4/14/2009 23:00	129	65.0	125	4	0	0	13	58	38	16	4				61.9	63.9	66.1	68.3	67.1
4/14/2009 23:15	107	65.1	106	1	0	0	15	41	35	14	2				63.9	63.9	65.1	68.5	77.2
4/14/2009 23:30	76	65.2	74	2	0	0	7	31	25	7	6				64.8	64.4	65.7	65.5	66.9
4/14/2009 23:45	59	65.4	56	2	1	0	8	25	16	6	4				61.3	64.9	67.2	64.6	71.4
Day Totals	**46080**	**68.3**	**44338**	**1563**	**153**	**26**	**4126**	**15595**	**14195**	**9157**	**3007**	**0**	**0**	**0**	**64.8**	**65.7**	**69.2**	**71.4**	**73.3**

AM Peak Hr	**7:15**
AM Peak Vol	**4292**
AM PHF	**0.9719**
PM Peak Hr	**17:15**
PM Peak Vol	**3277**
PM PHF	**0.8886**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: **Kittelson**
File Number: **901150**
Route: **SR 51**
Location: **N of BELL RD AFTE**

	Total	Avg	Small Vehcles 0-25' by Lane								Medium Vehicles 26-55' by Lane							
Count Date	**Volume**	**Speed**	**SB 1**	**SB 2**	**SB 3**	**SB 4**	**HOV**				**SB 1**	**SB 2**	**SB 3**	**SB 4**	**HOV**			
4/14/2009	51	65.7	9	20	13	2	4				1	0	0	0	0			
4/14/2009 0:15	59	67.6	6	33	9	5	4				0	0	0	0	0			
4/14/2009 0:30	48	66.6	5	23	11	5	3				0	1	0	0	0			
4/14/2009 0:45	39	64.7	8	19	8	1	1				0	1	0	1	0			
4/14/2009 1:00	28	64.6	5	10	7	3	2				1	0	0	0	0			
4/14/2009 1:15	15	65.1	4	6	5	0	0				0	0	0	0	0			
4/14/2009 1:30	24	64.7	1	10	7	3	2				1	0	0	0	0			
4/14/2009 1:45	33	64.7	3	14	11	5	0				0	0	0	0	0			
4/14/2009 2:00	27	65.3	4	11	9	2	0				0	1	0	0	0			
4/14/2009 2:15	22	67.9	1	7	9	2	2				0	1	0	0	0			
4/14/2009 2:30	17	64.9	3	4	7	1	0				0	1	0	0	0			
4/14/2009 2:45	25	65.9	4	10	6	1	2				0	1	1	0	0			
4/14/2009 3:00	28	66.8	4	10	11	1	1				0	1	0	0	0			
4/14/2009 3:15	27	65.3	3	8	11	2	0				0	0	2	0	0			
4/14/2009 3:30	39	66.8	3	13	12	2	0				1	2	5	0	0			
4/14/2009 3:45	55	67.1	6	21	21	5	0				1	0	1	0	0			
4/14/2009 4:00	59	66.8	8	25	17	2	6				0	1	0	0	0			
4/14/2009 4:15	63	67.2	3	27	23	3	5				0	0	1	0	0			
4/14/2009 4:30	122	66.9	3	49	47	13	6				0	2	1	1	0			
4/14/2009 4:45	149	68.5	8	45	56	14	23				0	1	1	0	0			
4/14/2009 5:00	204	68.6	18	65	73	29	15				0	2	1	1	0			
4/14/2009 5:15	260	68.2	11	91	102	39	16				0	0	0	0	1			
4/14/2009 5:30	423	68.3	23	108	149	85	41				1	10	1	0	2			
4/14/2009 5:45	588	69.4	24	179	182	125	58				0	6	5	5	1			
4/14/2009 6:00	575	69.8	39	160	191	124	40				2	8	6	3	1			
4/14/2009 6:15	701	68.8	38	208	238	160	32				0	10	6	8	0			
4/14/2009 6:30	890	69.5	52	239	288	240	41				7	8	9	2	2			
4/14/2009 6:45	948	69.1	60	199	329	276	45				1	16	9	6	2			
4/14/2009 7:00	927	70.1	61	229	311	251	52				2	8	7	2	2			
4/14/2009 7:15	1073	69.8	59	278	334	286	85				0	14	8	5	2			
4/14/2009 7:30	1074	69.5	78	291	308	293	75				2	9	8	7	0			
4/14/2009 7:45	1104	69.1	82	297	327	280	89				2	9	16	0	0			
4/14/2009 8:00	1041	69.4	80	288	310	266	61				0	13	15	3	2			
4/14/2009 8:15	969	69.4	77	254	271	256	71				1	10	13	4	3			
4/14/2009 8:30	1017	68.6	82	293	287	260	55				2	11	18	2	1			
4/14/2009 8:45	965	68.6	79	271	289	239	56				0	14	5	2	4			
4/14/2009 9:00	948	68.7	87	266	274	232	51				3	12	13	1	2			
4/14/2009 9:15	849	68.3	68	264	236	173	80				4	13	5	3	2			
4/14/2009 9:30	823	67.9	65	251	216	170	84				3	13	9	4	1			
4/14/2009 9:45	688	67.9	58	203	189	145	61				7	13	7	2	0			
4/14/2009 10:00	720	68.6	57	229	213	141	48				3	9	12	2	2			
4/14/2009 10:15	653	68.7	51	217	194	108	48				2	11	13	1	3			
4/14/2009 10:30	633	67.8	59	215	175	120	41				1	10	6	2	1			
4/14/2009 10:45	645	68.4	43	214	194	117	44				4	9	11	1	1			
4/14/2009 11:00	590	67.8	68	196	177	89	34				2	8	9	3	1			
4/14/2009 11:15	609	68.3	45	205	179	99	46				3	14	8	5	2			
4/14/2009 11:30	647	68.4	62	208	178	116	50				4	9	10	3	2			
4/14/2009 11:45	587	69.4	41	209	168	104	35				6	15	4	1	0			
4/14/2009 12:00	634	68.7	66	215	173	104	43				0	16	8	6	0			
4/14/2009 12:15	544	68.3	43	200	159	88	32				2	3	5	4	6			
4/14/2009 12:30	574	68.8	45	202	156	96	45				5	6	9	5	4			
4/14/2009 12:45	604	68.4	42	216	179	93	32				3	19	10	3	3			
4/14/2009 13:00	611	68.7	45	224	173	99	47				3	5	4	5	2			
4/14/2009 13:15	598	68.4	52	193	152	117	39				4	18	12	4	0			
4/14/2009 13:30	669	68.8	68	213	182	111	52				4	16	15	4	0			
4/14/2009 13:45	650	67.6	48	221	189	102	46				2	19	9	8	2			
4/14/2009 14:00	671	67.2	48	223	204	109	50				6	13	7	5	1			
4/14/2009 14:15	633	68.5	69	204	170	104	44				1	16	18	3	1			
4/14/2009 14:30	739	67.9	61	251	212	132	54				4	10	6	5	3			
4/14/2009 14:45	763	68.2	76	246	212	140	48				3	11	15	4	6			
4/14/2009 15:00	797	68.8	80	259	220	143	55				3	10	18	3	4			
4/14/2009 15:15	697	68.7	64	228	213	130	34				4	6	10	3	3			
4/14/2009 15:30	712	68.8	73	239	219	118	31				5	10	14	2	0			
4/14/2009 15:45	717	68.8	66	240	208	143	32				4	8	10	4	0			
4/14/2009 16:00	731	68.3	65	260	212	129	36				2	13	11	1	2			
4/14/2009 16:15	683	68.6	61	243	205	116	29				1	11	10	4	1			
4/14/2009 16:30	725	68.5	70	252	199	144	32				3	5	11	7	1			
4/14/2009 16:45	762	68.9	87	268	210	140	38				1	7	7	1	0			
4/14/2009 17:00	715	68.6	66	240	213	128	46				7	4	8	0	2			
4/14/2009 17:15	805	68.5	77	286	228	154	31				0	7	15	3	3			
4/14/2009 17:30	922	68.0	82	301	258	208	56				1	5	8	1	0			
4/14/2009 17:45	780	67.6	78	248	234	156	45				1	10	6	0	1			
4/14/2009 18:00	770	68.4	81	265	209	158	42				2	5	5	0	3			
4/14/2009 18:15	673	68.5	63	226	180	129	59				0	5	7	1	2			
4/14/2009 18:30	619	67.9	69	208	187	110	30				0	3	8	2	2			
4/14/2009 18:45	550	67.8	54	199	160	97	23				2	2	8	0	2			
4/14/2009 19:00	482	67.8	61	185	127	78	17				0	6	5	1	1			
4/14/2009 19:15	385	66.4	43	155	111	49	22				0	1	1	1	2			
4/14/2009 19:30	352	65.9	24	145	107	42	25				0	2	3	0	3			
4/14/2009 19:45	324	66.1	26	131	100	49	15				0	1	0	1	1			
4/14/2009 20:00	293	66.3	25	126	86	32	20				0	1	2	0	1			
4/14/2009 20:15	220	65.5	28	102	62	16	8				0	3	0	0	0			
4/14/2009 20:30	275	65.5	36	102	80	32	19				1	3	2	0	0			
4/14/2009 20:45	258	65.8	18	109	77	35	16				0	0	0	1	1			
4/14/2009 21:00	278	65.6	36	106	94	32	8				0	1	1	0	0			
4/14/2009 21:15	242	65.3	25	100	71	30	11				0	1	3	0	1			
4/14/2009 21:30	254	65.8	42	88	65	41	10				1	1	4	1	0			
4/14/2009 21:45	214	66.4	22	85	69	18	14				1	2	2	0	0			
4/14/2009 22:00	208	65.6	23	73	73	23	11				0	2	1	2	0			
4/14/2009 22:15	195	65.2	35	68	57	21	12				0	1	0	0	1			
4/14/2009 22:30	155	65.4	13	70	46	17	8				0	0	1	0	0			
4/14/2009 22:45	145	64.3	15	67	47	11	3				0	0	0	0	1			
4/14/2009 23:00	129	65.0	12	56	37	16	4				1	2	1	0	0			
4/14/2009 23:15	107	65.1	15	40	35	14	2				0	1	0	0	0			
4/14/2009 23:30	76	65.2	7	30	25	6	6				0	1	0	1	0			
4/14/2009 23:45	59	65.4	8	24	14	6	4				0	0	2	0	0			
Day Totals	**46080**	**68.3**	**3971**	**14924**	**13581**	**8961**	**2901**	**0**	**0**	**0**	**144**	**589**	**548**	**176**	**106**	**0**	**0**	**0**

AM Peak Hr	**7:15**
AM Peak Vol	**4292**
AM PHF	**0.9719**
PM Peak Hr	**17:15**
PM Peak Vol	**3277**
PM PHF	**0.8886**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: **Kittelson** | Site Ref: **3**
File Number: **901150** | Direction: **SB**
Route: **SR 51** | Latitude: **33.64358**
Location: **N of BELL RD AFTE** | Longitude: **-112.00218**

Count Date	Total Volume	Avg Speed	Large Vehicles 56-75' by Lane								Combination Vehicles76'+ by Lane							
			SB 1	SB 2	SB 3	SB 4	HOV				SB 1	SB 2	SB 3	SB 4	HOV			
4/14/2009	51	65.7	0	0	1	0	0				0	1	0	0	0			
4/14/2009 0:15	59	67.6	0	1	1	0	0				0	0	0	0	0			
4/14/2009 0:30	48	66.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 0:45	39	64.7	0	0	0	0	0				0	0	0	0	0			
4/14/2009 1:00	28	64.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 1:15	15	65.1	0	0	0	0	0				0	0	0	0	0			
4/14/2009 1:30	24	64.7	0	0	0	0	0				0	0	0	0	0			
4/14/2009 1:45	33	64.7	0	0	0	0	0				0	0	0	0	0			
4/14/2009 2:00	27	65.3	0	0	0	0	0				0	0	0	0	0			
4/14/2009 2:15	22	67.9	0	0	0	0	0				0	0	0	0	0			
4/14/2009 2:30	17	64.9	0	1	0	0	0				0	0	0	0	0			
4/14/2009 2:45	25	65.9	0	0	0	0	0				0	0	0	0	0			
4/14/2009 3:00	28	66.8	0	0	0	0	0				0	0	0	0	0			
4/14/2009 3:15	27	65.3	0	1	0	0	0				0	0	0	0	0			
4/14/2009 3:30	39	66.8	0	0	1	0	0				0	0	0	0	0			
4/14/2009 3:45	55	67.1	0	0	0	0	0				0	0	0	0	0			
4/14/2009 4:00	59	66.8	0	0	0	0	0				0	0	0	0	0			
4/14/2009 4:15	63	67.2	0	0	0	1	0				0	0	0	0	0			
4/14/2009 4:30	122	66.9	0	0	0	0	0				0	0	0	0	0			
4/14/2009 4:45	149	68.5	0	0	1	0	0				0	0	0	0	0			
4/14/2009 5:00	204	68.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 5:15	260	68.2	0	0	0	0	0				0	0	0	0	0			
4/14/2009 5:30	423	68.3	0	2	1	0	0				0	0	0	0	0			
4/14/2009 5:45	588	69.4	0	1	2	0	0				0	0	0	0	0			
4/14/2009 6:00	575	69.8	0	1	0	0	0				0	0	0	0	0			
4/14/2009 6:15	701	68.8	0	1	0	0	0				0	0	0	0	0			
4/14/2009 6:30	890	69.5	1	1	0	0	0				0	0	0	0	0			
4/14/2009 6:45	948	69.1	0	3	2	0	0				0	0	0	0	0			
4/14/2009 7:00	927	70.1	0	1	0	0	0				0	0	0	1	0			
4/14/2009 7:15	1073	69.8	0	1	1	0	0				0	0	0	0	0			
4/14/2009 7:30	1074	69.5	0	2	1	0	0				0	0	0	0	0			
4/14/2009 7:45	1104	69.1	0	1	0	0	0				0	0	1	0	0			
4/14/2009 8:00	1041	69.4	1	0	1	0	0				0	1	0	0	0			
4/14/2009 8:15	969	69.4	2	2	4	1	0				0	0	0	0	0			
4/14/2009 8:30	1017	68.6	0	3	1	1	0				0	1	0	0	0			
4/14/2009 8:45	965	68.6	0	3	1	2	0				0	0	0	0	0			
4/14/2009 9:00	948	68.7	0	1	5	1	0				0	0	0	0	0			
4/14/2009 9:15	849	68.3	0	0	1	0	0				0	0	0	0	0			
4/14/2009 9:30	823	67.9	1	4	2	0	0				0	0	0	0	0			
4/14/2009 9:45	688	67.9	1	2	0	0	0				0	0	0	0	0			
4/14/2009 10:00	720	68.6	0	2	1	0	0				0	1	0	0	0			
4/14/2009 10:15	653	68.7	0	3	0	1	0				0	1	0	0	0			
4/14/2009 10:30	633	67.8	0	1	2	0	0				0	0	0	0	0			
4/14/2009 10:45	645	68.4	0	4	1	0	0				0	1	1	0	0			
4/14/2009 11:00	590	67.8	0	2	1	0	0				0	0	0	0	0			
4/14/2009 11:15	609	68.3	0	1	1	1	0				0	0	0	0	0			
4/14/2009 11:30	647	68.4	0	1	3	0	0				0	0	1	0	0			
4/14/2009 11:45	587	69.4	1	1	2	0	0				0	0	0	0	0			
4/14/2009 12:00	634	68.7	0	0	1	1	0				0	1	0	0	0			
4/14/2009 12:15	544	68.3	0	0	2	0	0				0	0	0	0	0			
4/14/2009 12:30	574	68.8	0	0	0	0	0				0	0	1	0	0			
4/14/2009 12:45	604	68.4	0	2	0	0	0				0	1	1	0	0			
4/14/2009 13:00	611	68.7	0	0	2	2	0				0	0	0	0	0			
4/14/2009 13:15	598	68.4	0	4	1	0	0				0	2	0	0	0			
4/14/2009 13:30	669	68.8	0	1	2	1	0				0	0	0	0	0			
4/14/2009 13:45	650	67.6	1	0	0	0	0				1	1	0	1	0			
4/14/2009 14:00	671	67.2	1	2	1	0	0				0	0	1	0	0			
4/14/2009 14:15	633	68.5	0	1	2	0	0				0	0	0	0	0			
4/14/2009 14:30	739	67.9	0	0	0	0	0				0	0	1	0	0			
4/14/2009 14:45	763	68.2	0	1	0	0	0				0	0	1	0	0			
4/14/2009 15:00	797	68.8	0	1	0	0	0				0	0	1	0	0			
4/14/2009 15:15	697	68.7	1	1	0	0	0				0	0	0	0	0			
4/14/2009 15:30	712	68.8	0	0	0	1	0				0	0	0	0	0			
4/14/2009 15:45	717	68.8	0	0	1	1	0				0	0	0	0	0			
4/14/2009 16:00	731	68.3	0	0	0	0	0				0	0	0	0	0			
4/14/2009 16:15	683	68.6	0	0	1	1	0				0	0	0	0	0			
4/14/2009 16:30	725	68.5	0	0	1	0	0				0	0	0	0	0			
4/14/2009 16:45	762	68.9	0	1	1	0	0				0	0	0	1	0			
4/14/2009 17:00	715	68.6	0	1	0	0	0				0	0	0	0	0			
4/14/2009 17:15	805	68.5	0	1	0	0	0				0	0	0	0	0			
4/14/2009 17:30	922	68.0	0	1	0	1	0				0	0	0	0	0			
4/14/2009 17:45	780	67.6	0	0	0	0	0				0	1	0	0	0			
4/14/2009 18:00	770	68.4	0	0	0	0	0				0	0	0	0	0			
4/14/2009 18:15	673	68.5	0	0	1	0	0				0	0	0	0	0			
4/14/2009 18:30	619	67.9	0	0	0	0	0				0	0	0	0	0			
4/14/2009 18:45	550	67.8	0	1	2	0	0				0	0	0	0	0			
4/14/2009 19:00	482	67.8	0	1	0	0	0				0	0	0	0	0			
4/14/2009 19:15	385	66.4	0	0	0	0	0				0	0	0	0	0			
4/14/2009 19:30	352	65.9	0	0	0	1	0				0	0	0	0	0			
4/14/2009 19:45	324	66.1	0	0	0	0	0				0	0	0	0	0			
4/14/2009 20:00	293	66.3	0	0	0	0	0				0	0	0	0	0			
4/14/2009 20:15	220	65.5	0	0	1	0	0				0	0	0	0	0			
4/14/2009 20:30	275	65.5	0	0	0	0	0				0	0	0	0	0			
4/14/2009 20:45	258	65.8	0	1	0	0	0				0	0	0	0	0			
4/14/2009 21:00	278	65.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 21:15	242	65.3	0	0	0	0	0				0	0	0	0	0			
4/14/2009 21:30	254	65.8	0	0	0	0	0				0	1	0	0	0			
4/14/2009 21:45	214	66.4	0	1	0	0	0				0	0	0	0	0			
4/14/2009 22:00	208	65.6	0	0	0	0	0				0	0	0	0	0			
4/14/2009 22:15	195	65.2	0	0	0	0	0				0	0	0	0	0			
4/14/2009 22:30	155	65.4	0	0	0	0	0				0	0	0	0	0			
4/14/2009 22:45	145	64.3	0	0	1	0	0				0	0	0	0	0			
4/14/2009 23:00	129	65.0	0	0	0	0	0				0	0	0	0	0			
4/14/2009 23:15	107	65.1	0	0	0	0	0				0	0	0	0	0			
4/14/2009 23:30	76	65.2	0	0	0	0	0				0	0	0	0	0			
4/14/2009 23:45	59	65.4	0	1	0	0	0				0	0	0	0	0			
Day Totals	**46080**	**68.3**	**10**	**69**	**57**	**17**	**0**	**0**	**0**	**0**	**1**	**13**	**9**	**3**	**0**	**0**	**0**	**0**

AM Peak Hr	**7:15**
AM Peak Vol	**4292**
AM PHF	**0.9719**
PM Peak Hr	**17:15**
PM Peak Vol	**3277**
PM PHF	**0.8886**

Traffic Research & Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: KITTELSON
File Number: 0901151
Route: SR 51 ON-RAMP
Location: S of UNION HILLS DR

Site Ref: 4
Direction: SB
Latitude: 33.6520
Longitude: -112.0006

Count Date	4/14/2009																Average	
Count Time	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**
12:00	8	98															8	98
12:15	7	83															7	83
12:30	5	106															5	106
12:45	4	85															4	85
01:00	8	125															8	125
01:15	6	136															6	136
01:30	7	126															7	126
01:45	6	126															6	126
02:00	5	108															5	108
02:15	8	154															8	154
02:30	6	155															6	155
02:45	7	163															7	163
03:00	6	145															6	145
03:15	12	131															12	131
03:30	19	131															19	131
03:45	12	120															12	120
04:00	16	133															16	133
04:15	11	129															11	129
04:30	34	145															34	145
04:45	42	137															42	137
05:00	53	159															53	159
05:15	84	125															84	125
05:30	124	141															124	141
05:45	125	144															125	144
06:00	161	118															161	118
06:15	216	123															216	123
06:30	253	98															253	98
06:45	278	109															278	109
07:00	333	77															333	77
07:15	318	76															318	76
07:30	306	73															306	73
07:45	270	63															270	63
08:00	236	60															236	60
08:15	239	63															239	63
08:30	253	56															253	56
08:45	203	75															203	75
09:00	181	65															181	65
09:15	129	60															129	60
09:30	114	56															114	56
09:45	128	40															128	40
10:00	113	49															113	49
10:15	125	40															125	40
10:30	115	20															115	20
10:45	119	9															119	9
11:00	105	22															105	22
11:15	120	14															120	14
11:30	103	8															103	8
11:45	134	11															134	11
Totals	**5167**	**4490**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5167**	**4490**
Day Total	**9657**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**9657**	
AM Pct	53.5%																53.5%	
Peak Hour	6:45	14:15															6:45	14:15
Peak Volume	1235	617															1235	617
P.H.F	0.7978	0.8429															0.7978	0.8429

Traffic Research & Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: KITTELSON
File Number: 0901152
Route: SR 51 OFF-RAMP
Location: To BELL RD

Site Ref: 5
Direction: SB
Latitude: 33.64358
Longitude: -112.00218

Date/Time	Total	cls01	cls02	cls03	cls04	cls05	cls06	cls07	cls08	cls09	cls10	cls11	cls12	cls13	pct SU	pct CB
4/14/2009 0:00	12	0	12	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 0:15	9	0	6	3	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 0:30	4	0	2	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 0:45	4	0	2	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 1:00	5	0	4	1	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 1:15	6	0	4	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 1:30	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 1:45	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 2:00	4	0	3	1	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 2:15	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 2:30	4	0	3	1	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 2:45	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 3:00	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 3:15	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 3:30	4	0	2	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 3:45	5	0	4	1	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 4:00	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 4:15	6	0	3	3	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 4:30	15	0	15	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 4:45	14	0	11	2	0	0	1	0	0	0	0	0	0	0	7.1%	0.0%
4/14/2009 5:00	13	0	10	3	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 5:15	19	0	14	5	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 5:30	30	0	20	9	0	1	0	0	0	0	0	0	0	0	3.3%	0.0%
4/14/2009 5:45	51	0	35	16	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 6:00	34	0	22	12	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 6:15	64	0	51	13	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 6:30	45	0	33	12	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 6:45	71	0	57	14	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 7:00	80	0	63	16	1	0	0	0	0	0	0	0	0	0	1.3%	0.0%
4/14/2009 7:15	90	1	72	17	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 7:30	65	0	52	11	0	0	1	0	1	0	0	0	0	0	1.5%	1.5%
4/14/2009 7:45	86	1	62	22	0	0	1	0	0	0	0	0	0	0	1.2%	0.0%
4/14/2009 8:00	68	0	57	10	0	0	0	0	0	1	0	0	0	0	0.0%	1.5%
4/14/2009 8:15	90	0	67	22	0	0	0	0	0	1	0	0	0	0	0.0%	1.1%
4/14/2009 8:30	103	1	78	22	0	1	1	0	0	0	0	0	0	0	1.9%	0.0%
4/14/2009 8:45	87	0	70	16	0	0	0	0	0	1	0	0	0	0	0.0%	1.1%
4/14/2009 9:00	98	0	64	31	1	0	0	0	0	0	1	0	0	1	1.0%	2.0%
4/14/2009 9:15	87	0	56	30	0	0	1	0	0	0	0	0	0	0	1.1%	0.0%
4/14/2009 9:30	92	0	62	28	1	0	1	0	0	0	0	0	0	0	2.2%	0.0%
4/14/2009 9:45	84	1	63	20	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 10:00	77	0	54	23	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 10:15	95	0	63	32	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 10:30	76	0	47	29	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 10:45	87	0	60	25	2	0	0	0	0	0	0	0	0	0	2.3%	0.0%
4/14/2009 11:00	77	0	56	19	1	0	0	0	1	0	0	0	0	0	1.3%	1.3%
4/14/2009 11:15	80	0	62	17	1	0	0	0	0	0	0	0	0	0	1.3%	0.0%
4/14/2009 11:30	73	1	50	22	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 11:45	93	1	58	33	0	0	0	0	0	0	0	1	0	0	0.0%	1.1%

Traffic Research & Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client:	KITTELSON	Site Ref:	5
File Number:	0901152	Direction:	SB
Route:	SR 51 OFF-RAMP	Latitude:	33.64358
Location:	To BELL RD	Longitude:	-112.00218

Date/Time	Total	cls01	cls02	cls03	cls04	cls05	cls06	cls07	cls08	cls09	cls10	cls11	cls12	cls13	pct SU	pct CB
4/14/2009 12:00	91	1	61	27	1	1	0	0	0	0	0	0	0	0	2.2%	0.0%
4/14/2009 12:15	93	0	67	26	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 12:30	86	0	57	29	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 12:45	100	1	62	35	0	1	0	0	1	0	0	0	0	0	1.0%	1.0%
4/14/2009 13:00	101	0	67	32	0	1	0	0	0	1	0	0	0	0	1.0%	1.0%
4/14/2009 13:15	109	0	71	35	0	2	1	0	0	0	0	0	0	0	2.8%	0.0%
4/14/2009 13:30	101	0	72	26	2	1	0	0	0	0	0	0	0	0	3.0%	0.0%
4/14/2009 13:45	107	2	75	26	1	2	0	0	1	0	0	0	0	0	2.8%	0.9%
4/14/2009 14:00	112	2	75	32	1	2	0	0	0	0	0	0	0	0	2.7%	0.0%
4/14/2009 14:15	126	0	84	38	2	1	0	0	0	0	0	1	0	0	2.4%	0.8%
4/14/2009 14:30	98	0	67	30	0	1	0	0	0	0	0	0	0	0	1.0%	0.0%
4/14/2009 14:45	121	1	88	30	1	0	0	0	1	0	0	0	0	0	0.8%	0.8%
4/14/2009 15:00	106	0	78	27	0	0	0	1	0	0	0	0	0	0	0.9%	0.0%
4/14/2009 15:15	117	1	86	28	0	1	0	1	0	0	0	0	0	0	1.7%	0.0%
4/14/2009 15:30	115	0	83	32	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 15:45	131	0	92	37	0	2	0	0	0	0	0	0	0	0	1.5%	0.0%
4/14/2009 16:00	99	0	78	21	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 16:15	125	1	88	35	0	1	0	0	0	0	0	0	0	0	0.8%	0.0%
4/14/2009 16:30	91	2	68	20	0	1	0	0	0	0	0	0	0	0	1.1%	0.0%
4/14/2009 16:45	125	2	88	34	0	0	1	0	0	0	0	0	0	0	0.8%	0.0%
4/14/2009 17:00	112	2	79	31	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 17:15	140	0	112	27	0	0	0	0	1	0	0	0	0	0	0.0%	0.7%
4/14/2009 17:30	112	0	83	29	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 17:45	87	0	71	15	1	0	0	0	0	0	0	0	0	0	1.1%	0.0%
4/14/2009 18:00	114	0	85	26	0	1	1	0	1	0	0	0	0	0	1.8%	0.9%
4/14/2009 18:15	85	0	72	13	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 18:30	86	0	65	20	0	1	0	0	0	0	0	0	0	0	1.2%	0.0%
4/14/2009 18:45	73	0	56	17	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 19:00	69	0	54	14	0	1	0	0	0	0	0	0	0	0	1.4%	0.0%
4/14/2009 19:15	63	0	47	15	0	0	0	0	0	0	1	0	0	0	0.0%	1.6%
4/14/2009 19:30	60	0	46	14	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 19:45	48	0	34	14	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 20:00	54	0	40	14	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 20:15	50	0	41	9	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 20:30	44	0	36	8	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 20:45	41	0	33	8	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 21:00	25	0	21	4	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 21:15	37	0	25	11	0	1	0	0	0	0	0	0	0	0	2.7%	0.0%
4/14/2009 21:30	46	2	38	6	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 21:45	42	0	39	3	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 22:00	27	1	20	6	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 22:15	34	0	27	6	0	0	0	0	0	1	0	0	0	0	0.0%	2.9%
4/14/2009 22:30	25	0	23	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 22:45	26	0	20	6	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 23:00	15	0	11	4	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 23:15	18	0	16	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 23:30	13	0	10	3	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/14/2009 23:45	11	0	9	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
Day Totals	**5835**	**26**	**4261**	**1481**	**16**	**23**	**9**	**2**	**7**	**5**	**2**	**2**	**0**	**1**	**0.9%**	**0.3%**

AM Peak Hr	**8:15 AM**
AM Peak Vol	**378**
AM PHF	**0.788**
PM Peak Hr	**4:45 PM**
PM Peak Vol	**489**
PM PHF	**0.715**

Traffic Research & Analysis, Inc.
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Client:	KITTELSON		Site Ref:	5
File Number:	0901152		Direction:	SB
Route:	SR 51 OFF-RAMP		Latitude:	33.64358
Location:	To BELL RD		Longitude:	-112.00218

Date/Time	Total	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80+
4/14/2009 0:00	12	0	0	0	0	0	0	0	0	0	1	4	3	2	2	0	0	0
4/14/2009 0:15	9	0	0	0	0	0	0	0	0	0	1	1	6	0	1	0	0	0
4/14/2009 0:30	4	0	0	0	0	0	0	0	0	0	0	1	0	2	1	0	0	0
4/14/2009 0:45	4	0	0	0	0	0	0	0	0	0	0	0	1	2	0	1	0	0
4/14/2009 1:00	5	0	0	0	0	0	0	0	0	0	1	0	1	2	1	0	0	0
4/14/2009 1:15	6	0	0	0	0	0	0	0	0	0	0	1	3	2	0	0	0	0
4/14/2009 1:30	2	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
4/14/2009 1:45	5	0	0	0	0	1	0	0	0	1	1	1	1	0	0	0	0	0
4/14/2009 2:00	4	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0
4/14/2009 2:15	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
4/14/2009 2:30	4	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
4/14/2009 2:45	3	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0
4/14/2009 3:00	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
4/14/2009 3:15	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
4/14/2009 3:30	4	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0
4/14/2009 3:45	5	0	0	0	0	0	0	0	0	0	0	1	2	0	1	1	0	0
4/14/2009 4:00	3	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0
4/14/2009 4:15	6	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0
4/14/2009 4:30	15	0	0	0	0	0	0	0	0	0	1	2	4	4	1	2	0	1
4/14/2009 4:45	14	0	0	0	0	0	0	0	0	0	0	0	5	5	4	0	0	0
4/14/2009 5:00	13	0	0	0	0	0	0	0	0	0	0	0	4	2	6	1	0	0
4/14/2009 5:15	19	0	0	0	0	0	0	0	0	0	0	3	4	6	3	1	2	0
4/14/2009 5:30	30	0	0	0	0	0	0	0	0	0	0	4	9	12	4	1	0	0
4/14/2009 5:45	51	0	0	0	0	0	0	0	0	0	0	4	10	18	15	3	1	0
4/14/2009 6:00	34	0	0	0	0	0	0	0	0	0	1	2	9	17	3	2	0	0
4/14/2009 6:15	64	0	0	0	0	0	0	0	0	0	0	4	31	19	7	1	0	2
4/14/2009 6:30	45	0	0	0	0	0	0	0	0	1	0	2	14	18	9	1	0	0
4/14/2009 6:45	71	0	0	0	0	0	0	0	0	0	0	4	18	24	23	1	1	0
4/14/2009 7:00	80	0	0	0	0	0	0	0	0	0	0	4	31	31	12	2	0	0
4/14/2009 7:15	90	0	0	0	0	0	0	0	0	0	2	3	19	48	15	2	0	1
4/14/2009 7:30	65	0	0	0	0	0	0	0	0	0	0	4	18	28	12	2	1	0
4/14/2009 7:45	86	0	0	0	0	0	0	0	0	0	0	6	27	34	11	6	2	0
4/14/2009 8:00	68	0	0	0	0	0	0	0	0	0	1	6	28	21	10	2	0	0
4/14/2009 8:15	90	0	0	0	0	0	0	0	0	0	0	11	24	38	10	4	2	1
4/14/2009 8:30	103	0	0	0	0	0	0	0	0	0	3	15	37	28	13	5	2	0
4/14/2009 8:45	87	0	0	0	0	0	0	0	0	0	0	8	32	30	11	5	1	0
4/14/2009 9:00	98	0	0	0	0	0	0	0	0	0	2	22	37	26	9	1	1	0
4/14/2009 9:15	87	0	0	0	0	0	0	0	0	0	0	16	35	28	5	0	3	0
4/14/2009 9:30	92	0	0	0	0	0	0	0	0	0	0	16	25	41	8	1	1	0
4/14/2009 9:45	84	0	0	0	0	0	0	0	0	0	1	12	23	39	8	0	0	1
4/14/2009 10:00	77	0	0	0	0	0	0	0	0	0	4	7	25	29	9	2	1	0
4/14/2009 10:15	95	0	0	0	0	0	0	0	0	0	2	10	31	43	8	1	0	0
4/14/2009 10:30	76	0	0	0	0	0	0	0	0	0	2	11	30	21	8	3	1	0
4/14/2009 10:45	87	0	0	0	0	0	0	0	0	3	4	5	29	36	8	2	0	0
4/14/2009 11:00	77	0	0	0	0	0	0	0	0	0	0	11	26	27	10	1	2	0
4/14/2009 11:15	80	0	0	0	0	0	0	0	0	0	3	7	26	33	10	1	0	0
4/14/2009 11:30	73	0	0	0	0	0	0	0	0	0	0	13	21	23	14	1	1	0
4/14/2009 11:45	93	0	0	0	0	0	0	0	0	0	1	6	33	42	9	1	0	1
4/14/2009 12:00	91	0	0	0	0	0	0	0	0	0	0	14	36	27	13	1	0	0
4/14/2009 12:15	93	0	0	0	0	0	0	0	0	0	4	15	33	30	8	2	1	0
4/14/2009 12:30	86	0	0	0	0	0	0	0	0	0	6	11	34	15	16	4	0	0
4/14/2009 12:45	100	0	0	0	0	0	0	0	0	0	5	22	35	29	6	3	0	0
4/14/2009 13:00	101	0	0	0	0	0	0	0	0	1	2	9	28	36	20	4	0	1
4/14/2009 13:15	109	0	0	0	0	0	0	0	0	0	1	13	42	40	13	0	0	0
4/14/2009 13:30	101	0	0	0	0	0	0	0	0	0	2	16	40	33	8	2	0	0
4/14/2009 13:45	107	0	0	0	0	0	0	0	0	0	5	14	36	33	15	2	2	0
4/14/2009 14:00	112	0	0	0	0	0	0	0	0	0	3	17	33	31	19	9	0	0
4/14/2009 14:15	126	0	0	0	0	0	0	0	0	2	2	22	47	39	13	1	0	0
4/14/2009 14:30	98	0	0	0	0	0	0	0	0	0	0	4	31	36	24	3	0	0
4/14/2009 14:45	121	0	0	0	0	0	0	0	0	0	2	21	28	46	22	2	0	0
4/14/2009 15:00	106	0	0	0	0	0	0	0	0	0	2	6	34	39	19	2	2	2
4/14/2009 15:15	117	0	0	0	0	0	0	0	0	0	5	17	47	34	11	2	1	0
4/14/2009 15:30	115	0	0	0	0	0	0	0	0	0	0	8	41	56	7	1	2	0
4/14/2009 15:45	131	0	0	0	0	0	0	0	0	0	1	24	52	42	11	1	0	0
4/14/2009 16:00	99	0	0	0	0	0	0	0	0	0	3	14	25	36	18	2	1	0
4/14/2009 16:15	125	0	0	0	0	0	0	0	0	0	2	18	54	36	13	2	0	0
4/14/2009 16:30	91	0	0	0	0	0	0	0	0	0	1	7	22	39	19	3	0	0
4/14/2009 16:45	125	0	0	0	0	0	0	0	0	0	0	9	54	46	15	0	1	0
4/14/2009 17:00	112	0	0	0	0	0	0	0	0	0	5	18	47	26	13	3	0	0
4/14/2009 17:15	140	0	0	0	0	0	0	0	0	0	8	30	49	39	9	3	2	0
4/14/2009 17:30	112	0	0	0	0	0	0	0	0	0	5	28	37	30	8	2	2	0
4/14/2009 17:45	87	0	0	0	0	0	0	0	0	0	2	18	35	25	6	1	0	0
4/14/2009 18:00	114	0	0	0	0	0	0	0	0	0	1	11	46	35	13	5	3	0
4/14/2009 18:15	85	0	0	0	0	0	0	0	0	0	0	13	35	25	8	3	1	0
4/14/2009 18:30	86	0	0	0	0	0	0	0	0	0	3	27	24	26	5	1	0	0
4/14/2009 18:45	73	0	0	0	0	0	0	0	0	0	3	18	28	13	8	3	0	0
4/14/2009 19:00	69	0	0	0	0	0	0	0	0	1	2	16	20	20	7	3	0	0
4/14/2009 19:15	63	0	0	0	0	0	0	0	0	0	2	29	21	8	3	0	0	0
4/14/2009 19:30	60	0	0	0	0	0	0	0	0	0	5	10	21	20	3	0	1	0
4/14/2009 19:45	48	0	0	0	0	0	0	0	0	0	1	8	19	14	6	0	0	0
4/14/2009 20:00	54	0	0	0	0	0	0	0	0	0	3	11	16	15	9	0	0	0
4/14/2009 20:15	50	0	0	0	0	0	0	0	0	1	2	11	21	7	6	2	0	0
4/14/2009 20:30	44	0	0	0	0	0	0	0	0	0	4	12	14	8	4	1	1	0

Traffic Research & Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client:	KITTELSON	Site Ref:	5
File Number:	0901152	Direction:	SB
Route:	SR 51 OFF-RAMP	Latitude:	33.64358
Location:	To BELL RD	Longitude:	-112.00218

Date/Time	Total	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80+
4/14/2009 20:45	41	0	0	0	0	0	0	1	0	1	1	15	12	9	2	0	0	0
4/14/2009 21:00	25	0	0	0	0	0	0	0	0	0	3	7	4	7	3	1	0	0
4/14/2009 21:15	37	0	0	0	0	0	0	0	0	0	3	7	13	10	4	0	0	0
4/14/2009 21:30	46	0	0	0	0	0	0	0	0	2	4	12	14	6	7	1	0	0
4/14/2009 21:45	42	0	0	0	0	0	0	0	0	0	3	11	11	9	6	0	2	0
4/14/2009 22:00	27	0	0	0	0	0	0	0	0	0	2	9	7	5	3	1	0	0
4/14/2009 22:15	34	0	0	0	0	0	0	0	0	0	4	13	12	5	0	0	0	0
4/14/2009 22:30	25	0	0	0	0	0	0	0	0	0	0	6	6	10	2	1	0	0
4/14/2009 22:45	26	0	0	0	0	0	0	0	0	0	1	4	13	3	3	2	0	0
4/14/2009 23:00	15	0	0	0	0	0	0	0	0	0	1	1	9	3	1	0	0	0
4/14/2009 23:15	18	0	0	0	0	0	0	0	0	0	2	5	6	4	1	0	0	0
4/14/2009 23:30	13	0	0	0	0	0	0	0	0	0	1	7	1	2	1	1	0	0
4/14/2009 23:45	11	0	0	0	0	0	0	0	0	0	0	0	4	3	3	0	0	1
Day Totals	**5835**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**14**	**149**	**869**	**1986**	**1901**	**720**	**138**	**45**	**11**

AM Peak Hr	**8:15 AM**	Average Speed	**59.9**	Pct > 25 mph	**100%**
AM Peak Vol	**378**	Median Speed	**59.6**	Pct > 30 mph	**100%**
AM PHF	**0.788**	85th Pct Speed	**65.3**	Pct > 35 mph	**100%**
PM Peak Hr	**4:45 PM**	95th Pct Speed	**69.4**	Pct > 40 mph	**100%**
PM Peak Vol	**489**	Pace Speed	**55**	Pct > 45 mph	**100%**
PM PHF	**0.715**	Percent in Pace	**65.9%**	Pct > 50 mph	**97%**
		Speed Limit	**65**		
		Percent Speedin	**15.7%**		

Traffic Research & Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client:	KITTELSON	Site Ref:	4
File Number:	0901151	Direction:	SB
Route:	SR 51 ON-RAMP	Latitude:	33.65202
Location:	S of UNION HILLS DR	Longitude:	-112.00064

Date/Time	Total	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80+
4/13/2009 0:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 0:15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 0:30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 0:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 1:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 1:15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 1:30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 1:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 2:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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4/13/2009 2:30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 2:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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4/13/2009 7:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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4/13/2009 8:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 9:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 9:15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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4/13/2009 9:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 10:00	126	0	0	0	0	0	0	0	0	3	9	25	57	24	7	1	0	0
4/13/2009 10:15	132	0	0	0	0	0	0	0	0	0	4	19	64	34	10	1	0	0
4/13/2009 10:30	100	0	0	0	0	0	0	1	0	1	12	19	36	26	3	1	1	0
4/13/2009 10:45	84	0	0	0	0	0	0	0	0	1	6	27	31	16	3	0	0	0
4/13/2009 11:00	103	0	0	0	0	0	0	0	1	4	15	38	32	13	0	0	0	0
4/13/2009 11:15	116	0	0	0	0	0	0	0	2	2	14	39	40	18	0	0	0	1
4/13/2009 11:30	112	0	0	0	0	0	0	0	0	0	8	30	43	25	6	0	0	0
4/13/2009 11:45	110	0	0	0	0	0	0	0	0	0	14	15	40	29	10	0	2	0
4/13/2009 12:00	108	0	0	0	0	0	0	0	0	0	7	28	32	26	13	1	1	0
4/13/2009 12:15	104	0	0	0	0	0	0	0	0	0	7	25	37	30	4	1	0	0
4/13/2009 12:30	111	0	0	0	0	0	0	1	4	0	15	35	32	22	2	0	0	0
4/13/2009 12:45	96	0	0	0	0	0	0	0	0	3	4	35	32	17	3	2	0	0
4/13/2009 13:00	111	0	0	0	0	0	0	0	0	1	4	20	56	24	6	0	0	0
4/13/2009 13:15	101	0	0	0	0	0	0	0	0	0	0	18	43	32	7	1	0	0
4/13/2009 13:30	122	0	0	0	0	0	0	0	0	0	8	31	51	24	7	1	0	0
4/13/2009 13:45	103	0	0	0	0	0	0	0	0	0	6	23	47	25	1	0	1	0
4/13/2009 14:00	103	0	0	0	0	0	0	0	0	0	9	19	51	14	8	2	0	0
4/13/2009 14:15	121	0	0	0	0	0	0	0	0	0	7	38	46	24	5	1	0	0
4/13/2009 14:30	153	0	0	0	0	0	0	0	0	3	9	37	66	28	7	1	1	1
4/13/2009 14:45	145	0	0	0	0	0	0	0	0	0	8	30	70	29	6	1	1	0
4/13/2009 15:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 15:15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 15:30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 15:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 16:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 16:15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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4/13/2009 16:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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4/13/2009 17:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 18:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 18:15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 18:30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 18:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 19:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 19:15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 19:30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 19:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 20:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 20:15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 20:30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Traffic Research & Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client:	KITTELSON	Site Ref:	4
File Number:	0901151	Direction:	SB
Route:	SR 51 ON-RAMP	Latitude:	33.65202
Location:	S of UNION HILLS DR	Longitude:	-112.00064

Date/Time	Total	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80+
4/13/2009 20:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 21:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 21:15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 21:30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 21:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 22:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 22:15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 22:30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 22:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 23:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 23:15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 23:30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4/13/2009 23:45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Day Totals	**2261**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**7**	**18**	**166**	**551**	**906**	**480**	**108**	**14**	**7**	**2**

AM Peak Hr	**11:10 AM**	Average Speed	**57.1**	Pct > 25 mph	**100%**
AM Peak Vol	**455**	Median Speed	**57.0**	Pct > 30 mph	**100%**
AM PHF	**0.807**	85th Pct Speed	**62.9**	Pct > 35 mph	**100%**
PM Peak Hr	**2:00 PM**	95th Pct Speed	**65.8**	Pct > 40 mph	**100%**
PM Peak Vol	**522**	Pace Speed	**51**	Pct > 45 mph	**99%**
PM PHF	**0.763**	Percent in Pace	**63.6%**	Pct > 50 mph	**91%**
		Speed Limit	**65**		
		Percent Speedin	**5.8%**		

Entry-Entry Site Data

Traffic Research and Analysis, Inc.

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: **Kittelson**
File Number: **901153**
Route: **SR LP 202 RED MTN**
Location: **W of PRIEST DR ON-RMP MERGE**

Site Ref: **6**
Direction: **EB**
Latitude: **33.43651**
Longitude: **-111.95672**

							Volume by Lane								Average Speed by Lane				
Count Date	**Total Volume**	**Avg Speed**	**Len 0-25**	**Len 26-55**	**Len 56-75**	**Len 76+**	**EB 1**	**EB 2**	**EB 3**	**EB 4**	**EB HOV**				**EB 1**	**EB 2**	**EB 3**	**EB 4**	**HOV**
4/16/2009	351	64.0	346	4	0	1	26	104	121	71	29				60.3	62.1	63.6	66.9	69.1
4/16/2009 0:15	305	64.4	299	2	3	1	16	93	113	64	19				57.8	62.1	64.4	67.6	70.1
4/16/2009 0:30	257	65.1	251	5	0	1	11	94	86	53	13				59.3	63.3	64.5	68.5	72.5
4/16/2009 0:45	241	63.9	233	3	4	1	20	83	81	47	10				60.3	61.1	64.2	68.0	71.8
4/16/2009 1:00	170	64.0	156	6	8	0	8	56	65	34	7				59.8	61.7	64.1	68.0	67.9
4/16/2009 1:15	153	63.1	142	3	6	2	6	55	47	40	5				56.3	60.6	63.5	66.3	70.9
4/16/2009 1:30	111	63.0	105	4	1	1	8	29	45	22	7				59.9	60.9	62.8	66.1	66.3
4/16/2009 1:45	126	64.5	115	7	2	2	1	35	53	28	9				64.2	62.3	64.7	66.1	66.4
4/16/2009 2:00	86	64.4	78	3	3	2	6	22	37	16	5				63.6	62.7	63.6	65.9	74.1
4/16/2009 2:15	100	63.5	98	1	1	0	0	31	45	19	5				63.6	61.4	62.7	66.2	73.1
4/16/2009 2:30	91	64.6	83	1	7	0	4	27	33	22	5				62.9	62.8	64.0	67.0	68.4
4/16/2009 2:45	114	65.1	101	6	7	0	4	34	43	25	8				63.3	64.3	64.2	66.6	70.2
4/16/2009 3:00	101	64.8	86	10	5	0	5	36	36	15	9				62.9	61.4	63.9	71.4	72.0
4/16/2009 3:15	95	64.3	82	7	5	1	8	32	33	20	2				62.2	62.3	64.2	68.5	62.7
4/16/2009 3:30	109	62.8	86	16	7	0	8	34	45	20	2				61.7	59.3	64.1	65.4	69.3
4/16/2009 3:45	130	63.3	113	6	11	0	13	29	51	31	6				56.4	62.5	62.9	66.9	66.8
4/16/2009 4:00	115	63.1	100	10	5	0	11	30	39	31	4				58.1	60.6	63.4	66.6	66.3
4/16/2009 4:15	174	64.6	154	11	6	3	13	41	64	38	18				62.0	61.8	63.5	67.4	70.9
4/16/2009 4:30	268	65.9	260	4	4	0	37	61	82	56	32				62.2	62.9	65.4	68.8	72.2
4/16/2009 4:45	382	66.2	355	19	7	1	59	97	106	80	40				63.1	64.0	66.3	68.6	71.5
4/16/2009 5:00	485	66.4	443	29	11	2	101	126	121	83	54				62.7	64.4	66.2	69.2	74.3
4/16/2009 5:15	517	65.1	495	14	6	2	96	129	135	103	54				62.1	62.7	64.7	68.1	71.3
4/16/2009 5:30	849	65.4	797	41	10	1	143	200	211	185	110				62.0	62.6	65.4	67.9	70.6
4/16/2009 5:45	1112	66.8	1039	56	15	2	179	247	259	250	177				62.6	64.4	66.4	68.8	72.0
4/16/2009 6:00	964	66.6	874	71	14	5	182	241	237	202	102				62.9	64.7	66.7	69.1	72.5
4/16/2009 6:15	781	67.0	711	54	14	2	159	200	198	171	53				63.9	65.6	66.9	69.8	72.2
4/16/2009 6:30	908	66.0	814	77	16	1	175	245	231	210	47				63.8	63.8	66.3	69.0	70.2
4/16/2009 6:45	1027	65.1	930	84	12	1	204	270	257	236	60				63.1	63.1	64.8	68.3	70.3
4/16/2009 7:00	908	66.3	839	60	9	0	190	250	219	203	46				63.8	64.7	66.4	69.5	70.5
4/16/2009 7:15	1084	65.3	989	75	17	3	226	295	264	239	60				62.5	63.8	65.5	68.7	69.3
4/16/2009 7:30	1118	65.9	1020	69	25	4	207	279	308	267	57				62.6	64.4	66.0	68.6	72.2
4/16/2009 7:45	1136	65.9	1067	59	9	1	207	305	289	274	61				62.9	63.8	66.2	68.9	71.8
4/16/2009 8:00	1146	65.3	1064	70	12	0	225	301	287	274	59				61.8	63.6	65.9	68.3	70.6
4/16/2009 8:15	1093	65.7	1021	58	10	4	215	283	277	253	65				62.5	64.1	65.7	68.5	71.6
4/16/2009 8:30	1132	64.7	1063	61	6	2	249	268	300	248	67				61.7	62.5	65.2	67.8	70.1
4/16/2009 8:45	1198	65.2	1137	52	6	3	261	303	298	262	74				61.9	63.7	65.2	68.6	71.2
4/16/2009 9:00	1095	65.1	1014	67	8	6	237	283	275	229	71				61.6	63.6	65.6	68.1	71.1
4/16/2009 9:15	1027	65.7	952	56	16	3	223	255	265	194	90				62.4	64.1	65.7	68.8	72.1
4/16/2009 9:30	1075	65.6	1009	45	19	2	195	265	297	212	106				62.2	63.5	65.6	68.5	71.8
4/16/2009 9:45	1213	65.2	1142	54	15	2	250	302	294	242	125				61.8	62.8	64.8	68.8	72.0
4/16/2009 10:00	1209	65.5	1135	62	9	3	270	305	297	231	106				61.4	63.6	65.6	69.2	72.9
4/16/2009 10:15	1166	65.2	1092	59	13	2	230	313	274	222	127				62.2	63.1	64.6	68.6	70.8
4/16/2009 10:30	1091	66.0	1026	49	14	2	231	272	269	210	109				61.9	63.7	66.3	69.3	73.1
4/16/2009 10:45	1105	66.1	1044	37	23	1	202	287	269	226	121				62.8	64.4	65.2	69.3	72.1
4/16/2009 11:00	1249	65.6	1186	53	10	0	241	307	306	261	134				61.3	63.5	65.2	69.3	72.0
4/16/2009 11:15	1188	65.7	1136	42	9	1	217	312	305	222	132				62.0	63.4	65.4	69.5	71.9
4/16/2009 11:30	1309	65.8	1227	69	11	2	269	341	315	237	147				61.9	63.6	65.5	69.0	73.1
4/16/2009 11:45	1351	64.8	1290	45	15	1	282	337	317	261	154				61.3	62.7	64.7	67.5	71.6
4/16/2009 12:00	1266	65.8	1212	41	13	0	239	306	305	262	154				61.8	63.7	65.0	68.8	72.8
4/16/2009 12:15	1314	65.7	1254	48	10	2	220	355	324	276	139				62.6	63.3	65.5	68.4	71.5
4/16/2009 12:30	1423	65.1	1353	48	21	1	253	353	332	297	188				61.3	62.8	64.2	68.3	71.1
4/16/2009 12:45	1420	64.9	1348	50	21	1	263	367	351	272	167				61.6	62.5	64.1	68.4	71.4
4/16/2009 13:00	1454	65.6	1367	71	14	2	275	380	357	270	172				62.3	63.2	64.8	68.6	72.8
4/16/2009 13:15	1387	62.9	1332	39	12	4	265	350	326	273	173				58.8	60.5	62.3	66.2	69.9
4/16/2009 13:30	1418	64.0	1355	55	8	0	238	347	357	295	181				60.2	61.7	63.2	66.9	70.0
4/16/2009 13:45	1446	57.5	1362	70	14	0	276	346	327	288	209				53.6	54.3	57.2	62.3	61.5
4/16/2009 14:00	927	12.7	736	148	16	27	203	177	169	173	205				12.4	10.2	10.8	14.0	15.8
4/16/2009 14:15	934	12.5	750	142	15	27	213	172	173	175	201				9.9	10.4	11.1	14.1	16.7
4/16/2009 14:30	1304	15.7	1113	156	20	15	262	264	257	261	260				12.5	14.2	15.1	17.4	19.5
4/16/2009 14:45	1362	16.7	1129	190	20	23	284	262	263	262	291				14.2	15.1	15.6	18.1	20.4
4/16/2009 15:00	1421	18.6	1172	203	25	21	284	285	279	285	288				15.3	16.3	17.5	20.0	23.7
4/16/2009 15:15	1364	21.2	1191	144	18	11	287	285	267	296	229				19.4	16.6	17.7	18.5	37.0
4/16/2009 15:30	1308	22.2	1147	133	16	12	297	277	258	285	191				15.9	15.3	18.3	20.5	49.8
4/16/2009 15:45	1225	20.5	1070	121	19	15	276	252	238	258	201				15.3	14.9	15.9	19.1	42.1
4/16/2009 16:00	1297	19.7	1134	131	17	15	283	260	264	254	236				14.1	15.2	15.0	16.4	40.1
4/16/2009 16:15	1396	21.5	1265	111	13	7	314	286	288	296	212				15.7	14.7	16.9	19.4	48.3
4/16/2009 16:30	1701	28.2	1583	106	10	2	369	376	352	359	245				24.7	23.1	24.8	26.6	48.2
4/16/2009 16:45	1700	26.6	1573	107	15	5	383	375	349	362	231				23.3	23.6	22.6	23.4	48.1
4/16/2009 17:00	1594	24.7	1467	109	12	6	341	324	330	329	270				20.4	18.5	18.9	21.6	48.4
4/16/2009 17:15	1611	24.8	1484	106	13	8	371	343	326	333	238				20.2	19.7	19.5	22.4	49.9
4/16/2009 17:30	1695	25.1	1577	101	14	3	358	336	340	340	321				19.0	19.0	19.2	23.0	47.0
4/16/2009 17:45	1604	24.1	1490	101	10	3	337	326	312	348	281				17.2	17.4	20.3	21.8	47.4
4/16/2009 18:00	1662	27.6	1540	101	12	9	375	355	356	357	219				20.0	21.9	25.0	29.0	52.0
4/16/2009 18:15	1829	37.9	1762	63	2	2	355	416	410	407	241				38.7	34.0	33.9	36.0	53.6
4/16/2009 18:30	1667	62.6	1630	36	1	0	306	406	417	413	125				59.3	61.0	62.5	65.1	68.1
4/16/2009 18:45	1429	64.0	1404	21	4	0	240	354	351	348	136				62.1	61.7	63.9	65.9	69.2
4/16/2009 19:00	1250	64.5	1223	19	7	1	241	308	308	285	108				61.4	62.7	64.5	67.4	69.3
4/16/2009 19:15	1288	64.8	1266	17	3	2	274	323	304	245	142				61.3	62.8	64.4	68.2	71.3
4/16/2009 19:30	1265	63.5	1250	11	4	0	244	322	301	253	145				60.5	61.7	63.0	66.3	68.9
4/16/2009 19:45	1172	62.9	1145	18	8	1	220	306	275	237	134				59.3	60.4	62.1	66.0	70.3
4/16/2009 20:00	1103	63.3	1081	20	2	0	234	287	259	211	112				60.0	61.5	63.3	66.2	69.6
4/16/2009 20:15	1036	63.3	1012	18	5	1	244	259	243	203	87				60.3	61.7	63.1	66.4	70.3
4/16/2009 20:30	1143	63.2	1124	17	2	0	259	274	299	202	109				60.2	61.9	62.7	66.1	69.1
4/16/2009 20:45	973	63.5	951	17	4	1	228	248	226	172	99				60.3	61.6	63.4	66.5	71.0
4/16/2009 21:00	832	63.9	821	9	0	2	131	202	225	176	98				61.0	61.6	62.7	66.6	70.1
4/16/2009 21:15	864	64.5	850	9	5	0	188	214	212	167	83				62.2	62.8	64.6	67.1	68.8
4/16/2009 21:30	971	63.7	957	8	5	1	210	256	223	185	97				60.7	62.3	63.4	66.5	69.3
4/16/2009 21:45	852	63.8	840	8	3	1	184	233	212	145	78				60.3	62.2	64.1	66.7	70.4
4/16/2009 22:00	767	64.2	754	11	2	0	163	202	203	133	66				61.6	63.1	63.8	66.6	70.2
4/16/2009 22:15	767	64.5	749	12	4	2	171	203	185	133	75				62.1	63.2	63.8	66.6	71.0
4/16/2009 22:30	786	64.2	769	11	5	1	182	202	201	138	63				61.4	62.7	64.3	67.3	70.4
4/16/2009 22:45	666	64.5	653	6	5	2	139	174	181	117	55				61.3	63.2	64.2	67.6	71.5
4/16/2009 23:00	562	64.9	548	10	3	1	90	162	155	105	50				62.6	62.8	64.5	67.6	71.7
4/16/2009 23:15	590	64.6	582	4	2	2	116	166	165	103	40				61.0	63.1	65.1	67.6	72.0
4/16/2009 23:30	469	65.1	460	4	3	2	106	114	120	91	38				62.9	63.0	65.0	68.0	71.5
4/16/2009 23:45	412	65.3	399	8	3	2	64	120	124	76	28				62.7	64.3	64.9	68.2	70.1
Day Totals	**90941**	**52.9**	**85033**	**4685**	**906**	**317**	**17985**	**22054**	**21698**	**18690**	**10514**	**0**	**0**	**0**	**48.2**	**52.0**	**53.7**	**54.6**	**57.7**

AM Peak Hr	**11:45**
AM Peak Vol	**5354**
AM PHF	**0.9406**
PM Peak Hr	**17:30**
PM Peak Vol	**6790**
PM PHF	**0.9281**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: **Kittelson**
File Number: **901153**
Route: **SR LP 202 RED MTI**
Location: **W of PRIEST DR ON**

	Total	Avg	Small Vehcles 0-25' by Lane								Medium Vehicles 26-55' by Lane							
Count Date	**Volume**	**Speed**	**EB 1**	**EB 2**	**EB 3**	**EB 4**	**HOV**				**EB 1**	**EB 2**	**EB 3**	**EB 4**	**HOV**			
4/16/2009	351	64.0	25	102	120	70	29				0	2	1	1	0			
4/16/2009 0:15	305	64.4	15	91	111	63	19				0	1	0	1	0			
4/16/2009 0:30	257	65.1	11	93	83	51	13				0	0	3	2	0			
4/16/2009 0:45	241	63.9	20	80	78	45	10				0	0	1	2	0			
4/16/2009 1:00	170	64.0	8	47	61	33	7				0	3	2	1	0			
4/16/2009 1:15	153	63.1	6	48	44	40	4				0	2	0	0	1			
4/16/2009 1:30	111	63.0	7	27	42	22	7				0	2	2	0	0			
4/16/2009 1:45	126	64.5	1	31	46	28	9				0	2	5	0	0			
4/16/2009 2:00	86	64.4	4	21	33	15	5				2	1	0	0	0			
4/16/2009 2:15	100	63.5	0	30	45	18	5				0	1	0	0	0			
4/16/2009 2:30	91	64.6	3	23	31	21	5				0	0	1	0	0			
4/16/2009 2:45	114	65.1	4	30	36	24	7				0	2	2	1	1			
4/16/2009 3:00	101	64.8	5	31	30	11	9				0	3	5	2	0			
4/16/2009 3:15	95	64.3	7	26	28	19	2				1	4	2	0	0			
4/16/2009 3:30	109	62.8	6	21	37	20	2				2	10	4	0	0			
4/16/2009 3:45	130	63.3	9	25	44	29	6				3	0	1	2	0			
4/16/2009 4:00	115	63.1	10	26	33	27	4				0	4	4	2	0			
4/16/2009 4:15	174	64.6	10	35	56	35	18				1	4	5	1	0			
4/16/2009 4:30	268	65.9	35	58	79	56	32				2	0	2	0	0			
4/16/2009 4:45	382	66.2	56	85	98	76	40				2	7	6	4	0			
4/16/2009 5:00	485	66.4	96	110	105	80	52				4	10	10	3	2			
4/16/2009 5:15	517	65.1	93	120	127	101	54				2	5	5	2	0			
4/16/2009 5:30	849	65.4	134	184	193	180	106				6	13	14	5	3			
4/16/2009 5:45	1112	66.8	167	227	242	232	171				10	12	14	14	6			
4/16/2009 6:00	964	66.6	166	210	211	186	101				12	25	20	13	1			
4/16/2009 6:15	781	67.0	138	179	178	166	50				18	15	14	5	2			
4/16/2009 6:30	908	66.0	156	214	207	193	44				18	24	15	17	3			
4/16/2009 6:45	1027	65.1	187	227	233	226	57				16	39	17	9	3			
4/16/2009 7:00	908	66.3	176	232	198	193	40				12	14	19	10	5			
4/16/2009 7:15	1084	65.3	212	259	244	221	53				9	30	15	16	5			
4/16/2009 7:30	1118	65.9	190	243	287	247	53				13	27	13	12	4			
4/16/2009 7:45	1136	65.9	199	286	264	265	53				8	15	19	9	8			
4/16/2009 8:00	1146	65.3	213	271	268	260	52				12	25	17	11	5			
4/16/2009 8:15	1093	65.7	199	269	252	243	58				13	13	17	9	6			
4/16/2009 8:30	1132	64.7	241	246	285	232	59				7	22	11	14	7			
4/16/2009 8:45	1198	65.2	249	288	276	254	70				8	12	20	8	4			
4/16/2009 9:00	1095	65.1	219	253	257	217	68				15	24	15	10	3			
4/16/2009 9:15	1027	65.7	201	228	249	188	86				20	20	8	5	3			
4/16/2009 9:30	1075	65.6	184	246	274	204	101				9	13	14	4	5			
4/16/2009 9:45	1213	65.2	229	282	274	234	123				18	14	15	5	2			
4/16/2009 10:00	1209	65.5	260	280	275	219	101				10	19	17	11	5			
4/16/2009 10:15	1166	65.2	216	289	253	209	125				13	20	17	7	2			
4/16/2009 10:30	1091	66.0	220	251	247	200	108				11	15	16	6	1			
4/16/2009 10:45	1105	66.1	189	271	251	214	119				5	12	11	9	0			
4/16/2009 11:00	1249	65.6	231	294	281	250	130				8	12	21	8	4			
4/16/2009 11:15	1188	65.7	209	290	294	216	127				8	17	9	4	4			
4/16/2009 11:30	1309	65.8	257	312	291	223	144				11	24	21	11	2			
4/16/2009 11:45	1351	64.8	271	318	298	254	149				9	12	14	5	5			
4/16/2009 12:00	1266	65.8	229	290	288	254	151				6	12	14	6	3			
4/16/2009 12:15	1314	65.7	209	338	309	267	131				10	12	12	6	8			
4/16/2009 12:30	1423	65.1	239	328	314	288	184				10	16	11	8	3			
4/16/2009 12:45	1420	64.9	250	345	325	266	162				8	17	14	6	5			
4/16/2009 13:00	1454	65.6	256	357	330	262	162				16	19	20	6	10			
4/16/2009 13:15	1387	62.9	254	333	309	266	170				9	14	7	6	3			
4/16/2009 13:30	1418	64.0	221	327	344	287	176				15	18	9	8	5			
4/16/2009 13:45	1446	57.5	263	324	304	269	202				10	17	21	15	7			
4/16/2009 14:00	927	12.7	183	120	122	136	175				16	44	34	28	26			
4/16/2009 14:15	934	12.5	192	129	125	138	166				18	33	35	26	30			
4/16/2009 14:30	1304	15.7	247	222	207	217	220				14	36	36	34	36			
4/16/2009 14:45	1362	16.7	258	216	210	208	237				23	39	39	40	49			
4/16/2009 15:00	1421	18.6	253	234	218	234	233				25	39	49	43	47			
4/16/2009 15:15	1364	21.2	277	232	219	257	206				10	43	39	30	22			
4/16/2009 15:30	1308	22.2	280	236	203	245	183				14	29	46	37	7			
4/16/2009 15:45	1225	20.5	266	222	191	205	186				9	19	36	47	10			
4/16/2009 16:00	1297	19.7	269	231	212	207	215				9	24	42	35	21			
4/16/2009 16:15	1396	21.5	303	251	242	264	205				10	29	38	27	7			
4/16/2009 16:30	1701	28.2	364	355	317	309	238				3	20	31	45	7			
4/16/2009 16:45	1700	26.6	373	353	298	323	226				10	17	43	33	4			
4/16/2009 17:00	1594	24.7	332	286	298	288	263				8	28	30	38	5			
4/16/2009 17:15	1611	24.8	361	315	290	284	234				10	25	26	41	4			
4/16/2009 17:30	1695	25.1	347	314	304	302	310				8	21	32	31	9			
4/16/2009 17:45	1604	24.1	327	302	282	303	276				8	21	25	42	5			
4/16/2009 18:00	1662	27.6	363	327	317	319	214				10	19	34	33	5			
4/16/2009 18:15	1829	37.9	348	403	383	392	236				6	12	25	15	5			
4/16/2009 18:30	1667	62.6	301	398	410	404	117				5	7	7	9	8			
4/16/2009 18:45	1429	64.0	236	350	347	342	129				3	4	2	5	7			
4/16/2009 19:00	1250	64.5	235	301	302	278	107				4	6	5	3	1			
4/16/2009 19:15	1288	64.8	267	317	300	242	140				5	4	4	2	2			
4/16/2009 19:30	1265	63.5	243	316	297	250	144				0	5	3	2	1			
4/16/2009 19:45	1172	62.9	220	295	267	233	130				0	6	5	3	4			
4/16/2009 20:00	1103	63.3	232	283	252	205	109				2	3	7	5	3			
4/16/2009 20:15	1036	63.3	242	251	235	202	82				1	4	7	1	5			
4/16/2009 20:30	1143	63.2	255	270	295	200	104				4	3	3	2	5			
4/16/2009 20:45	973	63.5	223	241	220	169	98				4	4	5	3	1			
4/16/2009 21:00	832	63.9	130	199	221	176	95				1	2	3	0	3			
4/16/2009 21:15	864	64.5	185	209	208	166	82				1	4	2	1	1			
4/16/2009 21:30	971	63.7	208	251	219	184	95				1	3	2	0	2			
4/16/2009 21:45	852	63.8	181	230	209	144	76				1	1	3	1	2			
4/16/2009 22:00	767	64.2	162	197	198	132	65				1	4	4	1	1			
4/16/2009 22:15	767	64.5	170	195	179	131	74				1	3	5	2	1			
4/16/2009 22:30	786	64.2	179	194	197	136	63				1	6	2	2	0			
4/16/2009 22:45	666	64.5	139	171	172	116	55				0	2	4	0	0			
4/16/2009 23:00	562	64.9	88	157	151	103	49				2	1	4	2	1			
4/16/2009 23:15	590	64.6	116	162	161	103	40				0	2	2	0	0			
4/16/2009 23:30	469	65.1	106	108	118	90	38				0	1	2	1	0			
4/16/2009 23:45	412	65.3	61	119	118	75	26				3	0	3	0	2			
Day Totals	**90941**	**52.9**	**17187**	**20413**	**19986**	**17481**	**9966**	**0**	**0**	**0**	**653**	**1249**	**1296**	**992**	**495**	**0**	**0**	**0**

AM Peak Hr **11:45**
AM Peak Vol **5354**
AM PHF **0.9406**
PM Peak Hr **17:30**
PM Peak Vol **6790**
PM PHF **0.9281**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client:	**Kittelson**	Site Ref:	**6**
File Number:	**901153**	Direction:	**EB**
Route:	**SR LP 202 RED MTI**	Latitude:	**33.43651**
Location:	**W of PRIEST DR OI**	Longitude:	**-111.95672**

Count Date	Total Volume	Avg Speed	Large Vehicles 56-75' by Lane								Combination Vehicles76'+ by Lane							
			EB 1	EB 2	EB 3	EB 4	HOV				EB 1	EB 2	EB 3	EB 4	HOV			
4/16/2009	351	64.0	0	0	0	0	0				1	0	0	0	0			
4/16/2009 0:15	305	64.4	0	1	2	0	0				1	0	0	0	0			
4/16/2009 0:30	257	65.1	0	0	0	0	0				0	1	0	0	0			
4/16/2009 0:45	241	63.9	0	2	2	0	0				0	1	0	0	0			
4/16/2009 1:00	170	64.0	0	6	2	0	0				0	0	0	0	0			
4/16/2009 1:15	153	63.1	0	5	1	0	0				0	0	2	0	0			
4/16/2009 1:30	111	63.0	1	0	0	0	0				0	0	1	0	0			
4/16/2009 1:45	126	64.5	0	0	2	0	0				0	2	0	0	0			
4/16/2009 2:00	86	64.4	0	0	2	1	0				0	0	2	0	0			
4/16/2009 2:15	100	63.5	0	0	0	1	0				0	0	0	0	0			
4/16/2009 2:30	91	64.6	1	4	1	1	0				0	0	0	0	0			
4/16/2009 2:45	114	65.1	0	2	5	0	0				0	0	0	0	0			
4/16/2009 3:00	101	64.8	0	2	1	2	0				0	0	0	0	0			
4/16/2009 3:15	95	64.3	0	2	2	1	0				0	0	1	0	0			
4/16/2009 3:30	109	62.8	0	3	4	0	0				0	0	0	0	0			
4/16/2009 3:45	130	63.3	1	4	6	0	0				0	0	0	0	0			
4/16/2009 4:00	115	63.1	1	0	2	2	0				0	0	0	0	0			
4/16/2009 4:15	174	64.6	2	1	2	1	0				0	1	1	1	0			
4/16/2009 4:30	268	65.9	0	3	1	0	0				0	0	0	0	0			
4/16/2009 4:45	382	66.2	0	5	2	0	0				1	0	0	0	0			
4/16/2009 5:00	485	66.4	1	5	5	0	0				0	1	1	0	0			
4/16/2009 5:15	517	65.1	1	2	3	0	0				0	2	0	0	0			
4/16/2009 5:30	849	65.4	3	3	3	0	1				0	0	1	0	0			
4/16/2009 5:45	1112	66.8	2	6	3	4	0				0	2	0	0	0			
4/16/2009 6:00	964	66.6	3	4	4	3	0				1	2	2	0	0			
4/16/2009 6:15	781	67.0	3	4	6	0	1				0	2	0	0	0			
4/16/2009 6:30	908	66.0	1	6	9	0	0				0	1	0	0	0			
4/16/2009 6:45	1027	65.1	1	3	7	1	0				0	1	0	0	0			
4/16/2009 7:00	908	66.3	2	4	2	0	1				0	0	0	0	0			
4/16/2009 7:15	1084	65.3	5	5	3	2	2				0	1	2	0	0			
4/16/2009 7:30	1118	65.9	4	7	7	7	0				0	2	1	1	0			
4/16/2009 7:45	1136	65.9	0	4	5	0	0				0	0	1	0	0			
4/16/2009 8:00	1146	65.3	0	5	2	3	2				0	0	0	0	0			
4/16/2009 8:15	1093	65.7	3	1	4	1	1				0	0	4	0	0			
4/16/2009 8:30	1132	64.7	1	0	2	2	1				0	0	2	0	0			
4/16/2009 8:45	1198	65.2	4	1	1	0	0				0	2	1	0	0			
4/16/2009 9:00	1095	65.1	1	3	2	2	0				2	3	1	0	0			
4/16/2009 9:15	1027	65.7	2	6	7	1	0				0	1	1	0	1			
4/16/2009 9:30	1075	65.6	2	5	8	4	0				0	1	1	0	0			
4/16/2009 9:45	1213	65.2	2	6	4	3	0				1	0	1	0	0			
4/16/2009 10:00	1209	65.5	0	3	5	1	0				0	3	0	0	0			
4/16/2009 10:15	1166	65.2	1	3	3	6	0				0	1	1	0	0			
4/16/2009 10:30	1091	66.0	0	5	5	4	0				0	1	1	0	0			
4/16/2009 10:45	1105	66.1	8	3	7	3	2				0	1	0	0	0			
4/16/2009 11:00	1249	65.6	2	1	4	3	0				0	0	0	0	0			
4/16/2009 11:15	1188	65.7	0	4	2	2	1				0	1	0	0	0			
4/16/2009 11:30	1309	65.8	1	3	3	3	1				0	2	0	0	0			
4/16/2009 11:45	1351	64.8	2	7	4	2	0				0	0	1	0	0			
4/16/2009 12:00	1266	65.8	4	4	3	2	0				0	0	0	0	0			
4/16/2009 12:15	1314	65.7	1	4	3	2	0				0	1	0	1	0			
4/16/2009 12:30	1423	65.1	4	8	7	1	1				0	1	0	0	0			
4/16/2009 12:45	1420	64.9	4	5	12	0	0				1	0	0	0	0			
4/16/2009 13:00	1454	65.6	3	2	7	2	0				0	2	0	0	0			
4/16/2009 13:15	1387	62.9	2	2	8	0	0				0	1	2	1	0			
4/16/2009 13:30	1418	64.0	2	2	4	0	0				0	0	0	0	0			
4/16/2009 13:45	1446	57.5	3	5	2	4	0				0	0	0	0	0			
4/16/2009 14:00	927	12.7	4	5	3	3	1				0	8	10	6	3			
4/16/2009 14:15	934	12.5	2	2	5	3	3				1	8	8	8	2			
4/16/2009 14:30	1304	15.7	0	5	9	5	1				1	1	5	5	3			
4/16/2009 14:45	1362	16.7	2	4	4	9	1				1	3	10	5	4			
4/16/2009 15:00	1421	18.6	3	10	4	4	4				3	2	8	4	4			
4/16/2009 15:15	1364	21.2	0	9	5	4	0				0	1	4	5	1			
4/16/2009 15:30	1308	22.2	3	8	4	0	1				0	4	5	3	0			
4/16/2009 15:45	1225	20.5	1	4	10	2	2				0	7	1	4	3			
4/16/2009 16:00	1297	19.7	3	3	7	4	0				2	2	3	8	0			
4/16/2009 16:15	1396	21.5	1	3	6	3	0				0	3	2	2	0			
4/16/2009 16:30	1701	28.2	2	0	4	4	0				0	1	0	1	0			
4/16/2009 16:45	1700	26.6	0	3	6	5	1				0	2	2	1	0			
4/16/2009 17:00	1594	24.7	1	8	0	1	2				0	2	2	2	0			
4/16/2009 17:15	1611	24.8	0	2	7	4	0				0	1	3	4	0			
4/16/2009 17:30	1695	25.1	3	1	3	5	2				0	0	1	2	0			
4/16/2009 17:45	1604	24.1	2	2	4	2	0				0	1	1	1	0			
4/16/2009 18:00	1662	27.6	2	6	2	2	0				0	3	3	3	0			
4/16/2009 18:15	1829	37.9	0	1	1	0	0				1	0	1	0	0			
4/16/2009 18:30	1667	62.6	0	1	0	0	0				0	0	0	0	0			
4/16/2009 18:45	1429	64.0	1	0	2	1	0				0	0	0	0	0			
4/16/2009 19:00	1250	64.5	1	1	1	4	0				1	0	0	0	0			
4/16/2009 19:15	1288	64.8	2	0	0	1	0				0	2	0	0	0			
4/16/2009 19:30	1265	63.5	1	1	1	1	0				0	0	0	0	0			
4/16/2009 19:45	1172	62.9	0	4	3	1	0				0	1	0	0	0			
4/16/2009 20:00	1103	63.3	0	1	0	1	0				0	0	0	0	0			
4/16/2009 20:15	1036	63.3	1	3	1	0	0				0	1	0	0	0			
4/16/2009 20:30	1143	63.2	0	1	1	0	0				0	0	0	0	0			
4/16/2009 20:45	973	63.5	1	3	0	0	0				0	0	1	0	0			
4/16/2009 21:00	832	63.9	0	0	0	0	0				0	1	1	0	0			
4/16/2009 21:15	864	64.5	2	1	2	0	0				0	0	0	0	0			
4/16/2009 21:30	971	63.7	1	1	2	1	0				0	1	0	0	0			
4/16/2009 21:45	852	63.8	2	1	0	0	0				0	1	0	0	0			
4/16/2009 22:00	767	64.2	0	1	1	0	0				0	0	0	0	0			
4/16/2009 22:15	767	64.5	0	3	1	0	0				0	2	0	0	0			
4/16/2009 22:30	786	64.2	2	2	1	0	0				0	0	1	0	0			
4/16/2009 22:45	666	64.5	0	1	3	1	0				0	0	2	0	0			
4/16/2009 23:00	562	64.9	0	3	0	0	0				0	1	0	0	0			
4/16/2009 23:15	590	64.6	0	0	2	0	0				0	2	0	0	0			
4/16/2009 23:30	469	65.1	0	3	0	0	0				0	2	0	0	0			
4/16/2009 23:45	412	65.3	0	0	2	1	0				0	1	1	0	0			
Day Totals	**90941**	**52.9**	**127**	**288**	**310**	**149**	**32**	**0**	**0**	**0**	**18**	**104**	**106**	**68**	**21**	**0**	**0**	**0**

AM Peak Hr	**11:45**
AM Peak Vol	**5354**
AM PHF	**0.9406**
PM Peak Hr	**17:30**
PM Peak Vol	**6790**
PM PHF	**0.9281**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
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Client: **Kittelson** | Site Ref: **7**
File Number: **901154** | Direction: **EB**
Route: **SR LP 202 RED MTN** | Latitude: **33.43579**
Location: **Btwn PRIEST DR ON-RMP CENTER PKWY ON-RMP** | Longitude: **-111.94806**

Count Date	Total Volume	Avg Speed	Len 0-25	Len 26-55	Len 56-75	Len 76+	Volume by Lane EB 1	EB 2	EB 3	EB 4	EB HOV				Average Speed by Lane EB 1	EB 2	EB 3	EB 4	HOV
4/16/2009	0	0.0	0	0	0	0	0	0	0	0	0				62.4	0.0	66.1	65.7	68.5
4/16/2009 0:15	0	0.0	0	0	0	0	0	0	0	0	0				62.4	0.0	66.1	65.7	68.5
4/16/2009 0:30	0	0.0	0	0	0	0	0	0	0	0	0				62.4	0.0	66.1	65.7	68.5
4/16/2009 0:45	0	0.0	0	0	0	0	0	0	0	0	0				0.0	0.0	0.0	0.0	68.5
4/16/2009 1:00	0	0.0	0	0	0	0	0	0	0	0	0				0.0	0.0	0.0	0.0	68.5
4/16/2009 1:15	0	0.0	0	0	0	0	0	0	0	0	0				0.0	0.0	0.0	0.0	68.5
4/16/2009 1:30	0	0.0	0	0	0	0	0	0	0	0	0				0.0	0.0	0.0	0.0	68.5
4/16/2009 1:45	2	68.1	0	1	0	1	1	0	0	0	1				67.6	0.0	0.0	0.0	68.5
4/16/2009 2:00	79	63.9	2	5	6	66	30	17	18	13	1				62.6	64.8	65.1	64.0	68.5
4/16/2009 2:15	292	63.2	19	34	31	208	99	86	70	31	6				63.7	61.8	62.9	64.2	74.0
4/16/2009 2:30	118	64.2	40	56	10	12	31	25	30	23	9				62.4	63.8	65.0	64.8	66.9
4/16/2009 2:45	137	65.0	45	67	4	21	21	43	36	27	10				61.9	65.3	64.0	65.6	71.8
4/16/2009 3:00	121	63.8	50	59	11	1	27	30	34	21	9				60.4	62.1	63.9	68.0	69.4
4/16/2009 3:15	149	63.6	27	55	17	50	40	46	39	16	8				60.4	64.1	63.4	65.6	74.6
4/16/2009 3:30	523	63.5	21	43	74	385	196	143	131	43	10				63.6	62.4	63.0	63.9	83.1
4/16/2009 3:45	500	63.2	20	42	76	362	190	122	122	60	6				60.6	64.2	65.4	65.1	65.1
4/16/2009 4:00	303	63.9	20	31	35	217	121	69	59	39	15				63.0	63.1	64.3	65.1	70.0
4/16/2009 4:15	235	64.9	10	22	27	176	82	51	65	25	12				64.0	67.3	63.0	64.6	72.0
4/16/2009 4:30	405	64.1	15	38	34	318	158	97	79	50	21				62.5	63.7	64.0	67.9	69.7
4/16/2009 4:45	58	68.5	2	1	3	52	25	15	13	4	1				71.8	64.9	66.1	68.7	69.7
4/16/2009 5:00	46	65.6	0	1	0	45	14	10	13	6	3				64.5	62.4	63.4	76.5	69.7
4/16/2009 5:15	21	64.0	0	1	3	17	7	5	5	3	1				60.4	59.4	64.9	76.5	69.5
4/16/2009 5:30	37	64.7	2	3	2	30	14	9	6	5	3				60.1	65.0	61.4	70.8	81.2
4/16/2009 5:45	24	64.2	0	1	2	21	10	3	7	4	0				63.2	62.1	64.8	67.3	81.2
4/16/2009 6:00	7	64.4	0	0	0	7	3	4	0	0	0				62.4	65.9	64.8	67.3	81.2
4/16/2009 6:15	5	66.2	0	0	0	5	3	1	0	0	1				61.4	65.4	64.8	67.3	81.2
4/16/2009 6:30	12	63.4	0	1	0	11	6	2	1	1	2				61.5	67.1	66.4	69.8	60.6
4/16/2009 6:45	54	65.9	1	4	1	48	23	15	9	7	0				63.2	62.4	73.6	72.2	60.6
4/16/2009 7:00	354	65.1	41	53	41	219	110	94	92	36	22				63.7	64.1	65.9	67.8	68.0
4/16/2009 7:15	1132	64.0	329	486	142	175	290	275	282	220	65				60.9	63.3	64.4	66.9	68.5
4/16/2009 7:30	1217	64.3	509	568	88	52	305	295	304	244	69				60.7	63.6	64.9	67.1	71.3
4/16/2009 7:45	717	64.3	149	296	105	167	172	162	184	140	59				60.5	63.3	64.5	67.0	71.0
4/16/2009 8:00	6	61.2	0	0	0	6	4	1	1	0	0				59.5	60.3	68.9	67.0	71.0
4/16/2009 8:15	1148	64.0	918	178	21	31	310	295	257	220	66				60.0	63.7	64.7	67.5	68.9
4/16/2009 8:30	1217	63.9	1075	132	9	1	347	307	275	229	59				59.7	63.6	65.6	67.5	69.2
4/16/2009 8:45	1280	63.4	1151	114	11	4	387	318	288	233	54				58.9	63.5	64.8	67.8	69.2
4/16/2009 9:00	1217	63.9	1061	133	16	7	335	305	272	233	72				59.3	63.3	64.9	68.5	69.9
4/16/2009 9:15	1074	64.5	967	85	15	7	312	259	249	175	79				60.7	63.6	65.6	68.5	70.6
4/16/2009 9:30	1154	64.6	1042	89	20	3	302	272	281	205	94				60.3	64.3	65.1	67.9	70.4
4/16/2009 9:45	1304	64.4	1175	109	15	5	330	321	301	229	123				59.4	64.0	65.1	67.8	70.8
4/16/2009 10:00	1318	64.4	1179	125	11	3	362	335	288	222	111				59.7	63.4	65.5	68.4	71.8
4/16/2009 10:15	1283	64.1	1169	94	17	3	352	331	272	217	111				59.7	63.8	64.8	68.0	69.4
4/16/2009 10:30	1185	64.8	1064	99	19	3	316	306	277	187	99				59.9	64.2	66.0	68.8	71.1
4/16/2009 10:45	1210	65.0	1104	76	22	8	329	306	254	212	109				60.4	64.8	65.6	68.7	70.9
4/16/2009 11:00	1355	64.8	1235	110	8	2	360	341	280	246	128				59.7	64.2	65.5	68.3	72.3
4/16/2009 11:15	1339	64.9	1221	108	8	2	387	318	291	232	111				60.2	64.4	65.9	68.6	72.0
4/16/2009 11:30	1483	64.0	1340	127	11	5	413	372	319	239	140				58.4	63.3	65.3	68.7	71.1
4/16/2009 11:45	1524	63.3	1392	111	13	8	450	376	313	253	132				57.3	63.0	65.7	67.6	70.8
4/16/2009 12:00	1436	65.7	1295	123	15	3	397	343	315	239	142				60.5	65.4	66.9	69.0	72.5
4/16/2009 12:15	1483	64.7	1357	113	7	6	395	366	313	269	140				61.0	64.3	65.2	67.6	69.9
4/16/2009 12:30	1574	64.5	1417	134	17	6	418	360	329	298	169				58.8	64.1	65.6	68.1	70.7
4/16/2009 12:45	1563	63.5	1403	131	24	5	413	383	340	276	151				58.1	62.2	64.6	68.2	70.8
4/16/2009 13:00	1598	64.1	1440	132	18	8	430	381	343	270	174				57.9	63.9	65.1	68.1	71.9
4/16/2009 13:15	1500	59.3	1360	120	14	6	402	330	316	269	183				53.5	57.9	60.0	63.6	67.1
4/16/2009 13:30	1574	45.9	1443	120	9	2	295	300	297	329	353				40.9	43.9	45.2	47.5	51.0
4/16/2009 13:45	1356	40.0	1177	149	20	10	192	329	306	271	258				36.1	34.4	40.1	45.4	44.5
4/16/2009 14:00	1092	16.8	851	193	31	17	60	243	241	264	284				16.5	12.4	14.9	17.7	21.3
4/16/2009 14:15	1170	21.9	908	215	26	21	103	247	254	280	286				15.8	13.4	20.1	25.2	29.9
4/16/2009 14:30	1500	26.7	1218	260	17	5	286	281	287	302	344				16.5	20.7	26.6	32.4	35.0
4/16/2009 14:45	1701	40.5	1544	139	13	5	324	323	333	347	374				35.0	39.9	40.9	42.3	43.7
4/16/2009 15:00	1788	43.8	1642	130	13	3	341	330	337	387	393				39.9	43.1	44.2	45.1	46.0
4/16/2009 15:15	1723	44.1	1569	137	13	4	293	335	349	412	334				40.1	43.6	43.6	44.5	47.9
4/16/2009 15:30	1740	45.5	1595	133	9	3	316	333	355	405	331				40.6	43.5	45.3	46.6	51.2
4/16/2009 15:45	1627	45.3	1502	112	7	6	283	324	329	354	337				41.7	44.0	45.2	47.0	48.0
4/16/2009 16:00	1708	44.0	1594	101	10	3	306	334	344	359	365				39.7	42.7	44.8	45.7	46.3
4/16/2009 16:15	1829	46.2	1721	100	5	3	318	378	385	399	349				41.8	44.5	45.2	46.7	52.6
4/16/2009 16:30	2018	35.5	1763	234	12	9	369	428	439	436	346				30.2	31.8	33.3	36.0	47.8
4/16/2009 16:45	2004	33.6	1744	237	13	10	394	443	430	419	318				27.6	29.4	30.8	34.5	49.4
4/16/2009 17:00	1855	30.5	1600	228	22	5	322	385	397	400	351				25.6	25.7	26.2	30.4	45.1
4/16/2009 17:15	1911	32.7	1665	220	17	9	373	402	392	419	325				26.7	28.6	29.5	32.2	49.2
4/16/2009 17:30	1989	30.5	1699	272	16	2	367	409	409	418	386				26.3	26.8	27.6	29.0	43.2
4/16/2009 17:45	1887	30.0	1644	224	13	6	357	377	391	407	355				23.9	25.8	26.7	29.9	44.4
4/16/2009 18:00	1920	33.6	1673	229	12	6	379	394	433	423	291				27.0	29.2	30.7	34.7	51.1
4/16/2009 18:15	2012	39.4	1777	222	9	4	415	429	424	459	285				32.4	35.9	37.4	41.5	54.4
4/16/2009 18:30	1866	53.9	1721	142	2	1	424	417	412	443	170				47.3	52.4	54.5	57.7	62.6
4/16/2009 18:45	1580	63.3	1493	82	4	1	358	367	353	373	129				59.6	62.5	63.8	65.3	69.0
4/16/2009 19:00	1357	63.9	1295	54	6	2	307	347	312	291	100				60.1	63.0	64.8	66.8	67.9
4/16/2009 19:15	1399	64.2	1327	65	4	3	358	341	303	250	147				59.7	63.4	64.9	67.6	70.2
4/16/2009 19:30	1377	63.4	1318	54	4	1	331	345	303	258	140				59.2	62.6	63.8	66.7	68.7
4/16/2009 19:45	1286	62.9	1216	59	6	5	312	323	279	234	138				58.7	61.7	63.0	66.2	69.4
4/16/2009 20:00	1165	63.6	1112	51	1	1	288	286	283	209	99				59.3	63.0	64.5	66.6	69.0
4/16/2009 20:15	1131	63.7	1079	42	5	5	296	303	260	188	84				60.1	63.1	64.6	66.4	70.1
4/16/2009 20:30	1226	63.3	1163	60	3	0	327	299	283	210	107				59.8	62.9	63.4	66.2	68.9
4/16/2009 20:45	1023	64.1	968	49	3	3	262	271	223	183	84				60.3	63.2	64.5	67.3	71.2
4/16/2009 21:00	898	63.8	868	27	2	1	201	228	208	171	90				61.2	63.0	63.1	65.9	68.8
4/16/2009 21:15	920	64.7	888	27	3	2	227	254	204	163	72				61.9	63.9	65.1	67.4	69.0
4/16/2009 21:30	1022	63.9	978	38	4	2	258	255	237	178	94				60.6	63.8	63.8	66.6	68.3
4/16/2009 21:45	916	64.0	887	25	4	0	251	239	194	161	71				60.6	63.5	64.3	67.1	69.3
4/16/2009 22:00	824	64.0	794	27	3	0	228	208	197	138	53				61.7	63.3	64.4	66.3	69.7
4/16/2009 22:15	804	64.6	775	23	3	3	196	230	183	131	64				62.0	63.7	64.7	67.5	69.2
4/16/2009 22:30	838	64.7	797	33	6	2	238	209	193	136	62				62.0	64.1	64.9	67.9	70.1
4/16/2009 22:45	729	65.1	698	21	7	3	213	187	161	118	50				62.7	64.6	65.1	67.8	70.2
4/16/2009 23:00	597	65.0	574	18	3	2	165	143	144	101	44				62.5	64.4	64.9	67.7	71.1
4/16/2009 23:15	650	64.8	626	20	1	3	194	170	147	99	40				61.9	64.6	65.4	67.7	70.9
4/16/2009 23:30	488	65.4	473	10	3	2	142	133	103	85	25				63.4	65.3	64.7	68.3	69.5
4/16/2009 23:45	455	65.6	435	14	2	4	99	131	120	77	28				62.9	65.2	65.6	67.7	71.6
Day Totals	**91754**	**53.6**	**78481**	**8907**	**1389**	**2977**	**21497**	**21255**	**20007**	**17658**	**11337**	**0**	**0**	**0**	**51.8**	**53.3**	**53.9**	**54.6**	**55.4**

AM Peak Hr	**11:45**
AM Peak Vol	**6017**
AM PHF	**0.9557**
PM Peak Hr	**17:30**
PM Peak Vol	**7808**
PM PHF	**0.9702**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: **Kittelson**
File Number: **901154**
Route: **SR LP 202 RED MTI**
Location: **Btwn PRIEST DR O**

Count Date	Total Volume	Avg Speed	Small Vehcles 0-25' by Lane								Medium Vehicles 26-55' by Lane							
			EB 1	EB 2	EB 3	EB 4	HOV				EB 1	EB 2	EB 3	EB 4	HOV			
4/16/2009	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 0:15	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 0:30	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 0:45	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 1:00	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 1:15	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 1:30	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 1:45	2	68.1	0	0	0	0	0				0	0	0	0	1			
4/16/2009 2:00	79	63.9	0	1	0	1	0				1	0	1	3	0			
4/16/2009 2:15	292	63.2	1	5	5	4	4				1	11	13	8	1			
4/16/2009 2:30	118	64.2	5	4	10	14	7				19	13	14	8	2			
4/16/2009 2:45	137	65.0	4	9	12	15	5				10	27	16	10	4			
4/16/2009 3:00	121	63.8	9	7	15	11	8				15	19	16	8	1			
4/16/2009 3:15	149	63.6	3	9	7	5	3				11	20	12	8	4			
4/16/2009 3:30	523	63.5	3	5	5	7	1				7	8	17	8	3			
4/16/2009 3:45	500	63.2	2	7	6	4	1				7	4	21	9	1			
4/16/2009 4:00	303	63.9	2	5	1	11	1				7	6	8	4	6			
4/16/2009 4:15	235	64.9	1	0	3	2	4				6	4	6	4	2			
4/16/2009 4:30	405	64.1	4	2	3	2	4				7	4	7	12	8			
4/16/2009 4:45	58	68.5	0	1	0	1	0				0	0	0	1	0			
4/16/2009 5:00	46	65.6	0	0	0	0	0				0	0	1	0	0			
4/16/2009 5:15	21	64.0	0	0	0	0	0				0	0	0	1	0			
4/16/2009 5:30	37	64.7	1	0	0	0	1				0	0	0	2	1			
4/16/2009 5:45	24	64.2	0	0	0	0	0				0	0	1	0	0			
4/16/2009 6:00	7	64.4	0	0	0	0	0				0	0	0	0	0			
4/16/2009 6:15	5	66.2	0	0	0	0	0				0	0	0	0	0			
4/16/2009 6:30	12	63.4	0	0	0	0	0				0	0	0	0	1			
4/16/2009 6:45	54	65.9	0	0	0	1	0				0	1	1	2	0			
4/16/2009 7:00	354	65.1	6	7	12	9	7				9	9	19	8	8			
4/16/2009 7:15	1132	64.0	44	69	76	99	41				121	121	132	92	20			
4/16/2009 7:30	1217	64.3	89	88	140	149	43				175	158	129	81	25			
4/16/2009 7:45	717	64.3	12	25	33	55	24				50	79	80	60	27			
4/16/2009 8:00	6	61.2	0	0	0	0	0				0	0	0	0	0			
4/16/2009 8:15	1148	64.0	240	216	201	204	57				40	68	47	15	8			
4/16/2009 8:30	1217	63.9	323	268	239	197	48				23	37	33	29	10			
4/16/2009 8:45	1280	63.4	369	285	230	219	48				10	29	56	13	6			
4/16/2009 9:00	1217	63.9	302	261	226	209	63				25	38	41	20	9			
4/16/2009 9:15	1074	64.5	285	227	219	166	70				21	26	22	8	8			
4/16/2009 9:30	1154	64.6	280	250	238	190	84				20	13	37	10	9			
4/16/2009 9:45	1304	64.4	304	285	254	217	115				23	31	38	9	8			
4/16/2009 10:00	1318	64.4	342	303	232	208	94				20	27	51	11	16			
4/16/2009 10:15	1283	64.1	325	304	239	198	103				23	21	28	15	7			
4/16/2009 10:30	1185	64.8	296	275	230	174	89				17	24	39	10	9			
4/16/2009 10:45	1210	65.0	308	276	221	195	104				10	23	26	13	4			
4/16/2009 11:00	1355	64.8	343	311	232	228	121				15	28	44	16	7			
4/16/2009 11:15	1339	64.9	370	291	246	217	97				14	24	43	14	13			
4/16/2009 11:30	1483	64.0	396	330	267	217	130				15	37	48	18	9			
4/16/2009 11:45	1524	63.3	431	334	262	240	125				14	34	46	11	6			
4/16/2009 12:00	1436	65.7	368	308	263	222	134				21	31	48	16	7			
4/16/2009 12:15	1483	64.7	378	337	269	251	122				15	25	41	14	18			
4/16/2009 12:30	1574	64.5	394	327	271	276	149				19	22	55	19	19			
4/16/2009 12:45	1563	63.5	388	342	282	260	131				18	34	48	13	18			
4/16/2009 13:00	1598	64.1	400	346	279	258	157				26	30	50	11	15			
4/16/2009 13:15	1500	59.3	380	294	263	254	169				20	31	44	13	12			
4/16/2009 13:30	1574	45.9	274	270	260	311	328				18	27	32	18	25			
4/16/2009 13:45	1356	40.0	178	283	264	238	214				10	40	38	25	36			
4/16/2009 14:00	1092	16.8	55	206	202	211	177				5	26	30	44	88			
4/16/2009 14:15	1170	21.9	92	190	208	212	206				11	42	41	59	62			
4/16/2009 14:30	1500	26.7	261	229	208	244	276				24	47	71	54	64			
4/16/2009 14:45	1701	40.5	306	302	282	319	335				15	19	45	22	38			
4/16/2009 15:00	1788	43.8	322	300	292	358	370				16	25	40	26	23			
4/16/2009 15:15	1723	44.1	282	311	309	377	290				9	18	37	31	42			
4/16/2009 15:30	1740	45.5	304	310	300	379	302				11	15	53	26	28			
4/16/2009 15:45	1627	45.3	271	297	290	334	310				9	22	36	19	26			
4/16/2009 16:00	1708	44.0	298	311	308	337	340				8	19	32	18	24			
4/16/2009 16:15	1829	46.2	310	364	341	375	331				6	10	43	24	17			
4/16/2009 16:30	2018	35.5	355	385	347	370	306				9	42	86	58	39			
4/16/2009 16:45	2004	33.6	384	393	314	357	296				9	46	106	56	20			
4/16/2009 17:00	1855	30.5	310	324	305	335	326				11	53	82	59	23			
4/16/2009 17:15	1911	32.7	368	352	294	347	304				2	47	85	65	21			
4/16/2009 17:30	1989	30.5	357	366	291	338	347				8	42	111	75	36			
4/16/2009 17:45	1887	30.0	343	329	314	335	323				10	44	72	66	32			
4/16/2009 18:00	1920	33.6	365	349	335	358	266				12	40	90	62	25			
4/16/2009 18:15	2012	39.4	402	388	328	405	254				10	38	95	49	30			
4/16/2009 18:30	1866	53.9	416	385	349	418	153				8	31	63	23	17			
4/16/2009 18:45	1580	63.3	352	360	317	350	114				4	7	34	22	15			
4/16/2009 19:00	1357	63.9	296	339	288	276	96				9	7	23	11	4			
4/16/2009 19:15	1399	64.2	349	330	275	234	139				6	9	28	14	8			
4/16/2009 19:30	1377	63.4	326	331	276	249	136				4	12	26	8	4			
4/16/2009 19:45	1286	62.9	304	306	254	223	129				6	14	21	9	9			
4/16/2009 20:00	1165	63.6	286	279	257	202	88				1	7	26	6	11			
4/16/2009 20:15	1131	63.7	291	290	236	185	77				4	8	21	3	6			
4/16/2009 20:30	1226	63.3	321	288	256	200	98				6	9	26	10	9			
4/16/2009 20:45	1023	64.1	254	264	198	175	77				5	5	24	8	7			
4/16/2009 21:00	898	63.8	198	222	195	165	88				2	6	12	6	1			
4/16/2009 21:15	920	64.7	223	248	190	156	71				1	5	13	7	1			
4/16/2009 21:30	1022	63.9	257	244	215	172	90				0	9	20	5	4			
4/16/2009 21:45	916	64.0	247	230	184	158	68				1	8	10	3	3			
4/16/2009 22:00	824	64.0	225	203	186	129	51				2	4	11	8	2			
4/16/2009 22:15	804	64.6	194	217	177	127	60				0	9	6	4	4			
4/16/2009 22:30	838	64.7	230	201	179	127	60				5	6	11	9	2			
4/16/2009 22:45	729	65.1	211	182	142	114	49				1	3	12	4	1			
4/16/2009 23:00	597	65.0	162	135	136	98	43				2	4	8	3	1			
4/16/2009 23:15	650	64.8	192	164	136	96	38				2	4	9	3	2			
4/16/2009 23:30	488	65.4	138	127	99	84	25				2	3	4	1	0			
4/16/2009 23:45	455	65.6	97	126	111	74	27				2	4	5	2	1			
Day Totals	**91754**	**53.6**	**18814**	**18144**	**15939**	**15542**	**10042**	**0**	**0**	**0**	**1141**	**1953**	**3017**	**1652**	**1144**	**0**	**0**	**0**

AM Peak Hr **11:45**
AM Peak Vol **6017**
AM PHF **0.9557**
PM Peak Hr **17:30**
PM Peak Vol **7808**
PM PHF **0.9702**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client:	Kittelson	Site Ref:	7
File Number:	901154	Direction:	EB
Route:	SR LP 202 RED MTI	Latitude:	33.43579
Location:	Btwn PRIEST DR O	Longitude:	-111.94806

			Large Vehicles 56-75' by Lane								Combination Vehicles76'+ by Lane							
Count Date	Total Volume	Avg Speed	EB 1	EB 2	EB 3	EB 4	HOV				EB 1	EB 2	EB 3	EB 4	HOV			
4/16/2009	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 0:15	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 0:30	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 0:45	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 1:00	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 1:15	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 1:30	0	0.0	0	0	0	0	0				0	0	0	0	0			
4/16/2009 1:45	2	68.1	0	0	0	0	0				1	0	0	0	0			
4/16/2009 2:00	79	63.9	3	0	2	0	1				26	16	15	9	0			
4/16/2009 2:15	292	63.2	2	15	11	3	0				95	55	41	16	1			
4/16/2009 2:30	118	64.2	2	4	4	0	0				5	4	2	1	0			
4/16/2009 2:45	137	65.0	1	2	0	1	0				6	5	8	1	1			
4/16/2009 3:00	121	63.8	2	4	3	2	0				1	0	0	0	0			
4/16/2009 3:15	149	63.6	5	7	3	2	0				21	10	17	1	1			
4/16/2009 3:30	523	63.5	26	17	18	12	1				160	113	91	16	5			
4/16/2009 3:45	500	63.2	21	20	19	12	4				160	91	76	35	0			
4/16/2009 4:00	303	63.9	10	6	10	7	2				102	52	40	17	6			
4/16/2009 4:15	235	64.9	8	3	9	5	2				67	44	47	14	4			
4/16/2009 4:30	405	64.1	7	7	10	8	2				140	84	59	28	7			
4/16/2009 4:45	58	68.5	2	0	0	0	1				23	14	13	2	0			
4/16/2009 5:00	46	65.6	0	0	0	0	0				14	10	12	6	3			
4/16/2009 5:15	21	64.0	0	0	1	2	0				7	5	4	0	1			
4/16/2009 5:30	37	64.7	0	0	0	1	1				13	9	6	2	0			
4/16/2009 5:45	24	64.2	1	0	0	1	0				9	3	6	3	0			
4/16/2009 6:00	7	64.4	0	0	0	0	0				3	4	0	0	0			
4/16/2009 6:15	5	66.2	0	0	0	0	0				3	1	0	0	1			
4/16/2009 6:30	12	63.4	0	0	0	0	0				6	2	1	1	1			
4/16/2009 6:45	54	65.9	1	0	0	0	0				22	14	8	4	0			
4/16/2009 7:00	354	65.1	9	12	13	7	0				86	66	48	12	7			
4/16/2009 7:15	1132	64.0	51	39	29	19	4				74	46	45	10	0			
4/16/2009 7:30	1217	64.3	25	29	24	10	0				16	20	11	4	1			
4/16/2009 7:45	717	64.3	35	20	37	11	2				75	38	34	14	6			
4/16/2009 8:00	6	61.2	0	0	0	0	0				4	1	1	0	0			
4/16/2009 8:15	1148	64.0	9	7	3	1	1				21	4	6	0	0			
4/16/2009 8:30	1217	63.9	1	2	3	2	1				0	0	0	1	0			
4/16/2009 8:45	1280	63.4	6	2	2	1	0				2	2	0	0	0			
4/16/2009 9:00	1217	63.9	6	3	3	4	0				2	3	2	0	0			
4/16/2009 9:15	1074	64.5	6	2	5	1	1				0	4	3	0	0			
4/16/2009 9:30	1154	64.6	2	8	5	4	1				0	1	1	1	0			
4/16/2009 9:45	1304	64.4	2	5	5	3	0				1	0	4	0	0			
4/16/2009 10:00	1318	64.4	0	3	5	3	0				0	2	0	0	1			
4/16/2009 10:15	1283	64.1	4	4	5	3	1				0	2	0	1	0			
4/16/2009 10:30	1185	64.8	2	5	8	3	1				1	2	0	0	0			
4/16/2009 10:45	1210	65.0	9	4	4	4	1				2	3	3	0	0			
4/16/2009 11:00	1355	64.8	1	2	3	2	0				1	0	1	0	0			
4/16/2009 11:15	1339	64.9	3	3	1	0	1				0	0	1	1	0			
4/16/2009 11:30	1483	64.0	2	3	2	3	1				0	2	2	1	0			
4/16/2009 11:45	1524	63.3	4	4	3	1	1				1	4	2	1	0			
4/16/2009 12:00	1436	65.7	6	3	4	1	1				2	1	0	0	0			
4/16/2009 12:15	1483	64.7	0	3	2	2	0				2	1	1	2	0			
4/16/2009 12:30	1574	64.5	4	9	1	3	0				1	2	2	0	1			
4/16/2009 12:45	1563	63.5	4	7	9	3	1				3	0	1	0	1			
4/16/2009 13:00	1598	64.1	4	3	9	0	2				0	2	5	1	0			
4/16/2009 13:15	1500	59.3	2	3	6	1	2				0	2	3	1	0			
4/16/2009 13:30	1574	45.9	2	2	5	0	0				1	1	0	0	0			
4/16/2009 13:45	1356	40.0	3	4	3	6	4				1	2	1	2	4			
4/16/2009 14:00	1092	16.8	0	5	6	6	14				0	6	3	3	5			
4/16/2009 14:15	1170	21.9	0	8	2	5	11				0	7	3	4	7			
4/16/2009 14:30	1500	26.7	1	5	6	2	3				0	0	2	2	1			
4/16/2009 14:45	1701	40.5	1	2	4	5	1				2	0	2	1	0			
4/16/2009 15:00	1788	43.8	3	4	3	3	0				0	1	2	0	0			
4/16/2009 15:15	1723	44.1	0	6	3	2	2				2	0	0	2	0			
4/16/2009 15:30	1740	45.5	1	6	1	0	1				0	2	1	0	0			
4/16/2009 15:45	1627	45.3	1	3	2	0	1				2	2	1	1	0			
4/16/2009 16:00	1708	44.0	0	3	3	3	1				0	1	1	1	0			
4/16/2009 16:15	1829	46.2	2	2	1	0	0				0	2	0	0	1			
4/16/2009 16:30	2018	35.5	2	0	5	4	1				3	1	1	4	0			
4/16/2009 16:45	2004	33.6	1	1	5	5	1				0	3	5	1	1			
4/16/2009 17:00	1855	30.5	1	7	8	4	2				0	1	2	2	0			
4/16/2009 17:15	1911	32.7	0	0	11	6	0				3	3	2	1	0			
4/16/2009 17:30	1989	30.5	2	1	6	4	3				0	0	1	1	0			
4/16/2009 17:45	1887	30.0	4	2	2	5	0				0	2	3	1	0			
4/16/2009 18:00	1920	33.6	2	3	4	3	0				0	2	4	0	0			
4/16/2009 18:15	2012	39.4	3	1	1	4	0				0	2	0	1	1			
4/16/2009 18:30	1866	53.9	0	1	0	1	0				0	0	0	1	0			
4/16/2009 18:45	1580	63.3	1	0	2	1	0				1	0	0	0	0			
4/16/2009 19:00	1357	63.9	0	1	1	4	0				2	0	0	0	0			
4/16/2009 19:15	1399	64.2	2	0	0	2	0				1	2	0	0	0			
4/16/2009 19:30	1377	63.4	1	1	1	1	0				0	1	0	0	0			
4/16/2009 19:45	1286	62.9	2	1	2	1	0				0	2	2	1	0			
4/16/2009 20:00	1165	63.6	1	0	0	0	0				0	0	0	1	0			
4/16/2009 20:15	1131	63.7	1	1	2	0	1				0	4	1	0	0			
4/16/2009 20:30	1226	63.3	0	2	1	0	0				0	0	0	0	0			
4/16/2009 20:45	1023	64.1	1	1	1	0	0				2	1	0	0	0			
4/16/2009 21:00	898	63.8	1	0	0	0	1				0	0	1	0	0			
4/16/2009 21:15	920	64.7	2	1	0	0	0				1	0	1	0	0			
4/16/2009 21:30	1022	63.9	1	1	1	1	0				0	1	1	0	0			
4/16/2009 21:45	916	64.0	3	1	0	0	0				0	0	0	0	0			
4/16/2009 22:00	824	64.0	1	1	0	1	0				0	0	0	0	0			
4/16/2009 22:15	804	64.6	1	2	0	0	0				1	2	0	0	0			
4/16/2009 22:30	838	64.7	2	2	2	0	0				1	0	1	0	0			
4/16/2009 22:45	729	65.1	1	2	4	0	0				0	0	3	0	0			
4/16/2009 23:00	597	65.0	1	2	0	0	0				0	2	0	0	0			
4/16/2009 23:15	650	64.8	0	0	1	0	0				0	2	1	0	0			
4/16/2009 23:30	488	65.4	1	2	0	0	0				1	1	0	0	0			
4/16/2009 23:45	455	65.6	0	0	2	0	0				0	1	2	1	0			
Day Totals	**91754**	**53.6**	**340**	**357**	**382**	**227**	**83**	**0**	**0**	**0**	**1202**	**801**	**669**	**237**	**68**	**0**	**0**	**0**

AM Peak Hr	**11:45**
AM Peak Vol	**6017**
AM PHF	**0.9557**
PM Peak Hr	**17:30**
PM Peak Vol	**7808**
PM PHF	**0.9702**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: **Kittelson**
File Number: **901155**
Route: **SR LP 202 RED MTN**
Location: **W of SCOTTSDALE RD OFF-RMP**

Site Ref: **8**
Direction: **EB**
Latitude: **33.43561**
Longitude: **-111.93045**

							Volume by Lane								Average Speed by Lane				
Count Date	Total Volume	Avg Speed	Len 0-25	Len 26-55	Len 56-75	Len 76+	EB 1	EB 2	EB 3	EB 4	EB HOV				EB 1	EB 2	EB 3	EB 4	HOV
0:00	132	63.5	131	0	1	1	27	41	37	24	4				62.2	61.5	64.2	66.3	70.6
0:15	128	65.1	121	4	2	2	22	41	38	20	8				63.0	62.3	64.4	68.1	68.5
0:30	108	63.4	105	1	2	1	25	32	33	15	4				62.5	61.4	64.7	65.3	68.8
0:45	96	64.1	89	3	3	2	19	32	30	13	3				60.8	62.6	65.2	68.5	62.8
1:00	67	62.9	61	3	2	2	16	23	16	11	3				61.2	61.0	64.8	66.0	66.4
1:15	64	63.3	56	5	4	1	16	22	16	9	2				61.7	60.6	66.1	67.7	65.7
1:30	61	64.4	57	4	1	1	14	18	16	11	4				64.5	60.9	63.4	66.2	63.9
1:45	59	62.4	56	3	1	0	10	25	14	9	1				59.3	61.9	63.5	65.7	61.9
2:00	48	64.5	43	4	1	1	10	18	12	7	3				62.3	60.8	64.1	68.3	65.8
2:15	51	63.4	44	4	3	0	11	20	12	8	1				61.4	62.1	65.8	65.6	63.7
2:30	56	65.1	51	4	2	0	9	21	19	6	1				64.1	62.4	65.5	69.6	66.0
2:45	64	62.3	55	5	4	1	12	26	17	9	1				61.7	60.7	63.8	65.3	60.1
3:00	42	63.8	36	4	2	1	9	15	13	4	2				61.4	62.0	64.4	71.7	67.8
3:15	55	64.3	46	5	3	1	14	18	15	6	2				62.0	60.9	66.0	69.0	67.5
3:30	54	63.2	46	4	4	0	14	21	11	8	1				62.5	60.5	65.7	71.6	64.8
3:45	63	62.9	53	5	6	0	13	25	17	6	2				61.6	61.0	65.1	66.9	63.6
4:00	69	64.6	58	8	4	0	15	28	14	9	4				62.7	62.0	63.7	65.4	67.4
4:15	70	62.5	60	5	5	1	17	28	16	9	1				61.4	60.9	64.9	65.4	67.0
4:30	117	64.6	109	5	4	0	21	37	29	23	8				63.7	62.9	65.6	70.0	67.7
4:45	174	64.8	162	9	3	1	29	59	40	33	14				62.3	63.1	65.7	68.0	69.1
5:00	180	64.6	162	13	4	2	30	56	51	32	12				61.9	61.7	65.8	67.6	65.8
5:15	224	64.4	205	14	4	2	42	59	59	43	21				61.7	62.1	65.3	68.0	68.6
5:30	332	63.5	298	27	6	1	56	95	78	68	35				60.1	60.8	64.3	66.3	68.1
5:45	424	64.8	387	32	5	1	87	112	97	80	50				61.2	62.4	65.8	67.8	70.0
6:00	366	64.7	324	34	8	1	88	99	85	68	27				60.9	62.2	66.5	69.4	70.7
6:15	355	63.1	306	43	5	1	84	103	91	64	15				60.1	61.0	64.3	67.6	68.3
6:30	415	64.0	353	56	6	0	90	126	104	76	20				61.4	61.2	65.2	68.1	66.8
6:45	456	64.5	406	41	8	2	93	138	111	94	22				61.6	62.0	65.8	68.6	68.1
7:00	406	64.8	368	31	7	1	87	116	102	82	19				62.1	62.4	66.4	69.0	67.0
7:15	450	64.4	405	39	6	1	87	145	110	90	19				61.0	62.0	66.2	69.2	66.5
7:30	489	64.1	448	34	6	2	94	141	130	97	27				61.9	61.7	65.4	67.1	66.6
7:45	535	63.7	492	35	8	2	106	150	136	115	28				61.3	60.9	64.9	67.1	67.8
8:00	503	64.2	456	42	5	1	97	150	129	105	24				61.3	61.8	66.1	67.4	67.8
8:15	504	63.8	464	34	4	2	97	151	124	103	31				60.5	61.4	65.2	68.0	68.0
8:30	463	64.2	425	33	5	1	81	138	124	95	25				61.0	61.7	65.8	67.4	67.8
8:45	507	62.8	470	34	3	1	96	158	135	96	23				59.4	60.1	64.6	66.8	66.4
9:00	514	63.6	465	41	7	2	100	151	137	98	29				59.9	60.4	65.1	68.1	68.8
9:15	437	64.2	398	28	9	3	86	130	105	86	31				60.5	61.5	65.5	68.3	69.2
9:30	474	64.2	437	27	9	1	95	139	118	87	36				60.8	62.0	64.9	68.0	69.2
9:45	539	64.5	499	31	7	3	103	159	127	108	43				61.1	61.6	65.7	68.4	71.4
10:00	527	63.9	481	40	4	3	95	158	128	102	45				60.1	61.1	65.6	68.2	68.4
10:15	514	63.9	468	39	6	1	104	148	129	91	43				60.9	61.1	65.0	68.4	68.4
10:30	479	64.6	442	28	9	1	88	152	117	86	36				61.5	61.6	65.9	68.8	70.2
10:45	519	64.0	481	26	8	5	103	165	112	91	48				60.4	61.6	65.5	67.8	69.6
11:00	574	63.8	534	34	6	1	120	161	138	105	51				60.0	61.4	64.9	68.3	69.3
11:15	574	64.5	537	33	4	1	118	165	140	102	50				61.3	61.8	65.4	68.1	69.8
11:30	613	63.7	562	45	5	2	124	183	147	106	54				61.3	60.8	64.9	67.3	69.6
11:45	636	63.1	600	29	6	2	128	190	148	115	56				59.4	60.5	64.7	66.7	68.7
12:00	594	64.4	550	38	6	1	117	170	136	114	59				60.8	61.6	65.3	67.9	69.9
12:15	613	63.5	568	39	5	2	118	182	136	125	53				60.7	60.8	64.9	66.9	67.8
12:30	664	63.9	617	38	10	0	116	188	157	130	74				60.3	61.0	64.9	67.5	68.5
12:45	667	63.5	611	47	7	2	118	190	162	126	72				60.3	60.2	64.0	67.0	68.7
13:00	688	63.2	634	44	9	2	131	200	153	127	78				59.6	60.6	63.7	67.2	68.9
13:15	665	63.5	620	36	5	4	138	177	161	119	71				60.3	60.9	64.2	67.0	69.0
13:30	699	64.1	657	39	3	0	117	180	156	136	111				60.5	61.0	65.1	66.7	67.8
13:45	646	63.8	607	33	6	1	123	165	144	127	88				61.1	61.2	64.7	66.3	67.4
14:00	583	64.9	556	21	5	2	100	157	122	117	89				62.6	62.0	65.9	68.2	67.9
14:15	633	63.6	593	36	4	1	114	171	129	129	91				60.4	60.6	65.2	66.4	66.8
14:30	757	63.2	715	37	5	1	146	181	158	146	126				59.5	59.9	64.6	66.1	66.8
14:45	865	62.9	813	46	5	2	152	208	176	179	150				59.2	59.4	63.3	65.7	67.5
15:00	864	63.1	810	49	5	1	143	196	184	189	154				60.1	60.6	63.0	64.7	67.1
15:15	861	62.0	810	46	4	1	129	207	191	218	116				60.3	59.8	62.4	63.4	64.6
15:30	861	62.6	813	43	6	1	131	203	193	218	117				60.3	60.6	63.0	64.3	64.8
15:45	848	62.5	811	31	5	1	139	199	183	205	123				60.1	60.1	62.4	65.2	65.1
16:00	875	62.1	837	34	4	0	145	200	198	203	131				60.5	60.0	62.7	63.7	63.6
16:15	941	60.5	905	33	3	1	151	215	217	232	127				59.0	58.1	60.6	62.3	63.2
16:30	1041	56.9	999	37	4	1	163	233	240	247	159				56.5	54.3	56.5	58.0	60.1
16:45	1026	48.6	975	47	3	2	170	235	229	242	151				49.4	45.2	46.6	48.5	56.1
17:00	988	36.9	897	84	6	2	166	215	217	218	173				40.4	33.8	33.2	33.8	46.1
17:15	1008	42.1	947	58	3	1	168	217	239	235	150				45.7	39.4	39.8	37.6	52.6
17:30	1012	37.9	932	74	5	1	169	222	226	216	179				39.6	34.2	34.1	35.1	48.7
17:45	991	36.3	914	71	5	1	167	214	217	227	166				40.3	32.7	32.3	32.8	47.3
18:00	948	37.9	863	77	7	2	156	214	219	222	138				43.0	35.6	35.4	32.9	47.8
18:15	941	39.6	871	64	5	2	155	211	213	228	135				42.6	35.4	36.4	37.0	52.4
18:30	890	52.4	855	33	2	0	139	211	210	226	105				51.1	49.1	51.2	54.1	60.1
18:45	724	62.7	699	23	2	0	128	187	176	180	54				60.4	59.9	63.5	65.2	65.7
19:00	600	63.3	582	15	3	1	108	160	152	137	44				60.5	60.7	63.6	66.4	67.4
19:15	609	63.4	589	17	2	1	101	179	148	116	67				60.3	60.5	64.3	66.7	68.3
19:30	617	62.8	599	16	2	1	111	179	147	118	63				60.2	59.9	63.8	65.9	67.7
19:45	540	62.6	523	13	5	0	100	162	124	102	54				59.4	59.3	63.8	65.5	67.7
20:00	505	62.9	488	15	2	1	94	148	128	87	48				60.0	60.2	64.0	66.2	67.6
20:15	493	62.8	474	16	4	0	95	148	116	94	41				60.1	59.8	63.9	66.3	68.4
20:30	550	62.3	533	16	1	0	113	162	134	99	44				59.8	59.8	63.6	65.2	66.3
20:45	439	62.9	425	12	3	0	83	127	112	81	37				60.3	60.1	63.6	66.1	68.9
21:00	389	62.5	383	3	2	1	68	111	99	77	35				60.7	59.9	63.1	65.7	66.5
21:15	387	62.7	374	10	3	1	67	120	104	68	29				61.2	59.8	63.6	65.8	66.5
21:30	435	62.8	426	7	3	0	80	122	113	78	44				60.1	60.2	63.5	65.8	65.9
21:45	378	62.3	369	7	2	0	72	119	99	58	31				60.6	60.5	63.6	65.5	66.0
22:00	340	62.2	333	5	2	1	62	101	95	60	23				59.5	59.9	63.6	65.1	67.0
22:15	322	63.3	311	8	2	1	55	104	83	53	27				61.9	61.0	64.2	66.4	66.9
22:30	342	63.2	332	8	3	1	56	110	83	65	29				60.3	61.2	64.5	66.6	65.6
22:45	295	63.8	286	5	3	1	50	97	72	53	24				62.0	61.4	64.1	66.9	68.6
23:00	242	63.8	235	5	2	1	48	75	58	46	16				61.6	61.2	64.7	66.5	69.6
23:15	257	63.7	250	4	2	1	53	82	65	44	14				61.3	61.6	65.6	66.3	67.9
23:30	197	63.2	191	4	1	2	36	61	56	35	10				60.5	61.2	63.9	66.7	68.8
23:45	182	64.2	174	5	2	1	27	59	56	29	11				62.1	62.7	65.2	66.9	67.6
Day Totals	**45574**	**59.5**	**42641**	**2455**	**390**	**90**	**8269**	**12343**	**10786**	**9281**	**4896**	**0**	**0**	**0**	**57.9**	**57.5**	**60.0**	**60.9**	**63.1**

AM Peak Hr **11:45**
AM Peak Vol **2506**
AM PHF **0.9435**
PM Peak Hr **16:30**
PM Peak Vol **4062**
PM PHF **0.9764**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: **Kittelson**
File Number: **901155**
Route: **SR LP 202 RED MTI**
Location: **W of SCOTTSDALE**

Count Date	Total Volume	Avg Speed	Small Vehcles 0-25' by Lane								Medium Vehicles 26-55' by Lane							
			EB 1	EB 2	EB 3	EB 4	HOV				EB 1	EB 2	EB 3	EB 4	HOV			
0:00	132	63.5	26	41	37	24	4				0	0	0	0	0			
0:15	128	65.1	20	39	36	19	8				2	1	0	1	1			
0:30	108	63.4	25	30	33	15	4				1	0	0	0	0			
0:45	96	64.1	17	30	27	13	3				0	1	2	0	1			
1:00	67	62.9	13	22	14	10	3				1	1	2	1	0			
1:15	64	63.3	14	18	14	9	2				1	3	1	0	0			
1:30	61	64.4	13	16	14	10	4				1	2	1	0	0			
1:45	59	62.4	8	25	14	9	1				2	1	1	0	0			
2:00	48	64.5	8	15	11	7	3				2	2	1	0	0			
2:15	51	63.4	9	17	12	7	1				1	2	1	1	0			
2:30	56	65.1	9	18	18	6	1				1	3	0	0	0			
2:45	64	62.3	11	21	14	9	1				1	3	1	0	1			
3:00	42	63.8	8	14	10	3	2				1	2	1	0	1			
3:15	55	64.3	12	16	12	6	2				2	2	2	0	0			
3:30	54	63.2	12	17	10	8	1				2	3	0	0	0			
3:45	63	62.9	11	19	16	6	2				1	3	1	0	0			
4:00	69	64.6	14	21	12	8	4				2	5	1	1	0			
4:15	70	62.5	13	25	14	8	1				1	2	1	1	0			
4:30	117	64.6	18	35	26	23	8				2	1	2	1	0			
4:45	174	64.8	25	55	37	32	14				3	3	3	1	1			
5:00	180	64.6	27	48	46	30	11				3	5	3	2	1			
5:15	224	64.4	38	54	53	41	20				4	4	4	3	1			
5:30	332	63.5	49	82	70	63	35				6	11	6	5	1			
5:45	424	64.8	77	100	87	75	48				9	10	8	4	2			
6:00	366	64.7	77	88	71	64	25				9	10	11	3	2			
6:15	355	63.1	74	85	75	58	15				8	15	15	6	1			
6:30	415	64.0	77	106	84	70	17				13	19	17	5	3			
6:45	456	64.5	81	122	96	88	20				11	14	11	4	2			
7:00	406	64.8	81	105	91	75	16				7	8	9	6	2			
7:15	450	64.4	79	129	98	85	15				7	15	10	4	4			
7:30	489	64.1	85	127	121	91	24				8	11	8	5	3			
7:45	535	63.7	99	137	118	112	26				7	9	15	3	2			
8:00	503	64.2	88	135	116	97	21				8	15	11	7	3			
8:15	504	63.8	87	140	115	97	27				8	9	8	6	4			
8:30	463	64.2	74	129	114	88	22				6	9	9	7	3			
8:45	507	62.8	90	145	124	91	20				5	11	10	5	3			
9:00	514	63.6	89	132	126	92	27				9	16	10	4	3			
9:15	437	64.2	77	119	93	83	28				6	8	9	2	3			
9:30	474	64.2	89	129	105	80	35				6	8	9	4	1			
9:45	539	64.5	95	145	115	104	40				6	10	10	3	3			
10:00	527	63.9	88	143	113	97	42				7	13	14	4	3			
10:15	514	63.9	97	136	114	82	40				6	10	13	8	3			
10:30	479	64.6	81	142	104	80	35				5	6	11	5	2			
10:45	519	64.0	96	152	101	86	47				4	9	10	3	1			
11:00	574	63.8	113	150	126	100	46				7	10	9	4	5			
11:15	574	64.5	109	154	130	98	46				8	10	10	3	4			
11:30	613	63.7	117	167	130	97	52				7	13	16	8	2			
11:45	636	63.1	120	180	136	110	56				7	8	10	4	1			
12:00	594	64.4	107	156	122	108	58				7	12	13	6	1			
12:15	613	63.5	112	171	122	115	50				5	11	12	10	3			
12:30	664	63.9	107	174	141	124	71				6	10	14	6	3			
12:45	667	63.5	108	174	144	117	68				9	13	15	7	4			
13:00	688	63.2	125	188	134	118	70				5	11	12	9	8			
13:15	665	63.5	132	166	145	112	66				5	10	12	6	5			
13:30	699	64.1	110	168	141	130	108				6	10	15	6	4			
13:45	646	63.8	118	157	127	121	84				4	7	15	4	5			
14:00	583	64.9	95	151	113	112	86				3	4	8	4	3			
14:15	633	63.6	104	159	119	123	89				8	11	10	6	3			
14:30	757	63.2	142	166	145	140	123				3	12	13	6	4			
14:45	865	62.9	148	194	162	167	142				4	13	12	10	8			
15:00	864	63.1	135	186	167	177	146				7	8	15	12	8			
15:15	861	62.0	125	197	175	209	105				3	9	15	9	11			
15:30	861	62.6	126	193	175	210	110				3	7	18	8	7			
15:45	848	62.5	136	193	168	195	120				2	5	13	9	3			
16:00	875	62.1	143	191	187	194	124				3	7	10	8	7			
16:15	941	60.5	146	208	204	226	121				4	7	12	6	6			
16:30	1041	56.9	160	225	225	238	152				3	6	13	8	8			
16:45	1026	48.6	168	228	208	228	144				2	6	20	14	7			
17:00	988	36.9	160	202	181	192	163				6	12	33	25	10			
17:15	1008	42.1	166	210	212	218	142				2	7	25	16	8			
17:30	1012	37.9	165	213	189	199	167				3	9	34	16	12			
17:45	991	36.3	164	203	188	206	153				2	10	26	21	13			
18:00	948	37.9	153	200	184	199	128				2	12	33	21	10			
18:15	941	39.6	151	205	185	207	124				2	6	27	20	10			
18:30	890	52.4	134	207	195	219	101				4	4	15	7	4			
18:45	724	62.7	126	183	166	175	51				1	3	11	5	4			
19:00	600	63.3	107	156	144	133	43				1	4	8	3	1			
19:15	609	63.4	98	175	141	112	64				2	4	6	3	3			
19:30	617	62.8	108	175	139	115	62				2	4	8	2	1			
19:45	540	62.6	96	156	120	99	53				3	3	4	2	2			
20:00	505	62.9	93	145	122	84	46				1	3	6	3	3			
20:15	493	62.8	93	143	109	91	38				1	3	6	3	3			
20:30	550	62.3	111	159	127	96	41				2	2	7	3	3			
20:45	439	62.9	82	123	106	77	37				1	3	6	3	1			
21:00	389	62.5	64	111	97	77	35				2	1	1	0	0			
21:15	387	62.7	65	116	99	67	28				1	3	4	1	2			
21:30	435	62.8	78	118	110	78	43				1	3	3	0	1			
21:45	378	62.3	70	116	97	57	30				2	2	2	2	1			
22:00	340	62.2	62	100	91	60	22				0	1	3	0	2			
22:15	322	63.3	53	99	82	51	27				1	4	2	2	1			
22:30	342	63.2	54	105	81	65	27				1	3	2	0	2			
22:45	295	63.8	50	95	67	52	23				0	2	2	1	1			
23:00	242	63.8	47	71	58	44	15				0	3	0	2	1			
23:15	257	63.7	52	80	63	43	14				0	1	2	1	1			
23:30	197	63.2	35	58	55	34	10				0	2	1	1	0			
23:45	182	64.2	27	58	52	29	10				1	1	3	1	1			
Day Totals	**45574**	**59.5**	**7829**	**11578**	**9816**	**8786**	**4633**	**0**	**0**	**0**	**337**	**603**	**832**	**430**	**254**	**0**	**0**	**0**

AM Peak Hr **11:45**
AM Peak Vol **2506**
AM PHF **0.9435**
PM Peak Hr **16:30**
PM Peak Vol **4062**
PM PHF **0.9764**

Traffic Research and Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: **Kittelson**
File Number: **901155**
Route: **SR LP 202 RED MTI**
Location: **W of SCOTTSDALE**

Site Ref: **8**
Direction: **EB**
Latitude: **33.43561**
Longitude: **-111.93045**

Count Date	Total Volume	Avg Speed	Large Vehicles 56-75' by Lane								Combination Vehicles76'+ by Lane							
			EB 1	EB 2	EB 3	EB 4	HOV				EB 1	EB 2	EB 3	EB 4	HOV			
0:00	132	63.5	1	0	0	0	0				1	0	0	0	0			
0:15	128	65.1	1	1	1	0	0				0	1	1	0	0			
0:30	108	63.4	0	2	0	1	0				0	1	0	0	0			
0:45	96	64.1	2	1	1	0	0				1	1	1	0	0			
1:00	67	62.9	1	1	0	0	0				2	0	0	1	0			
1:15	64	63.3	2	2	1	0	0				0	0	1	0	0			
1:30	61	64.4	0	0	1	0	0				0	0	0	1	0			
1:45	59	62.4	1	0	0	0	0				0	0	0	0	0			
2:00	48	64.5	0	1	0	0	0				0	1	0	0	0			
2:15	51	63.4	1	2	0	0	0				0	0	0	0	0			
2:30	56	65.1	0	1	1	0	0				0	0	0	0	0			
2:45	64	62.3	0	2	2	0	0				0	1	1	0	0			
3:00	42	63.8	0	0	2	0	0				0	0	0	1	0			
3:15	55	64.3	1	1	1	1	0				0	0	1	0	0			
3:30	54	63.2	1	2	2	0	0				0	0	0	0	0			
3:45	63	62.9	2	4	0	1	0				0	0	0	0	0			
4:00	69	64.6	0	3	1	0	0				0	0	0	0	0			
4:15	70	62.5	3	1	1	1	0				0	0	1	0	0			
4:30	117	64.6	1	2	1	0	0				0	0	0	0	0			
4:45	174	64.8	1	2	0	1	0				1	0	0	0	0			
5:00	180	64.6	1	2	1	0	0				0	1	1	0	0			
5:15	224	64.4	1	2	1	0	0				1	0	2	0	0			
5:30	332	63.5	1	3	1	1	0				0	0	1	0	0			
5:45	424	64.8	1	2	1	1	0				0	1	1	0	0			
6:00	366	64.7	2	2	3	1	1				0	0	1	0	0			
6:15	355	63.1	1	3	2	0	0				1	1	0	0	0			
6:30	415	64.0	0	2	3	1	1				0	0	0	0	0			
6:45	456	64.5	2	2	4	1	0				0	1	0	1	0			
7:00	406	64.8	0	3	2	2	1				0	1	1	0	0			
7:15	450	64.4	2	2	1	2	0				0	0	1	0	0			
7:30	489	64.1	1	3	1	1	0				1	0	1	1	0			
7:45	535	63.7	1	5	2	0	0				0	0	2	0	0			
8:00	503	64.2	2	1	2	1	1				0	0	0	1	0			
8:15	504	63.8	2	1	1	1	1				1	1	1	0	0			
8:30	463	64.2	2	1	1	1	1				0	1	1	0	0			
8:45	507	62.8	1	2	1	0	0				0	1	0	0	0			
9:00	514	63.6	2	3	1	2	0				0	1	1	0	0			
9:15	437	64.2	3	2	3	1	1				1	2	1	0	0			
9:30	474	64.2	1	3	4	3	0				0	0	1	0	0			
9:45	539	64.5	2	4	1	1	0				1	1	1	0	0			
10:00	527	63.9	1	2	2	0	0				0	1	1	1	0			
10:15	514	63.9	2	2	2	1	0				0	0	1	1	0			
10:30	479	64.6	2	4	3	1	0				0	1	0	1	0			
10:45	519	64.0	2	3	2	2	0				1	2	1	1	1			
11:00	574	63.8	1	1	3	1	1				0	0	1	0	1			
11:15	574	64.5	1	1	1	2	0				1	1	0	0	0			
11:30	613	63.7	1	2	1	1	1				0	1	0	1	0			
11:45	636	63.1	1	3	2	1	0				1	0	1	0	0			
12:00	594	64.4	3	2	1	1	0				1	0	0	0	0			
12:15	613	63.5	1	1	2	1	0				1	0	1	0	0			
12:30	664	63.9	3	5	2	1	0				0	0	0	0	0			
12:45	667	63.5	1	3	3	2	0				1	1	1	1	0			
13:00	688	63.2	2	1	7	0	0				0	1	1	0	0			
13:15	665	63.5	1	1	2	1	0				0	1	3	1	0			
13:30	699	64.1	1	2	1	0	0				0	0	0	0	0			
13:45	646	63.8	1	2	2	2	0				1	0	0	0	0			
14:00	583	64.9	2	1	1	1	0				1	1	1	0	0			
14:15	633	63.6	1	1	1	1	0				1	1	0	0	0			
14:30	757	63.2	1	3	1	0	0				0	1	1	0	0			
14:45	865	62.9	0	1	2	2	0				1	1	1	0	0			
15:00	864	63.1	1	3	1	1	0				0	0	1	0	0			
15:15	861	62.0	1	1	2	1	0				1	0	0	1	0			
15:30	861	62.6	2	3	1	0	0				1	0	0	0	0			
15:45	848	62.5	2	2	2	1	0				0	0	1	0	1			
16:00	875	62.1	0	3	1	1	0				0	0	0	0	0			
16:15	941	60.5	1	1	1	1	0				0	1	0	0	0			
16:30	1041	56.9	1	1	2	1	0				1	1	0	0	0			
16:45	1026	48.6	1	1	1	1	0				1	0	1	0	0			
17:00	988	36.9	1	2	2	2	1				0	0	1	0	1			
17:15	1008	42.1	0	1	1	1	0				0	0	1	0	0			
17:30	1012	37.9	1	1	2	1	1				0	0	1	1	0			
17:45	991	36.3	0	1	3	0	1				1	0	1	0	0			
18:00	948	37.9	2	3	1	2	0				0	0	1	1	0			
18:15	941	39.6	2	0	1	1	2				1	0	1	1	0			
18:30	890	52.4	1	1	0	1	0				0	0	0	0	0			
18:45	724	62.7	1	1	0	1	0				0	0	0	0	0			
19:00	600	63.3	1	0	1	2	0				0	1	0	1	0			
19:15	609	63.4	1	1	0	1	0				1	0	1	0	0			
19:30	617	62.8	1	0	1	1	0				0	1	0	0	0			
19:45	540	62.6	1	3	0	1	0				0	0	0	0	0			
20:00	505	62.9	1	1	1	0	0				0	0	0	1	0			
20:15	493	62.8	1	2	1	0	0				0	0	0	0	0			
20:30	550	62.3	0	1	0	0	0				0	0	0	0	0			
20:45	439	62.9	1	1	0	1	0				0	0	0	0	0			
21:00	389	62.5	2	0	0	0	0				1	0	1	0	0			
21:15	387	62.7	1	1	1	0	0				0	0	0	1	0			
21:30	435	62.8	1	1	1	1	0				0	0	0	0	0			
21:45	378	62.3	1	1	0	0	0				0	0	0	0	0			
22:00	340	62.2	0	1	1	0	0				1	0	0	0	0			
22:15	322	63.3	1	1	0	1	0				1	0	0	0	0			
22:30	342	63.2	1	2	0	0	0				0	0	1	0	0			
22:45	295	63.8	0	1	2	0	0				0	0	1	0	0			
23:00	242	63.8	1	1	0	0	0				0	1	0	0	0			
23:15	257	63.7	1	1	0	1	0				0	1	1	0	0			
23:30	197	63.2	1	1	0	0	0				1	1	0	0	0			
23:45	182	64.2	0	1	1	0	0				0	0	1	0	0			
Day Totals	**45574**	**59.5**	**86**	**139**	**104**	**54**	**8**	**0**	**0**	**0**	**18**	**24**	**35**	**12**	**2**	**0**	**0**	**0**

AM Peak Hr	**11:45**
AM Peak Vol	**2506**
AM PHF	**0.9435**
PM Peak Hr	**16:30**
PM Peak Vol	**4062**
PM PHF	**0.9764**

Traffic Research & Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: KITTELSON
File Number: 0901156
Route: SR 202 RED MTN ON-RMP
Location: E of PRIEST DR

Site Ref: 9
Direction: EB
Latitude: 33.43624
Longitude: -111.95498

Date/Time	Total	cls01	cls02	cls03	cls04	cls05	cls06	cls07	cls08	cls09	cls10	cls11	cls12	cls13	pct SU	pct CB
4/16/2009 0:00	70	1	48	20	1	0	0	0	0	0	0	0	0	0	1.4%	0.0%
4/16/2009 0:15	23	0	18	5	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 0:30	21	0	19	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 0:45	16	0	12	3	1	0	0	0	0	0	0	0	0	0	6.3%	0.0%
4/16/2009 1:00	15	0	15	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 1:15	15	0	9	6	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 1:30	16	0	14	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 1:45	13	0	10	2	0	0	0	0	0	1	0	0	0	0	0.0%	7.7%
4/16/2009 2:00	7	0	4	2	0	0	0	0	0	1	0	0	0	0	0.0%	14.3%
4/16/2009 2:15	15	0	14	1	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 2:30	8	0	5	1	1	0	0	0	0	1	0	0	0	0	12.5%	12.5%
4/16/2009 2:45	8	0	5	3	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 3:00	13	0	5	6	1	0	0	0	0	1	0	0	0	0	7.7%	7.7%
4/16/2009 3:15	8	0	4	3	0	0	0	0	0	1	0	0	0	0	0.0%	12.5%
4/16/2009 3:30	5	0	1	3	1	0	0	0	0	0	0	0	0	0	20.0%	0.0%
4/16/2009 3:45	9	0	3	2	3	1	0	0	0	0	0	0	0	0	44.4%	0.0%
4/16/2009 4:00	16	0	8	4	2	0	0	0	0	2	0	0	0	0	12.5%	12.5%
4/16/2009 4:15	13	0	6	6	0	0	0	0	0	1	0	0	0	0	0.0%	7.7%
4/16/2009 4:30	19	0	9	8	2	0	0	0	0	0	0	0	0	0	10.5%	0.0%
4/16/2009 4:45	17	0	13	1	3	0	0	0	0	0	0	0	0	0	17.6%	0.0%
4/16/2009 5:00	27	0	15	8	1	1	2	0	0	0	0	0	0	0	14.8%	0.0%
4/16/2009 5:15	31	0	14	11	4	1	1	0	0	0	0	0	0	0	19.4%	0.0%
4/16/2009 5:30	29	0	22	5	2	0	0	0	0	0	0	0	0	0	6.9%	0.0%
4/16/2009 5:45	45	0	26	14	2	2	0	0	1	0	0	0	0	0	8.9%	2.2%
4/16/2009 6:00	51	0	32	16	2	0	1	0	0	0	0	0	0	0	5.9%	0.0%
4/16/2009 6:15	55	0	25	21	5	4	0	0	0	0	0	0	0	0	16.4%	0.0%
4/16/2009 6:30	71	1	43	21	5	1	0	0	0	0	0	0	0	0	8.5%	0.0%
4/16/2009 6:45	67	0	40	23	1	1	0	0	1	1	0	0	0	0	3.0%	3.0%
4/16/2009 7:00	77	0	49	22	2	0	1	0	1	2	0	0	0	0	3.9%	3.9%
4/16/2009 7:15	84	0	57	22	0	3	0	0	1	1	0	0	0	0	3.6%	2.4%
4/16/2009 7:30	101	1	63	31	4	0	2	0	0	0	0	0	0	0	5.9%	0.0%
4/16/2009 7:45	88	1	47	32	6	1	1	0	0	0	0	0	0	0	9.1%	0.0%
4/16/2009 8:00	99	1	60	30	3	0	0	0	3	1	1	0	0	0	3.0%	5.1%
4/16/2009 8:15	85	0	51	32	2	0	0	0	0	0	0	0	0	0	2.4%	0.0%
4/16/2009 8:30	94	0	51	40	3	0	0	0	0	0	0	0	0	0	3.2%	0.0%
4/16/2009 8:45	99	0	61	33	0	1	0	0	0	4	0	0	0	0	1.0%	4.0%
4/16/2009 9:00	80	0	50	26	3	0	0	0	0	0	1	0	0	0	3.8%	1.3%
4/16/2009 9:15	69	1	48	19	1	0	0	0	0	0	0	0	0	0	1.4%	0.0%
4/16/2009 9:30	83	0	52	29	1	1	0	0	0	0	0	0	0	0	2.4%	0.0%
4/16/2009 9:45	87	1	54	28	3	0	1	0	0	0	0	0	0	0	4.6%	0.0%
4/16/2009 10:00	101	1	68	26	2	1	0	0	1	2	0	0	0	0	3.0%	3.0%
4/16/2009 10:15	84	0	47	35	1	1	0	0	0	0	0	0	0	0	2.4%	0.0%
4/16/2009 10:30	106	0	61	44	0	0	0	0	0	1	0	0	0	0	0.0%	0.9%
4/16/2009 10:45	102	0	64	33	5	0	0	0	0	0	0	0	0	0	4.9%	0.0%
4/16/2009 11:00	156	0	108	44	0	2	2	0	0	0	0	0	0	0	2.6%	0.0%
4/16/2009 11:15	144	1	108	32	1	1	0	0	0	1	0	0	0	0	1.4%	0.7%
4/16/2009 11:30	166	0	102	57	2	3	1	0	1	0	0	0	0	0	3.6%	0.6%
4/16/2009 11:45	159	2	102	48	3	0	2	0	1	1	0	0	0	0	3.1%	1.3%
4/16/2009 12:00	149	0	99	42	4	2	0	0	1	1	0	0	0	0	4.0%	1.3%
4/16/2009 12:15	144	0	90	49	2	1	1	0	1	0	0	0	0	0	2.8%	0.7%
4/16/2009 12:30	155	1	103	42	5	3	0	1	0	0	0	0	0	0	5.8%	0.0%
4/16/2009 12:45	135	0	94	36	2	0	0	1	1	1	0	0	0	0	2.2%	1.5%
4/16/2009 13:00	184	0	118	60	5	1	0	0	0	0	0	0	0	0	3.3%	0.0%
4/16/2009 13:15	114	1	64	42	6	1	0	0	0	0	0	0	0	0	6.1%	0.0%
4/16/2009 13:30	121	0	74	43	0	1	1	0	1	1	0	0	0	0	1.7%	1.7%
4/16/2009 13:45	32	0	24	8	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 14:00	53	1	32	18	0	1	0	0	1	0	0	0	0	0	1.9%	1.9%

Traffic Research & Analysis, Inc.
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Phoenix, AZ 85018
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Client:	KITTELSON	Site Ref:	9
File Number:	0901156	Direction:	EB
Route:	SR 202 RED MTN ON-RMP	Latitude:	33.43624
Location:	E of PRIEST DR	Longitude:	-111.95498

Date/Time	Total	cls01	cls02	cls03	cls04	cls05	cls06	cls07	cls08	cls09	cls10	cls11	cls12	cls13	pct SU	pct CB
4/16/2009 14:15	59	0	32	26	0	1	0	0	0	0	0	0	0	0	1.7%	0.0%
4/16/2009 14:30	106	1	63	39	2	1	0	0	0	0	0	0	0	0	2.8%	0.0%
4/16/2009 14:45	98	0	67	30	1	0	0	0	0	0	0	0	0	0	1.0%	0.0%
4/16/2009 15:00	86	0	67	16	3	0	0	0	0	0	0	0	0	0	3.5%	0.0%
4/16/2009 15:15	87	1	67	16	3	0	0	0	0	0	0	0	0	0	3.4%	0.0%
4/16/2009 15:30	100	1	75	19	5	0	0	0	0	0	0	0	0	0	5.0%	0.0%
4/16/2009 15:45	77	2	61	10	4	0	0	0	0	0	0	0	0	0	5.2%	0.0%
4/16/2009 16:00	102	1	77	19	5	0	0	0	0	0	0	0	0	0	4.9%	0.0%
4/16/2009 16:15	152	0	117	19	13	0	1	0	2	0	0	0	0	0	9.2%	1.3%
4/16/2009 16:30	129	0	95	17	16	1	0	0	0	0	0	0	0	0	13.2%	0.0%
4/16/2009 16:45	146	2	96	34	11	1	2	0	0	0	0	0	0	0	9.6%	0.0%
4/16/2009 17:00	125	1	109	12	3	0	0	0	0	0	0	0	0	0	2.4%	0.0%
4/16/2009 17:15	145	0	103	31	10	0	0	0	1	0	0	0	0	0	6.9%	0.7%
4/16/2009 17:30	94	1	65	16	11	0	0	0	0	1	0	0	0	0	11.7%	1.1%
4/16/2009 17:45	100	2	70	19	6	0	1	0	1	1	0	0	0	0	7.0%	2.0%
4/16/2009 18:00	129	4	90	28	7	0	0	0	0	0	0	0	0	0	5.4%	0.0%
4/16/2009 18:15	131	0	106	22	0	3	0	0	0	0	0	0	0	0	2.3%	0.0%
4/16/2009 18:30	127	2	106	19	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 18:45	95	1	63	30	0	1	0	0	0	0	0	0	0	0	1.1%	0.0%
4/16/2009 19:00	104	0	81	23	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 19:15	98	0	76	22	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 19:30	80	1	62	13	2	1	0	0	0	1	0	0	0	0	3.8%	1.3%
4/16/2009 19:45	64	0	48	16	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 20:00	88	1	69	16	0	1	0	0	0	0	1	0	0	0	1.1%	1.1%
4/16/2009 20:15	81	1	61	19	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 20:30	72	0	47	24	0	0	0	0	0	1	0	0	0	0	0.0%	1.4%
4/16/2009 20:45	59	2	46	10	0	1	0	0	0	0	0	0	0	0	1.7%	0.0%
4/16/2009 21:00	54	0	40	14	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 21:15	55	0	42	13	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 21:30	48	0	37	10	0	0	0	0	0	1	0	0	0	0	0.0%	2.1%
4/16/2009 21:45	51	1	43	7	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 22:00	34	0	25	9	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 22:15	38	1	27	9	0	0	0	0	0	1	0	0	0	0	0.0%	2.6%
4/16/2009 22:30	47	0	36	9	0	1	0	0	0	1	0	0	0	0	2.1%	2.1%
4/16/2009 22:45	38	0	27	11	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 23:00	53	0	32	21	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 23:15	21	0	15	6	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 23:30	34	0	27	7	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 23:45	28	0	18	9	0	0	0	0	0	1	0	0	0	0	0.0%	3.6%
Day Totals	**7089**	**40**	**4828**	**1892**	**205**	**47**	**20**	**2**	**19**	**33**	**3**	**0**	**0**	**0**	**3.9%**	**0.8%**

AM Peak Hr	**11:10 AM**
AM Peak Vol	**629**
AM PHF	**0.782**
PM Peak Hr	**12:15 PM**
PM Peak Vol	**618**
PM PHF	**0.746**

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Location:	E of PRIEST DR	Longitude:	-111.95498

Date/Time	Total	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80+
4/16/2009 0:00	70	0	0	0	0	0	0	0	1	0	3	16	24	16	7	1	2	0
4/16/2009 0:15	23	0	0	0	0	0	0	0	0	1	1	3	6	6	5	1	0	0
4/16/2009 0:30	21	0	0	0	0	0	0	0	0	0	0	3	3	6	8	1	0	0
4/16/2009 0:45	16	0	0	0	0	0	0	0	0	0	1	1	6	4	3	1	0	0
4/16/2009 1:00	15	0	0	0	0	0	0	0	0	0	0	2	3	7	2	1	0	0
4/16/2009 1:15	15	0	0	0	0	0	0	0	0	0	1	3	5	2	3	1	0	0
4/16/2009 1:30	16	0	0	0	0	0	0	0	0	0	1	2	0	9	1	3	0	0
4/16/2009 1:45	13	0	0	0	0	0	0	0	0	0	0	0	6	5	1	1	0	0
4/16/2009 2:00	7	0	0	0	0	0	0	0	0	0	0	2	2	1	1	0	1	0
4/16/2009 2:15	15	0	0	0	0	0	0	0	0	0	1	6	4	3	1	0	0	0
4/16/2009 2:30	8	0	0	0	0	0	0	0	0	0	2	2	2	1	0	1	0	0
4/16/2009 2:45	8	0	0	0	0	0	0	0	0	0	1	2	3	1	1	0	0	0
4/16/2009 3:00	13	0	0	0	0	0	0	0	0	0	2	2	1	5	3	0	0	0
4/16/2009 3:15	8	0	0	0	0	0	0	0	0	0	1	0	2	0	4	1	0	0
4/16/2009 3:30	5	0	0	0	0	0	0	0	0	0	1	2	1	1	0	0	0	0
4/16/2009 3:45	9	0	0	0	0	0	0	0	0	2	1	2	2	0	2	0	0	0
4/16/2009 4:00	16	0	0	0	0	0	0	0	0	0	5	2	3	3	3	0	0	0
4/16/2009 4:15	13	0	0	0	0	0	0	0	0	0	2	1	3	4	3	0	0	0
4/16/2009 4:30	19	0	0	0	0	0	0	0	0	1	0	5	4	6	2	1	0	0
4/16/2009 4:45	17	0	0	0	0	0	0	0	0	0	0	8	7	1	1	0	0	0
4/16/2009 5:00	27	0	0	0	0	0	0	0	0	2	4	8	4	6	3	0	0	0
4/16/2009 5:15	31	0	0	0	0	0	0	0	0	0	0	13	6	9	2	1	0	0
4/16/2009 5:30	29	0	0	0	0	0	0	1	0	1	2	8	6	9	2	0	0	0
4/16/2009 5:45	45	0	0	0	0	0	0	0	0	0	4	13	14	11	3	0	0	0
4/16/2009 6:00	51	0	0	0	0	0	0	0	0	1	6	17	15	7	4	1	0	0
4/16/2009 6:15	55	0	0	0	0	0	0	0	0	1	6	11	18	11	6	2	0	0
4/16/2009 6:30	71	0	0	0	0	0	0	0	0	0	4	21	32	13	0	0	0	1
4/16/2009 6:45	67	0	0	0	0	0	0	0	0	0	3	13	21	20	8	2	0	0
4/16/2009 7:00	77	0	0	0	0	0	0	0	0	0	10	16	29	10	9	3	0	0
4/16/2009 7:15	84	0	0	0	0	0	0	0	0	3	4	27	22	19	8	0	0	1
4/16/2009 7:30	101	0	0	0	0	0	0	0	0	11	17	12	25	25	9	2	0	0
4/16/2009 7:45	88	0	0	0	0	0	0	0	1	0	7	18	29	20	8	4	1	0
4/16/2009 8:00	99	0	0	0	0	0	0	0	0	1	8	26	35	19	10	0	0	0
4/16/2009 8:15	85	0	0	0	0	0	0	0	0	1	8	25	25	12	9	5	0	0
4/16/2009 8:30	94	0	0	0	0	0	0	0	0	0	7	28	27	20	10	1	1	0
4/16/2009 8:45	99	0	0	0	0	0	0	0	0	3	11	19	36	20	8	1	1	0
4/16/2009 9:00	80	0	0	0	0	0	0	0	0	0	8	14	23	21	13	1	0	0
4/16/2009 9:15	69	0	0	0	0	0	0	0	0	1	4	12	17	25	6	3	1	0
4/16/2009 9:30	83	0	0	0	0	0	0	0	1	0	2	17	23	21	15	4	0	0
4/16/2009 9:45	87	0	0	0	0	0	0	0	0	0	2	10	31	32	8	2	2	0
4/16/2009 10:00	101	0	0	0	0	0	0	0	0	0	7	18	31	32	11	2	0	0
4/16/2009 10:15	84	0	0	0	0	0	0	0	0	0	5	14	33	20	8	1	3	0
4/16/2009 10:30	106	0	0	0	0	0	0	0	0	1	0	10	41	39	10	3	2	0
4/16/2009 10:45	102	0	0	0	0	0	0	0	1	0	3	17	34	31	12	3	1	0
4/16/2009 11:00	156	0	0	0	0	0	0	0	0	0	2	12	58	62	20	2	0	0
4/16/2009 11:15	144	0	0	0	0	0	0	0	0	0	0	17	59	45	14	8	1	0
4/16/2009 11:30	166	0	0	0	0	0	0	1	2	2	11	32	51	49	12	4	2	0
4/16/2009 11:45	159	0	0	0	0	0	0	0	0	2	1	27	68	42	8	8	3	0
4/16/2009 12:00	149	0	0	0	0	0	0	0	0	0	7	21	42	49	22	8	0	0
4/16/2009 12:15	144	0	0	0	0	0	0	0	1	0	12	31	42	33	15	8	1	1
4/16/2009 12:30	155	0	0	0	0	0	0	2	3	9	6	32	50	41	10	1	1	0
4/16/2009 12:45	135	0	0	0	0	0	0	0	0	0	12	22	55	28	14	4	0	0
4/16/2009 13:00	184	0	0	0	1	2	6	3	3	3	27	53	48	27	11	0	0	0
4/16/2009 13:15	114	0	0	0	0	1	4	3	8	14	21	24	18	18	2	1	0	0
4/16/2009 13:30	121	0	0	0	1	6	1	0	2	5	7	24	29	24	16	5	1	0
4/16/2009 13:45	32	0	0	0	0	1	1	1	4	8	10	5	2	0	0	0	0	0
4/16/2009 14:00	53	0	0	0	0	0	0	4	13	11	11	8	4	2	0	0	0	0
4/16/2009 14:15	59	0	0	0	1	0	0	3	11	16	17	8	3	0	0	0	0	0
4/16/2009 14:30	106	0	0	4	7	1	1	4	11	18	36	16	4	4	0	0	0	0
4/16/2009 14:45	98	0	0	0	0	3	0	8	13	24	27	15	8	0	0	0	0	0
4/16/2009 15:00	86	4	26	19	24	4	4	1	2	1	1	0	0	0	0	0	0	0
4/16/2009 15:15	87	3	27	11	18	15	5	0	1	4	0	1	1	1	0	0	0	0
4/16/2009 15:30	100	3	28	24	21	21	2	0	1	0	0	0	0	0	0	0	0	0
4/16/2009 15:45	77	4	45	13	7	3	2	2	0	1	0	0	0	0	0	0	0	0
4/16/2009 16:00	102	7	67	14	10	4	0	0	0	0	0	0	0	0	0	0	0	0
4/16/2009 16:15	152	3	136	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/16/2009 16:30	129	5	119	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/16/2009 16:45	146	2	110	29	4	1	0	0	0	0	0	0	0	0	0	0	0	0
4/16/2009 17:00	125	5	107	11	2	0	0	0	0	0	0	0	0	0	0	0	0	0
4/16/2009 17:15	145	13	104	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/16/2009 17:30	94	8	69	5	10	2	0	0	0	0	0	0	0	0	0	0	0	0
4/16/2009 17:45	100	3	39	24	12	15	2	1	0	1	2	0	0	1	0	0	0	0
4/16/2009 18:00	129	0	44	37	32	8	3	3	1	1	0	0	0	0	0	0	0	0
4/16/2009 18:15	131	1	32	37	36	19	2	0	1	1	1	0	1	0	0	0	0	0
4/16/2009 18:30	127	1	17	20	30	19	7	4	7	4	6	1	3	5	2	0	1	0
4/16/2009 18:45	95	1	7	9	27	18	10	1	5	2	3	5	4	3	0	0	0	0
4/16/2009 19:00	104	0	0	0	0	0	0	0	0	0	4	24	38	27	8	1	1	1
4/16/2009 19:15	98	0	0	0	0	0	0	0	2	0	4	19	46	22	4	1	0	0
4/16/2009 19:30	80	0	0	0	0	0	0	0	0	0	4	18	37	11	5	5	0	0
4/16/2009 19:45	64	0	0	0	0	0	0	0	0	0	0	18	19	16	9	2	0	0
4/16/2009 20:00	88	0	0	0	0	0	0	0	0	0	10	16	30	21	10	1	0	0
4/16/2009 20:15	81	0	0	0	0	0	0	0	0	0	6	15	31	21	4	3	1	0
4/16/2009 20:30	72	0	0	0	0	0	0	0	0	1	3	20	21	14	11	1	1	0

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Route:	SR 202 RED MTN ON-RMP	Latitude:	33.43624
Location:	E of PRIEST DR	Longitude:	-111.95498

Date/Time	Total	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80+
4/16/2009 20:45	59	0	0	1	0	0	0	0	1	3	12	17	12	7	5	1	0	0
4/16/2009 21:00	54	0	0	0	0	0	0	0	0	0	2	7	19	16	6	2	0	2
4/16/2009 21:15	55	0	0	0	0	0	0	0	0	0	3	15	20	11	6	0	0	0
4/16/2009 21:30	48	0	0	0	0	0	0	0	0	0	2	6	21	11	7	1	0	0
4/16/2009 21:45	51	0	0	0	0	0	0	0	0	0	1	11	11	15	10	1	2	0
4/16/2009 22:00	34	0	0	0	0	0	0	0	0	0	2	6	9	11	4	2	0	0
4/16/2009 22:15	38	0	0	0	0	0	0	0	0	0	1	5	10	12	9	1	0	0
4/16/2009 22:30	47	0	0	0	0	0	0	0	0	0	3	8	15	13	6	1	1	0
4/16/2009 22:45	38	0	0	0	0	0	0	0	0	1	1	4	10	13	7	1	1	0
4/16/2009 23:00	53	0	0	0	0	0	0	0	0	0	2	8	12	17	8	4	1	1
4/16/2009 23:15	21	0	0	0	0	0	0	0	0	0	2	5	5	4	5	0	0	0
4/16/2009 23:30	34	0	0	0	0	0	0	0	0	0	0	5	11	10	4	2	2	0
4/16/2009 23:45	28	0	0	0	0	0	0	0	0	0	2	2	8	9	4	3	0	0
Day Totals	**7089**	**63**	**977**	**304**	**243**	**143**	**50**	**42**	**96**	**162**	**439**	**1034**	**1599**	**1248**	**511**	**136**	**35**	**7**

AM Peak Hr	**11:10 AM**	Average Speed	**45.8**	Pct > 25 mph	**76%**
AM Peak Vol	**629**	Median Speed	**55.0**	Pct > 30 mph	**75%**
AM PHF	**0.782**	85th Pct Speed	**63.4**	Pct > 35 mph	**74%**
PM Peak Hr	**12:15 PM**	95th Pct Speed	**68.2**	Pct > 40 mph	**73%**
PM Peak Vol	**618**	Pace Speed	**55**	Pct > 45 mph	**71%**
PM PHF	**0.746**	Percent in Pace	**39.9%**	Pct > 50 mph	**64%**
		Speed Limit	**55**		
		Percent Speedin	**49.9%**		

Traffic Research & Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client: KITTELSON
File Number: 0901157
Route: SR 202 RED MTN ON-RMP
Location: E of CENTER PKWY

Site Ref: 10
Direction: EB
Latitude: 33.43568
Longitude: -111.94636

Date/Time	Total	cls01	cls02	cls03	cls04	cls05	cls06	cls07	cls08	cls09	cls10	cls11	cls12	cls13	pct SU	pct CB
4/16/2009 0:00	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 0:15	10	1	6	3	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 0:30	8	0	8	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 0:45	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 1:00	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 1:15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--
4/16/2009 1:30	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 1:45	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 2:00	4	0	1	3	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 2:15	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 2:30	3	0	2	0	0	1	0	0	0	0	0	0	0	0	33.3%	0.0%
4/16/2009 2:45	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 3:00	4	1	1	1	0	0	0	1	0	0	0	0	0	0	25.0%	0.0%
4/16/2009 3:15	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 3:30	6	0	3	3	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 3:45	6	0	4	1	0	0	0	0	0	1	0	0	0	0	0.0%	16.7%
4/16/2009 4:00	6	0	6	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 4:15	9	0	4	2	0	0	0	0	0	3	0	0	0	0	0.0%	33.3%
4/16/2009 4:30	6	0	2	4	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 4:45	6	0	4	1	0	0	0	0	0	1	0	0	0	0	0.0%	16.7%
4/16/2009 5:00	7	0	6	1	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 5:15	3	0	2	1	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 5:30	5	0	1	3	0	0	0	0	0	1	0	0	0	0	0.0%	20.0%
4/16/2009 5:45	10	1	6	2	0	1	0	0	0	0	0	0	0	0	10.0%	0.0%
4/16/2009 6:00	18	0	11	5	0	0	0	0	2	0	0	0	0	0	0.0%	11.1%
4/16/2009 6:15	8	0	3	1	0	1	0	0	2	1	0	0	0	0	12.5%	37.5%
4/16/2009 6:30	20	0	13	3	1	0	1	2	0	0	0	0	0	0	20.0%	0.0%
4/16/2009 6:45	10	0	5	3	0	0	0	0	2	0	0	0	0	0	0.0%	20.0%
4/16/2009 7:00	14	0	4	8	2	0	0	0	0	0	0	0	0	0	14.3%	0.0%
4/16/2009 7:15	16	0	10	5	0	1	0	0	0	0	0	0	0	0	6.3%	0.0%
4/16/2009 7:30	16	0	11	3	0	0	0	0	1	1	0	0	0	0	0.0%	12.5%
4/16/2009 7:45	18	0	9	9	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 8:00	27	0	17	10	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 8:15	19	0	9	9	0	0	1	0	0	0	0	0	0	0	5.3%	0.0%
4/16/2009 8:30	19	0	11	8	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 8:45	22	0	13	7	2	0	0	0	0	0	0	0	0	0	9.1%	0.0%
4/16/2009 9:00	12	0	8	3	0	0	1	0	0	0	0	0	0	0	8.3%	0.0%
4/16/2009 9:15	19	0	13	5	1	0	0	0	0	0	0	0	0	0	5.3%	0.0%
4/16/2009 9:30	22	0	12	9	0	0	0	0	1	0	0	0	0	0	0.0%	4.5%
4/16/2009 9:45	17	0	6	11	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 10:00	16	0	10	4	2	0	0	0	0	0	0	0	0	0	12.5%	0.0%
4/16/2009 10:15	17	0	9	8	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 10:30	29	0	22	6	0	0	0	0	0	1	0	0	0	0	0.0%	3.4%
4/16/2009 10:45	24	0	18	6	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 11:00	28	0	17	10	0	1	0	0	0	0	0	0	0	0	3.6%	0.0%
4/16/2009 11:15	30	0	19	11	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 11:30	38	0	33	5	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 11:45	33	0	25	8	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 12:00	28	0	20	7	0	0	0	1	0	0	0	0	0	0	3.6%	0.0%
4/16/2009 12:15	26	0	17	9	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 12:30	21	0	10	11	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 12:45	37	0	28	9	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 13:00	42	0	28	14	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 13:15	41	0	31	10	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 13:30	59	1	36	21	0	1	0	0	0	0	0	0	0	0	1.7%	0.0%
4/16/2009 13:45	109	0	74	34	0	1	0	0	0	0	0	0	0	0	0.9%	0.0%
4/16/2009 14:00	146	0	95	47	4	0	0	0	0	0	0	0	0	0	2.7%	0.0%

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Client: KITTELSON
File Number: 0901157
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Location: E of CENTER PKWY

Site Ref: 10
Direction: EB
Latitude: 33.43568
Longitude: -111.94636

Date/Time	Total	cls01	cls02	cls03	cls04	cls05	cls06	cls07	cls08	cls09	cls10	cls11	cls12	cls13	pct SU	pct CB
4/16/2009 14:15	98	0	70	28	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 14:30	189	1	123	64	1	0	0	0	0	0	0	0	0	0	0.5%	0.0%
4/16/2009 14:45	116	3	90	23	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 15:00	153	2	108	43	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 15:15	121	1	87	33	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 15:30	209	3	147	58	0	1	0	0	0	0	0	0	0	0	0.5%	0.0%
4/16/2009 15:45	169	2	132	33	1	1	0	0	0	0	0	0	0	0	1.2%	0.0%
4/16/2009 16:00	218	2	167	49	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 16:15	211	1	165	45	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 16:30	217	2	161	53	1	0	0	0	0	0	0	0	0	0	0.5%	0.0%
4/16/2009 16:45	201	0	157	44	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 17:00	205	0	162	43	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 17:15	228	1	170	57	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 17:30	178	2	140	36	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 17:45	92	0	75	17	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 18:00	95	0	79	16	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 18:15	50	0	41	8	1	0	0	0	0	0	0	0	0	0	2.0%	0.0%
4/16/2009 18:30	46	1	36	9	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 18:45	23	0	19	4	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 19:00	39	0	29	10	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 19:15	20	0	18	1	0	0	0	0	1	0	0	0	0	0	0.0%	5.0%
4/16/2009 19:30	20	0	20	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 19:45	32	0	25	5	0	0	0	0	2	0	0	0	0	0	0.0%	6.3%
4/16/2009 20:00	30	0	22	7	0	0	0	0	1	0	0	0	0	0	0.0%	3.3%
4/16/2009 20:15	14	0	12	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 20:30	14	0	10	4	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 20:45	11	0	8	3	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 21:00	20	0	15	5	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 21:15	8	0	6	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 21:30	8	0	4	3	0	1	0	0	0	0	0	0	0	0	12.5%	0.0%
4/16/2009 21:45	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 22:00	12	1	8	3	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 22:15	9	0	6	2	0	1	0	0	0	0	0	0	0	0	11.1%	0.0%
4/16/2009 22:30	6	0	5	1	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 22:45	7	0	5	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 23:00	7	0	6	1	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 23:15	6	0	6	0	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 23:30	9	0	7	2	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
4/16/2009 23:45	7	0	6	1	0	0	0	0	0	0	0	0	0	0	0.0%	0.0%
Day Totals	**4216**	**26**	**3073**	**1062**	**16**	**11**	**3**	**4**	**12**	**9**	**0**	**0**	**0**	**0**	**0.8%**	**0.5%**

AM Peak Hr	**10:55 AM**
AM Peak Vol	**129**
AM PHF	**0.672**
PM Peak Hr	**4:05 PM**
PM Peak Vol	**856**
PM PHF	**0.849**

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Client:	KITTELSON	Site Ref:	10
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Route:	SR 202 RED MTN ON-RMP	Latitude:	33.43568
Location:	E of CENTER PKWY	Longitude:	-111.94636

Date/Time	Total	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80+
4/16/2009 0:00	5	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	1	0
4/16/2009 0:15	10	0	0	0	0	0	0	0	0	0	2	4	2	2	0	0	0	0
4/16/2009 0:30	8	0	0	0	0	0	0	0	0	1	0	3	3	1	0	0	0	0
4/16/2009 0:45	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
4/16/2009 1:00	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
4/16/2009 1:15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/16/2009 1:30	5	0	0	0	0	0	0	0	0	0	1	2	1	1	0	0	0	0
4/16/2009 1:45	2	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
4/16/2009 2:00	4	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0
4/16/2009 2:15	2	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
4/16/2009 2:30	3	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
4/16/2009 2:45	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
4/16/2009 3:00	4	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	0	0
4/16/2009 3:15	2	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
4/16/2009 3:30	6	0	0	0	0	0	0	0	0	0	2	2	2	0	0	0	0	0
4/16/2009 3:45	6	0	0	0	0	0	0	0	1	0	0	2	2	0	1	0	0	0
4/16/2009 4:00	6	0	0	0	0	0	0	0	0	2	0	2	1	1	0	0	0	0
4/16/2009 4:15	9	0	0	0	0	0	0	0	3	0	0	3	1	1	1	0	0	0
4/16/2009 4:30	6	0	0	0	0	0	0	0	1	2	0	2	1	0	0	0	0	0
4/16/2009 4:45	6	0	0	0	0	0	0	0	1	0	1	1	2	0	1	0	0	0
4/16/2009 5:00	7	0	0	0	0	0	0	0	0	0	1	4	1	1	0	0	0	0
4/16/2009 5:15	3	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0
4/16/2009 5:30	5	0	0	0	0	0	0	0	0	1	0	3	1	0	0	0	0	0
4/16/2009 5:45	10	0	0	0	0	0	0	0	0	2	2	2	1	2	0	0	1	0
4/16/2009 6:00	18	0	0	0	0	0	0	0	4	2	2	3	4	2	1	0	0	0
4/16/2009 6:15	8	0	0	0	0	0	1	0	1	3	1	1	1	0	0	0	0	0
4/16/2009 6:30	20	0	0	0	0	0	0	1	0	2	2	8	4	1	1	0	1	0
4/16/2009 6:45	10	0	0	0	0	0	0	0	2	0	3	1	3	1	0	0	0	0
4/16/2009 7:00	14	0	0	0	0	0	0	0	2	3	0	2	3	3	1	0	0	0
4/16/2009 7:15	16	0	0	0	0	0	0	0	0	3	4	2	4	3	0	0	0	0
4/16/2009 7:30	16	0	0	0	0	0	0	0	0	3	4	3	5	1	0	0	0	0
4/16/2009 7:45	18	0	0	0	0	0	0	0	0	1	2	4	6	4	0	1	0	0
4/16/2009 8:00	27	0	0	0	0	0	0	0	0	1	8	5	13	0	0	0	0	0
4/16/2009 8:15	19	0	0	0	0	0	0	0	0	1	7	7	3	0	1	0	0	0
4/16/2009 8:30	19	0	0	0	0	0	0	0	1	0	4	4	7	3	0	0	0	0
4/16/2009 8:45	22	0	0	0	0	0	0	0	0	3	1	13	3	0	1	1	0	0
4/16/2009 9:00	12	0	0	0	0	0	0	0	0	1	5	5	1	0	0	0	0	0
4/16/2009 9:15	19	0	0	0	0	0	0	0	1	0	6	6	5	0	1	0	0	0
4/16/2009 9:30	22	0	0	0	0	0	0	0	1	2	3	7	6	3	0	0	0	0
4/16/2009 9:45	17	0	0	0	0	1	0	0	1	0	3	3	9	0	0	0	0	0
4/16/2009 10:00	16	0	0	0	0	0	0	0	1	2	3	4	0	4	0	1	1	0
4/16/2009 10:15	17	0	0	0	0	0	0	0	0	0	1	10	4	2	0	0	0	0
4/16/2009 10:30	29	0	0	0	0	0	0	0	0	2	6	9	8	1	0	3	0	0
4/16/2009 10:45	24	0	0	0	0	0	0	0	0	1	5	9	7	2	0	0	0	0
4/16/2009 11:00	28	0	0	0	0	0	0	0	0	1	5	9	12	1	0	0	0	0
4/16/2009 11:15	30	0	0	0	0	0	0	0	0	1	8	9	7	4	1	0	0	0
4/16/2009 11:30	38	0	0	0	0	0	0	0	0	1	5	16	10	5	0	1	0	0
4/16/2009 11:45	33	0	0	0	0	0	0	0	3	2	2	11	10	3	1	0	1	0
4/16/2009 12:00	28	0	0	0	0	0	0	0	0	3	4	9	9	3	0	0	0	0
4/16/2009 12:15	26	0	0	0	0	0	0	0	0	5	4	7	8	2	0	0	0	0
4/16/2009 12:30	21	0	0	0	0	0	0	0	0	1	3	8	6	2	1	0	0	0
4/16/2009 12:45	37	0	0	0	0	0	0	0	1	2	5	11	13	5	0	0	0	0
4/16/2009 13:00	42	0	0	0	0	0	0	0	0	4	12	15	7	4	0	0	0	0
4/16/2009 13:15	41	0	0	0	0	0	0	0	1	0	10	12	13	3	2	0	0	0
4/16/2009 13:30	59	0	0	0	0	0	0	2	7	9	15	19	4	3	0	0	0	0
4/16/2009 13:45	109	0	0	0	0	0	0	0	14	35	34	19	4	2	0	1	0	0
4/16/2009 14:00	146	0	0	0	0	0	0	5	6	29	55	37	12	1	0	1	0	0
4/16/2009 14:15	98	0	0	0	0	0	0	2	10	15	27	29	12	3	0	0	0	0
4/16/2009 14:30	189	0	0	0	0	0	0	0	9	33	50	67	24	5	1	0	0	0
4/16/2009 14:45	116	0	0	0	0	0	0	0	3	5	28	41	28	11	0	0	0	0
4/16/2009 15:00	153	0	0	0	0	2	14	94	31	5	1	3	0	3	0	0	0	0
4/16/2009 15:15	121	0	0	0	0	1	13	71	28	2	1	3	1	0	1	0	0	0
4/16/2009 15:30	209	0	0	0	0	1	36	132	31	8	1	0	0	0	0	0	0	0
4/16/2009 15:45	169	0	0	0	0	1	24	101	37	5	0	0	0	0	1	0	0	0
4/16/2009 16:00	218	0	0	0	0	0	49	140	25	3	1	0	0	0	0	0	0	0
4/16/2009 16:15	211	0	0	0	1	1	57	115	32	4	1	0	0	0	0	0	0	0
4/16/2009 16:30	217	0	0	0	0	8	83	107	19	0	0	0	0	0	0	0	0	0
4/16/2009 16:45	201	0	0	0	0	15	96	78	12	0	0	0	0	0	0	0	0	0
4/16/2009 17:00	205	0	0	0	0	13	104	72	16	0	0	0	0	0	0	0	0	0
4/16/2009 17:15	228	0	0	0	1	12	120	84	10	1	0	0	0	0	0	0	0	0
4/16/2009 17:30	178	0	0	0	1	10	76	83	8	0	0	0	0	0	0	0	0	0
4/16/2009 17:45	92	0	0	0	0	4	24	48	12	4	0	0	0	0	0	0	0	0
4/16/2009 18:00	95	0	0	0	0	1	16	53	12	8	4	0	1	0	0	0	0	0
4/16/2009 18:15	50	0	0	0	0	0	9	30	7	2	0	1	1	0	0	0	0	0
4/16/2009 18:30	46	0	0	1	0	0	7	23	8	1	2	3	1	0	0	0	0	0
4/16/2009 18:45	23	0	0	0	0	0	6	5	2	4	2	4	0	0	0	0	0	0
4/16/2009 19:00	39	0	0	0	0	0	0	1	0	3	6	12	12	3	2	0	0	0
4/16/2009 19:15	20	0	0	0	0	0	0	0	1	1	2	9	6	0	1	0	0	0
4/16/2009 19:30	20	0	0	0	0	0	0	0	0	5	5	6	3	0	1	0	0	0
4/16/2009 19:45	32	0	0	0	0	0	0	0	2	3	11	10	3	2	0	1	0	0
4/16/2009 20:00	30	0	0	0	0	0	0	1	2	2	5	9	8	2	1	0	0	0
4/16/2009 20:15	14	0	0	0	0	0	0	0	0	1	5	4	2	1	1	0	0	0
4/16/2009 20:30	14	0	0	0	0	0	0	0	0	1	6	3	4	0	0	0	0	0

Traffic Research & Analysis, Inc.
3844 East Indian School Road
Phoenix, AZ 85018
(602) 840-1500

Client:	KITTELSON	Site Ref:	10
File Number:	0901157	Direction:	EB
Route:	SR 202 RED MTN ON-RMP	Latitude:	33.43568
Location:	E of CENTER PKWY	Longitude:	-111.94636

Date/Time	Total	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80+
4/16/2009 20:45	11	0	0	0	0	0	0	0	0	1	3	4	2	0	0	1	0	0
4/16/2009 21:00	20	0	0	0	0	0	0	0	0	1	3	4	5	7	0	0	0	0
4/16/2009 21:15	8	0	0	0	0	0	0	0	0	0	2	2	1	1	2	0	0	0
4/16/2009 21:30	8	0	0	0	0	0	0	0	1	1	0	1	3	1	1	0	0	0
4/16/2009 21:45	4	0	0	0	0	0	0	0	0	0	1	2	0	1	0	0	0	0
4/16/2009 22:00	12	0	0	0	0	0	0	0	0	2	3	2	4	0	0	0	0	1
4/16/2009 22:15	9	0	0	0	0	0	0	0	1	0	2	3	2	1	0	0	0	0
4/16/2009 22:30	6	0	0	0	0	0	0	0	0	0	1	1	3	1	0	0	0	0
4/16/2009 22:45	7	0	0	0	0	0	0	0	0	0	0	2	4	1	0	0	0	0
4/16/2009 23:00	7	0	0	0	0	0	0	0	0	0	2	2	2	1	0	0	0	0
4/16/2009 23:15	6	0	0	0	0	0	0	0	0	0	0	1	4	0	1	0	0	0
4/16/2009 23:30	9	0	0	0	0	0	0	0	0	0	0	6	1	1	1	0	0	0
4/16/2009 23:45	7	0	0	0	0	0	0	0	0	0	2	3	2	0	0	0	0	0
Day Totals	**4216**	**0**	**0**	**1**	**3**	**70**	**735**	**1249**	**371**	**255**	**421**	**566**	**375**	**122**	**30**	**12**	**5**	**1**

AM Peak Hr	**10:55 AM**	Average Speed	**40.2**	Pct > 25 mph	**98%**
AM Peak Vol	**129**	Median Speed	**35.8**	Pct > 30 mph	**81%**
AM PHF	**0.672**	85th Pct Speed	**54.3**	Pct > 35 mph	**51%**
PM Peak Hr	**4:05 PM**	95th Pct Speed	**59.4**	Pct > 40 mph	**42%**
PM Peak Vol	**856**	Pace Speed	**25**	Pct > 45 mph	**36%**
PM PHF	**0.849**	Percent in Pace	**46.7%**	Pct > 50 mph	**26%**
		Speed Limit	**55**		
		Percent Speedin	**12.9%**		